CHAPTER OUTLINE

The Case for Simulations and Games

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WHAT’S NEW IN THIS CHAPTER?

WILL ONLINE LEARNING GAMES replace books, lectures, and traditional step-by-step e-learning? Are younger generations better served by experiential multimedia? Do educational games and simulations offer a more effective and more motivational learning alternative than other interactive formats such as case studies? Are there proven principles to guide design of effective learning games? Unfortunately, when it comes to learning, there is quite a bit we don’t know about simulations and games. However, we are beginning to accumulate new evidence published since the second edition of e-Learning and the Science of Instruction about how games and simulations can be designed to promote learning. In this chapter we take an evidence-based approach to help you define tradeoffs and leverage proven techniques when considering simulations and games to achieve your learning goals.
In Chapter 1 we introduced the activity matrix shown in Figure 16.1. Since by definition games and simulations involve high degrees of overt learner engagement, they will fall into the right-hand side of the matrix. Your challenge is to maintain their entertainment or motivational features while at the same time to foster learning. Games and simulations that fall into the lower-right quadrant promote a lot of behavioral activity, but fail to support cognitive processes that require deliberation and reflection. If your goal is learning of cognitive skills, your game or simulation will need to effectively support both psychological and behavioral activity and fall into the upper-right quadrant.

**Figure 16.1. The Psychological-Behavioral Activity Matrix.**
Adapted from Stull and Mayer, 2007.

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**DESIGN DILEMMA: YOU DECIDE**

**Scene: The Spreadsheet Training Project Meeting**

Sandy: “Did you know that just about two-thirds of our staff play either video or computer games in their free time? And it’s not just the young new hires either! Some tell me they spend up to twenty hours a week playing these
games. The workforce of today—those who have been playing online games for years—have different brains! Their nervous systems are attuned to high engagement rich multimedia. These Millennials are turned off by anything that even looks like traditional training!

Let’s leverage the popularity of games with a spreadsheet adventure theme. We could design a fantasy scenario where spreadsheet solutions open doors to new worlds that offer clues and tools. Take a look at the storyboard our graphic artist created. The visuals alone make you want to jump into the game!”

Figure 16.2. A Fantasy Theme for a Learning Game.

Credit: Mark Palmer.

Matt: “OK. This sounds exciting. . . . but how long will it take to develop this game? And how will it affect our production budget? And what about learning time? How long do you think it will take to play the game
The Case for Simulations and Games

According to the Entertainment Software Association’s annual report (2010), video and computer games are ubiquitous in American households—and not just among the young. Sixty-seven percent of American households play computer or video games. The average age of game players is thirty-four, with 26 percent over the age of fifty. Males outplay females, making up 60 percent of the gaming population. You can see in Figure 16.3 that the most popular types of digital games have not changed since the 2006 data we reported in the second edition of this book. Action and sports remain the most popular video games, and strategy and family/children’s games capture the greatest market share among computer games. Since 1996, there

compared to completing a traditional tutorial? If we invest in this game, will they learn how to use spreadsheets as effectively and efficiently as if we used a traditional lesson that just shows them how? And will their new spreadsheet skills transfer to the kinds of spreadsheets they need to develop in their work roles?”

Sandy is excited about teaching spreadsheet concepts and tasks in a highly interactive game-type environment, but Matt has some questions. Based on your own experience or intuition, which of the following options would you select:

A. Sandy is correct. Raised on games, the younger workforce will learn more effectively from game-type lessons.

B. More participants will complete a game-type course than will complete a traditional tutorial.

C. Learning by exploration and discovery is more effective than learning by explanations and traditional practice exercises.

D. Constructing a gaming environment will be more expensive than developing a traditional course; however, the investment will pay off in higher completion rates and better transfer of skills.
has been a steady increase in the annual dollar sales of computer and video games, which peaked at $11.7 billion in 2008.

**Figure 16.3. Sales of Video and Computer Game Types.**

Enthusiasts hope to leverage the popularity of entertainment games and simulations to improve learning outcomes. Some argue that the Millennial generation, raised on games and simulations, has different neurological requirements and expectations that demand highly interactive media-intensive learning environments.

In medical education high-fidelity simulations are recommended because (1) managed health care has resulted in shorter patient stays with consequent fewer clinical teaching opportunities than in the past, (2) patient safety is enhanced when procedures can be learned and practiced on simulators, (3) new medical procedures such as sigmoidoscopy, laparoscopy, and robotics involve motor and perceptual skills that can be effectively practiced via simulators, and (4) deliberate practice involving repetitive performances leads to improved skills (Issenberg, McGaghie, Petrusa, Gordon, & Scalese, 2005).
Instructional games (also called serious games) are popular among some adult learners. In a review of research on computer simulations used in many business school settings, Anderson and Lawton (2009) found that, with a few exceptions, learners prefer simulation exercises more than either lectures or case discussions. Not all games, however, are equally embraced. In a survey evaluation of two games designed for new hire orientation, Carson (2009) attributed a relatively low participation in the game to usability issues and perceived lack of relevance.

Given that at least some games and simulations are highly popular with a sizable population segment, what evidence do we have about their instructional effectiveness and efficiency? Will a simulation or game result in higher e-learning completion rates compared to standard tutorials? Will learning be faster? Will learners feel more positive about the instructional experience as well as about the knowledge and skills learned? Do the Millennials benefit more from games than from traditional training methods? What is the cost/benefit of simulations and games? How can you tell an effective game or simulation from an ineffective one? Our goal in this chapter is to look beyond the hyperbole on multimedia games and simulations to see what controlled evidence tells us about their learning potential.

**What Are Simulations and Games?**

Suppose you wanted to teach the basics of genetics. You could develop a structured linear interactive tutorial. Alternatively, you could opt for a more experiential environment like the genetics simulation in Figure 16.4. In this simulation, learners can change the genes on the chromosomes and immediately see how the dragon features are altered. In Figure 16.5, the simulation has been converted into a game by giving learners a goal to change the lower-left dragon to match the one in the upper left.

**What Are Simulations?**

A simulation is a model of a real-world system. Simulated environments respond in dynamic and rule-based ways to user responses. For example, in
Chapter 16: Simulations and Games in e-Learning

Figure 16.4. Simulation of Laws of Genetics.

Figure 16.5. Game Based on Simulation of Laws of Genetics.
the genetics simulation in Figure 16.4, when the user changes the h gene on chromosome 1 to a dominant gene H, horns appear on the dragon, reflecting the laws of genetics. De Jong (2011) defines computer simulations as “computer programs that have as their core a computational model of a system or process. The system or process that is modeled normally has a natural world origin and the model that is created is usually a simplification of the real world phenomenon” (p. 446).

There are two basic types of simulations: operational and conceptual. Operational simulations are designed primarily to teach procedural skills, whereas conceptual simulations focus on learning of domain-specific concepts and strategic knowledge. In workforce learning, operational simulations have been used for training of software applications, medical procedures, and safety-related skills, such as aircraft piloting and industrial control operations. In contrast, conceptual simulations, such as the one shown in Figure 16.4, are primarily designed to build far transfer knowledge of a specific domain as well as associated inquiry or problem-solving skills. Conceptual simulations in the educational arena have modeled principles of physics, genetics, chemistry, botany and ecology, to name a few. In professional and workforce learning, conceptual simulations have been designed to teach business management strategies, military combat decision making, bank loan analysis, medical diagnostics, and equipment troubleshooting, among others.

What Are Games?

From PacMan to Jeopardy to Doom, online games reveal a diverse array of formats and features. In Table 16.1 we summarize some of the major genres of commercial online video games. If you don’t agree with our categories, you are probably correct, as games are in a constant state of evolution and many could be classified as hybrids of two or more of these classes. Mayer and Johnson (2010) list four common features of games: (1) rule-based, allowing players to understand the environment, (2) responsive, allowing the learner to experience control, (3) challenging, and (4) cumulative so that the current state of the environment reflects the player’s previous actions and shows progress toward goals. In contrast to most games built for entertainment, educational games are designed to help learners achieve
### Table 16.1. Some Genres of Video Games.


<table>
<thead>
<tr>
<th>Genre</th>
<th>Description</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Action</td>
<td>Use quick reflexes, accuracy, and timing to overcome obstacles. Often emphasis on combat.</td>
<td>Pong, Street Fighter, Donkey Kong</td>
</tr>
<tr>
<td>Shooter</td>
<td>Combat with projectile weapons such as guns and missiles</td>
<td>Doom, Halo Series, Call of Duty: Modern Warfare Series, Space Invaders</td>
</tr>
<tr>
<td>Action-Adventure</td>
<td>Focus on exploration and usually involve item gathering, simple puzzle solving, and combat.</td>
<td>Adventure Myst, Resident Evil 4</td>
</tr>
<tr>
<td>Role Play</td>
<td>Assume role of one or more “adventurers” who specialize in specific skill sets while progressing through a predetermined storyline.</td>
<td>Final Fantasy Series, Grand Theft Auto, World of Warcraft</td>
</tr>
<tr>
<td>Simulation</td>
<td>Designed to emulate aspects of a real or fictional reality including simulations involving construction, vehicle operations, biology, pet management, etc.</td>
<td>SimCity, Flight Simulator, The Sims</td>
</tr>
<tr>
<td>Strategy</td>
<td>Focus on game play requiring careful and skillful thinking and planning in order to achieve victory</td>
<td>Civilization Series, Empire Earth, Master of Orion</td>
</tr>
<tr>
<td>Music</td>
<td>Challenge the player to follow sequences of movement or develop specific rhythms.</td>
<td>Guitar Hero, Rock Band</td>
</tr>
<tr>
<td>Sports</td>
<td>Emulate playing of traditional sports</td>
<td>Madden NFL Series</td>
</tr>
</tbody>
</table>
specific learning objectives while at the same time providing a motivational environment.

For example, in Figure 16.6 we show a screen shot from a business management game. Lemonade Tycoon 2 sets different goals in different modes: time mode (make as much money as possible in a given time frame) or money mode (be the first team to attain a set amount of money). Players control their marketing budget, stock levels, recipes, and prices and make decisions regarding hiring employees, investing in equipment, and so forth. The Lemonade Tycoon game involves a simulation. However, not all learning games incorporate simulations. For example, quiz games such as Jeopardy are not simulation based.

Figure 16.6. Lemonade Tycoon—A business Simulation Game.

Do Games and Simulations Teach?

Yes, simulations and games teach, but the lesson learned is not always the intended one. For example, Rieber (2005) tested the effectiveness of the
simulation shown in Figure 16.7 for teaching physics principles of velocity and acceleration. The player manipulates the ball’s acceleration by clicking on the large arrows. To add a motivational element to the simulation, some participants were given a game goal to earn points by making the ball flip-flop as many times as possible inside the small box in the center of the overhead view.

**Figure 16.7. The Flip Flop Game Interface.**

Participants using the game version reported much higher enjoyment than those who worked with the simulation without the game goals. However, when tested on physics principles, the gaming group scored significantly lower than those who explored the simulation without a game goal! The flip-flop game players focused exclusively on improving their scores and in the process failed to reflect on the physics principles underlying the model.

In this experiment, we see that a gaming environment can be a lot of fun and at the same time depress learning. Why? The game goals generated behaviors that were antagonistic to the instructional goals. We would classify
this game in the lower-right quadrant of our Activity Matrix in Figure 16.1. The game prompted a lot of behavioral activity that did not translate into the psychological activity needed to achieve the instructional goals.

Games must be designed in ways that promote learning. That way we can get the best of both worlds—fun and learning! Later in this chapter we will focus on design guidelines to optimize learning from simulations and games.

What Research (Fails to) Tell Us About Games and Simulations

In the second edition of this book, we summarized reviews of the effectiveness of games and simulations, concluding that better quality research studies were needed. For example, Gosen and Washbush (2004) reported that of 155 studies reviewed, not one met all of the criteria for sound research.

Six years later, we don’t see major changes among the reviews scholars have published on simulations and games. For example, in 2008, Hannafin and Vermillion note: “Games are very motivating and have tremendous potential in education, but despite a rapidly growing research base, there is yet insufficient evidence to draw definitive conclusions” (p. 215). In a review of computer-based business simulations, Anderson and Lawton (2009) draw three main conclusions: (1) students like business simulation exercises more than either lectures or case discussion, (2) there is little correlation between learner ratings of the simulation and actual performance in the simulation, and (3) there is little objective evidence for the relative educational merits of simulations versus case studies or lectures. Specifically, they observe: “We have continued to be very disappointed with how little we can objectively demonstrate regarding what students learn from participating in simulation exercises” (p. 200). Van Eck (2007) summarizes the challenges facing digital game-based learning: “We do not yet have the theoretical and research base we need to establish guidelines for practice, and, while we have everyone’s attention now, we do not yet know what to say” (p. 31).

Fortunately, the most recent research has refocused the general question: “Are games and simulations effective? to ask “What features of games and simulations lead to learning?” Mayer (2011b) calls this research perspective a value-added approach. In a value-added study, different versions of a game or simulation are tested and conclusions drawn regarding how to design games
and simulations that are both motivating and educational. For example, we summarized research in Chapter 9 showing better learning from a botany game when the script was conversational using first and second person than when the language was more formal (See Figures 9.6 and 9.7).

In the remainder of this chapter we review the following evidence-based principles to maximize the learning potential of games and simulations:

**Principle 1:** Match game types to learning goals

**Principle 2:** Make learning essential to game progress

**Principle 3:** Build in proven instructional strategies

**Principle 4:** Build in guidance and structure

**Principle 5:** Manage complexity

**Principle 6:** Make relevance salient

### Games and Simulations Principle 1: Match Game Types to Learning Goals

To be effective, the goals, activities, feedback, and interfaces of simulations and games must align with the desired instructional outcomes. The flip-flop game illustrated in Figure 16.7 included elements that were antagonistic to the learning objectives. Learning occurred, but it was not the intended learning. Specifically, the rapid-fire response requirements of the flip-flop game were counterproductive to the deeper reflection needed to learn physics principles.

In Table 16.1 we summarized the most common genres of commercial video games. Which genres are best suited for various learning outcomes? Van Eck (2007) suggests that “depending on what kinds of skills one wants to foster in digital game-based learning practice, different forms and styles of games will be required. Card games, Jeopardy-style games, action games, and adventure games can all be digital in form, yet each will have its own characteristics that make it more or less suited to different instructional uses” (p. 41).

Based on evidence to date, we recommend that, for cognitive learning outcomes, games with time goals that require fast responses are not a good
match. However, rapid response games may be well suited for skills that must become automated through extensive drill and practice. Train engineers, for example, must be able to rapidly identify the meaning of a track signal and quickly respond. It is easy to see how a gaming environment could make the drill and practice involved in this skill more fun. We look to future research to validate the match between game types, game features, and learning.

Games and Simulations Principle 2: Make Learning Essential to Game Progress

Ensure that game progress and success translate into learning. In other words, the learning required to succeed in a game should be the same learning required by your instructional objectives. Belanich, Sibley, and Orvis (2004) evaluated learning of twenty-one individuals who played the America's Army game with questions assessing information presented during the game. Participants completed four sections of the game, including marksmanship training, an obstacle course, weapons familiarization, and an operational training mission. The research team compared learning of information that was relevant to playing the game with information that did not impact progress in the game. For example, a relevant question asks: “During basic rifle marksmanship qualifying, how many rounds are in a magazine?” In contrast, “What is written on the lane posts of the obstacle course?” is irrelevant to game progress. As you can see in Figure 16.8, learning of relevant information was greater with an effect size of .65, which is moderate. The research team recommends that “instructional objectives should be integrated into the game’s storyline so that the training material is relevant to the progression of the game” (p. 17).

Games and Simulations Principle 3: Build in Proven Instructional Strategies

Throughout this book we have highlighted instructional strategies that are proven to accelerate learning. We’ve discussed the benefits of worked examples, self-explanation questions, audio narration, explanatory feedback, pretraining, relevant visuals, and personalization techniques, to name just a
few. Rather than start at ground zero, why not integrate these proven features into games and simulations in ways that maintain their motivational benefits? Mayer (2011b) has summarized a number of multimedia principles we have reviewed in this book that have proven beneficial in games with high effect sizes, including modality, personalization, and pretraining. In this section we review a sampling of research studies that compared learning from versions of the same game or simulation environment that varied one or more of these proven instructional strategies.

**Incorporate Explanatory Feedback**

Knowledge of results that incorporates guidance is one of the most important instructional elements in any simulation or game. Feedback was the single most commonly mentioned success factor among research studies on the effectiveness of medical simulations (Issenberg, McGaghie, Petrusa, Gordon, & Scalese, 2005). Feedback may be built into a simulator, provided by an instructor, or provided in a video replay reviewed after a simulator session. The source of the feedback is less important than its presence and quality. Controlled comparisons of different versions of the Design-A-Plant

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**Figure 16.8. Players Recognized More Game-Relevant Information Than Game-Irrelevant Information.**

Based on data from Belanich, Sibley, and Orvis, 2004.
and Circuit games summarized in the following paragraphs support the value of incorporating feedback into games or simulations.

Moreno (2004) evaluated learning and efficiency of two versions of a botany game called Design-A-Plant. See Figure 9.9 to review the Design-A-Plant interface. In Design-A-Plant, learners are given a goal to construct a plant with the best combinations of roots, leaves, and stems to survive in planets of different environmental features. The game goal is to design a plant that succeeds in a specific environment. The instructional goal is to learn how plant features are adaptive to various environmental conditions.

In one version of Design-A-Plant, a learning agent provided explanatory feedback to learner responses. A comparison version offered only “correct–incorrect” feedback. In the explanatory feedback version, when the learner makes a correct selection, the agent confirms the choice with a statement such as: “Yes, in a low sunlight environment, a large leaf has more room to make food by photosynthesis.” For an incorrect choice, the agent responds with a statement such as: “Hmmmm, your deep roots will not help your plant collect the scarce rain that is on the surface of the soil.” This feedback is followed by the correct choice.

The explanatory feedback version resulted in better learning and was also rated as more helpful than the versions that only provided correct or incorrect feedback. There were no differences in student ratings of motivation or interest for the two versions. Adding explanations to the feedback improved learning, but did not detract from the enjoyment of the game.

In a follow-up experiment, Moreno and Mayer (2005) confirmed these findings. Learners working with versions that provided explanatory feedback scored twice as much on a transfer post-test, with an effect size of 1.87, which is very high.

Mayer and Johnson (2010) compared learning from different versions of an arcade game designed to teach basic principles of how an electric circuit works. Learning from a version of the Circuit game with explanatory feedback improved performance during the game as well as on a transfer test, with effect sizes of 1.31 and .68, respectively.

**Add Self-Explanation Questions**

In Chapter 11, we reviewed evidence showing that adding a self-explanation question to a worked example boosted the instructional benefits of the
example. Mayer and Johnson (2010) tested the benefits of adding self-explanation questions to the Circuit game. In Figure 16.9 you can compare one screen from the basic game to a screen that added a checklist of explanations to each game problem. For example, two of the checklist options are: “If you add a battery in serial, you increase flow rate of the current” or “If you add a battery in parallel with another battery, you do not change the flow rate of the current.” As you can see in Figure 16.10, the game version with the

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**Figure 16.9. A Screen Shot from the Circuit Game Without and with Self-Explanation Questions.**


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**Figure 16.10. Better Learning with Self-Explanation Questions Added to a Game.**

Based on data from Mayer and Johnson, 2010.
self-explanation checklist improved performance during the game as well as on a transfer test, with high effect sizes. In a recently published follow-up study, Johnson and Mayer (2010) replicated the results of their first study, finding that the self-explanation groups achieved scores on a transfer test of about 74 percent, compared to 53 percent from the game version without self-explanations.

Games and Simulations Principle 4: Build in Guidance and Structure

Perhaps one of the most important guidelines we can offer is to design simulations and games that offer structure and learning support. In fact, much recent research focuses on strategies you can use to guide experiential learning. Here we review several techniques that have emerged from this research.

Avoid Discovery Learning

If there is one thing we do know about experiential learning, it’s that pure discovery learning, whether by an individual alone or with a group, does not pay off. The assumption that mental activity must be predicated on physical activity is a teaching fallacy (Mayer, 2004). “Instructional programs evaluated over the past fifty years consistently point to the ineffectiveness of pure discovery. Activity may help promote meaningful learning, but instead of behavioral activity per se, the kind of activity that really promotes meaningful learning is cognitive activity” (p. 17).

Judge the value of any simulation or game not on the activity but rather on the degree to which the activity promotes appropriate cognitive processing. “Guidance, structure, and focused goals should not be ignored. This is the consistent and clear lesson of decade after decade of research on the effects of discovery methods” (Mayer, 2004, p. 17).

We discourage the creation of games and simulations that are highly exploratory—environments that at best are inefficient for learning and at worst defeat learning completely. One way to mitigate these unintended consequences is to incorporate guidance into simulations and games.
Design Guidance Appropriate for Inquiry Simulations

An inquiry simulation is a simulation designed to teach scientific investigation skills such as the Genetics simulation we show in Figure 16.4. In a review of research on inquiry simulations, De Jong (2011) concludes that the following types of guidance benefit learning: (1) help learners identify relevant variables, (2) provide hypotheses in a “ready-made” manner such as in a menu rather than asking learners to derive hypotheses on their own, (3) offer a domain-specific structure for the inquiry process through a set of concrete assignments, and (4) require learners to reflect on their activities and the results of their activities. For example, in the genetics simulation shown in Figures 16.4 and 16.5, the program might suggest a specific strategy such as:

“Change one gene on a single chromosome, record the change observed in the dragon, then change the corresponding gene on the paired chromosome. What do you notice when one of the chromosomes contains a dominant (capital letter) gene? What happens when both chromosomes contain a recessive (small letter) gene? Based on your observations, write a hypothesis about dominant and recessive genes. Next plan a dragon experiment to test your hypotheses.”

Incorporate Visualization Support

Success in some simulations or games may rely on spatial skills. For these types of games, instructional aids can promote learning by providing external spatial representations as guides. For example, Mayer, Mautone, and Prothero (2002) evaluated different types of support for a geology simulation game called the Profile Game. In the game learners collect data from a planet whose surface is obscured by clouds. Players draw a line on the interface and the computer shows a profile line indicating how far above and below sea level the surface is at each point on the line. By drawing many lines, learners can determine whether the section contains a mountain, trough, island, or other feature.

Participants were provided with strategy aids in text, visual aids diagramming the various geological features, or no aids. Figure 16.11 shows a sample of the visual aid. The visual aids led to best game performance. The
research team concludes that “students need support in how to interact with geology simulations, particularly support in building and using spatial representations” (p. 181).

**Figure 16.11 This Visual Aid Helped Learners Identify Geological Features in a Geology Simulation Game.**


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**Incorporate Instructional Explanations**

An instructional explanation is a brief tutorial that states the principles or concepts being illustrated in the simulation or game. We have evidence that learning from games or simulations with explanations is better than from games and simulations without explanations. There are two main ways to integrate explanations. They can be included as feedback to learner responses, as we described previously in this chapter. Additionally, explanations can be offered in the form of hints appearing between simulation rounds. When
using a simulation or game lacking explanations, learners try to achieve the goals of the game and learn at the same time. These two activities may lead to mental overload and it's usually the game—not the learning—that takes precedence.

Rieber, Tzeng, and Tribble (2004) evaluated learning of laws of motion from a game in which learners clicked to kick a ball to position it on a target on the screen. The game score was based on the time needed to reach the goal. Learning was measured with a multiple-choice test that assessed understanding of the physics principles. Some participants received hints between game rounds such as:

“This simulation is based on Newton's laws of motion. Newton's second law says that the speed of an object depends on size of the force acting upon it. Therefore, an object kicked two times to the right would move at a speed twice as fast as a ball kicked only once.” (p. 314)

Those who received hints had an average pretest-posttest gain of 32 points compared to 13 points for those who did not receive hints!

The research team concluded that “Discovery learning within a simulation can be very inefficient, ineffective, and frustrating to students, but providing students with short explanations at just the right time can offset these limitations” (p. 319). A brief and succinct instructional explanation incorporated into a simulation can improve learning and at the same time not detract from the game experience.

Taken together, the research we have reviewed in this section recommends that you design guided experiential environments. No doubt there are many techniques for effective guidance and we will expand our list as research accumulates on this important issue.

**Games and Simulations Principle 5: Manage Complexity**

In 2007 a major technology firm commissioned two adventure games for new hire orientation. In one of the games, Rise of the Shadow Specters, the
player assumes the role of a new employee on a fantasy planet and finds that Shadow Specters have attacked the network, thereby threatening the planet. The goal is to defeat the specters by answering questions and opening secret doors to learn about the business. In a survey evaluation, Carson (2009) reported that relatively low participation in the game among new workers was due to poor usability, perceived lack of relevance, and the time commitment required to play the game.

These results likely reflect two issues: cognitive overload due to interface design complexity and failure to motivate, reflecting a perceived lack of game relevance to the job. In this section we summarize several techniques you can use to manage complexity in games and simulations.

**Move from Simple to Complex Goals**

Begin a game or simulation with a relatively low challenge task or goal and move gradually to more complex environments. For example, in the genetics simulation game shown in Figure 16.5, the challenge of the game can be adjusted by changing the number of genes needed to match the test dragon to the target dragon or by the complexity of the genetic relationships required to achieve a given match. Game complexity can be controlled by asking learners to select a game difficulty level based on their relevant experience or by dynamically adapting game complexity based on accuracy of responses during the game.

**Provide Training Wheels**

Carroll (2000) described a “training wheels” principle for software simulations. He recommended that learners work with a simulation in which only some of the functionality is enabled. Although the full interface may be visible, only relevant elements of it work. In that way, learners cannot go too far astray during early trials. As more tasks are learned, the constraints are gradually relaxed until the user is working with a highly functional system. For example, when initially working with a software simulation, only a few commands or icons are functional. As the learner gains experience, greater functionality is added.
Align Pace to Instructional Goals

According to some, the new generation of gamers is not patient. They have learned to multitask and to respond to multiple digital information sources quickly. Slow game pace was one complaint of players of an Indiana Jones adventure game (Ju & Wagner, 1997). While fast-paced games may be more popular, they are also likely to lead to greater overload and to fewer opportunities for reflection. For example, in comparing learning from a paper-based explanation of wave formation to a multimedia animated, narrated version, Mayer and Jackson (2005) found better learning from the paper group because learners could interact with the material at their own pace and were less likely to experience cognitive overload.

Games that rely on rapid responses to win may benefit learning of skills that require responses based on speed and accuracy. If your instructional goals require application of concepts and rules, games that proceed under learner control of pacing and do not reward speed will be more effective.

Ensure Ease of Use

Previously in this chapter, we reviewed findings by Mayer and Johnson (2010) showing the benefits of encouraging reflection by requiring learners to select self-explanations during playing of a Circuit game. You can review the game interface and results in Figures 16.9 and 16.10. In a recent follow-up study, Johnson and Mayer (2010) compared learning among three versions of the Circuit game: the base game shown in Figure 16.9 A, the base game with a checklist of self-explanation questions shown in Figure 16.9 B, and the base game in which the learners were required to generate their own self-explanations by typing them into a window to the right of each circuit problem (not shown in Figure 16.9). The research team found that requiring learners to select an explanation from a list improved learning, whereas requiring them to type in their own explanations gave no better results than the base-game. Asking game players to generate and type in their own explanations apparently added too much cognitive load and/or disrupted the game flow.

Holzinger, Kickmeier-Rust, Wassentheurer, and Hessinger (2009) compared learning of arterial blood flow principles from a simulation
called HAEMOSIM. Learning was compared from three instructional versions. One group studied a traditional text description. Group 2 used HAEMOSIM unaided, while Group 3 used HAEMOSIM preceded by a thirty-second video that explained how to use the simulation and described the main parameters involved. Learning was much better from HAEMOSIM only when preceded by the explanatory video. The research team concludes that “It is essential to provide additional help and guidance on the proper use of a simulation before beginning to learn with the simulation” (p. 300).

Similar findings were reported by Lazonder, Hagemans, and De Jong (2010), who compared simulation performance among three groups. One group was provided pretraining on the different variables in the simulation and also had access to the information during the simulation. A second group received no pretraining but had access to the information during the simulation. A third group worked with the simulation without any help. Participants who had access to simulation information outperformed those who had no help, with the group that received information both before and during the task scoring highest.

A lesson learned from these experiments is the importance of making the interface user-friendly with techniques such as providing a checklist rather than requiring typing. In addition, performance of novice learners benefits from pretraining as well as embedded help that explains how the game or simulation works and/or provides domain-specific background knowledge.

Adapt Complexity to Learner Expertise

Interface complexity is a function of the type and display of images used in a game or simulation. Lee, Plass, and Homer (2006) created a conceptual simulation of Boyles and Charles Laws that describe the relationships between gas pressure and gas volume (Boyles Law) and gas temperature and gas volume (Charles Law). The research team created high- and low-complexity simulations by varying the visual representations and the number of variables learners could manipulate at once. A simple version used concrete imagery such as a weight to represent pressure or a flame to represent temperature and only allowed manipulation of one variable at a time—either
pressure or temperature. A complex version used abstract imagery in the form of a slider bar and allowed manipulation of two variables (heat and temperature) at once. In Figure 16.12 we compare the concrete and abstract imagery versions. Learners with minimal background in science benefitted from the concrete version. In contrast, high prior knowledge students learned equally well from the concrete and abstract representations.

Figure 16.12. A Simple and Complex Simulation Interface for Ideal Gas Laws.

From Lee, Plass, and Homer, 2006.

Games and Simulations Principle 6: Make Relevance Salient

Consider the context and genre of the game or simulation to ensure that its relevance to job roles is immediately clear. Workforce learners are subject to many demands, have limited time, and will often discard learning environments that do not immediately appear relevant.

Although fantasy game interfaces such as Figure 16.1 may be visually stimulating, their lack of correspondence with the work environment may actually detract from the motivational potential of the game. High-fantasy
elements are considered motivational in games and simulations designed for entertainment (Malone & Lepper, 1987). However, the fantasy features may not always motivate workforce learners.

The relevance of any game can be enhanced by providing learning objectives, pretraining explanations, embedded explanations, and/or interfaces that either mirror or are analogous to work role demands. We will need additional research to define features that optimize learning and motivation in games and simulation environments designed for workforce learners.

What We Don’t Know About Games and Simulations

Although our knowledge base is growing, there remains much to learn. We do know that, for some, games are motivational and, when well designed, can improve learning. We are also confident that well-designed simulations can offer instructional environments for practice and learning that are unavailable or unsafe in the workplace. The research of the next few years should give more guidance about how to design simulation and game features that effectively balance motivational and learning elements. Here is a list of some important questions for which we need empirical data:

1. Guidance for guidance. We reviewed accumulating evidence that guidance is an essential ingredient of an effective learning simulation or game. However, we need more information on the most appropriate format, source, and type of guidance to use for different instructional goals at different learning stages.

2. Simulation and game taxonomies for different learning outcomes. We know it’s important to match the simulation or game goal, actions, feedback, and interface to the instructional goals. However, we have only general guidelines for making an appropriate match, most of which lack empirical verification. Will arcade games with rapid response features be most effective for visual discrimination
or motor skills? Will adventure or strategy games be best aligned to learning cause-and-effect relationships? Are memory goals such as learning product knowledge best supported by game-show-type formats? An empirically based taxonomy of game formats aligned to learning outcomes should help game and simulation designers make optimal matches.

3. **Cost/benefit of games and simulations.** To design and implement a computer game or simulation of any complexity requires an investment of time and resources. In addition to development costs, participant time is invested in interacting with the simulation or game. What are the efficiencies of games? How does the time to achieve an instructional goal from a game compare with achieving the same goal from a book or tutorial? When does the motivational appeal of a game offset the investment in development and learning time? For example, will an embedded game result in higher completion of e-learning as well as equal or better learning contrasted to traditional methods? In most commercial settings, there is a cost attached to the development and use of learning environments, and we have much to learn about the cost/benefit tradeoffs of games and simulations.

4. **Collaboration in games.** In Chapter 13 we reviewed the benefits of collaborative learning, which are realized when the collaborative assignment and incentives are optimized. A promising new area of research involves comparison of learning from games played solo with collaborative play.

5. **Value-added research on games.** How can we add proven instructional methods to enhance learning to games and simulations in ways that do not appreciably detract from the motivational elements of the game? Some examples of value-added research that we reviewed in this chapter revealed the benefits of adding explanatory feedback and self-explanation questions to games. A promising avenue of research is to identify other proven strategies that can be integrated into games and simulations.
DESIGN DILEMMA: RESOLVED

We started this chapter with a debate between Sandy and Matt on embedding the spreadsheet lesson content into an adventure game context. The options included:

A. Sandy is correct. Raised on games, the younger workforce will learn more effectively from game-type lessons.

B. More participants will complete a lesson based on a game than will complete a traditional tutorial.

C. Learning by exploration and experience is more effective than learning by explanations and traditional practice exercises.

D. Constructing a gaming environment will be more expensive than developing a traditional course; however, the investment will pay off in higher course completion rates and better learning.

While we would like to select Option D, at this time we do not have sufficient evidence to support it. Rather than ask whether games are a good idea or a bad idea, a better question is What kinds and features of games will offer cost/benefit for a given learner population and instructional goal. We look forward to additional research that specifies instructional methods that improve learning from simulations and games in workforce learning.

WHAT TO LOOK FOR IN e-LEARNING GAMES AND SIMULATIONS

- Goals, rules, activities, feedback, and consequences are aligned to desired learning outcomes.

- Sufficient structure and guidance are included to help learners reach instructional goals.

- Feedback to learner responses includes explanations.

- Explanations are incorporated between play rounds.
COMING NEXT

In the previous chapters we have provided guidelines and examples based on evidence regarding a number of important issues e-learning designers and developers must address. In the next and final chapter, we summarize all of the guidelines to end our book with a comprehensive review of evidence-based principles of e-learning design.

Suggested Readings


