GAME-BASED LEARNING:

WHAT IT IS, WHY IT WORKS, AND WHERE IT'S GOING

Education is not the filling of a pail, but the lighting of a fire. –William Butler Yeats

Introduction

Deconstruct the fun in any good game, and it becomes clear that what makes it enjoyable is the built-in learning process.

To progress in a game is to learn; when we are actively engaged with a game, our minds are experiencing the pleasure of grappling with (and coming to understand) a new system. This is true whether the game is considered "entertainment" (e.g., World of Warcraft) or "serious" (e.g., an FAA-approved flight simulator).

The implications of delivering game experiences for education and training are enormous. In the US, nearly 170 million people played computer and videogames in 2008[i], spending a record $11.7 billion[ii]. Harness the power of well-designed games to achieve specific learning goals, and the result is a workforce of highly motivated learners who avidly engage with and practice applying problem-solving skills.

Because of good game design, more than 11 million subscribers[iii] spend an average of 23 hours per week[iv] immersed in World of Warcraft. A growing core of game-based learning experts use the same design principles to make it compelling for surgical students to practice and hone proper laparoscopic techniques on a virtual patient[v], or inspire first responders to frequently rehearse and sharpen their training in a simulated hazardous materials emergency[vi]. The emerging truth: the same factors that make well-designed games highly motivating also make them ideal learning environments.

What is Effective Game-based Learning, and Why Does it Work?

When education or training feels dull, we are not being engaged and motivated. In other words, we're not really learning. "Learning" doesn't mean rote memorization—it means acquiring the skills and thought processes needed to respond appropriately under pressure, in a variety of situations.

We don't need more time in the classroom to learn how to think and perform in the face of real-world challenges. We need effective, interactive experiences that motivate and actively engage us in the learning process. This is where game-based learning comes in. As it turns out, for many years, videogame designers have been producing and refining highly motivating learning environments for their players to enjoy.

Good game-based learning applications can draw us into virtual environments that look and feel familiar and relevant. According to Dr. Susan Ambrose, director of Carnegie Mellon's Eberly Center for Teaching Excellence, this is motivational because we can quickly see and understand the connection between the learning experience and our real-life work.

Within an effective game-based learning environment, we work toward a goal, choosing actions and experiencing the consequences of those actions along the way. We make mistakes in a risk-free setting, and through experimentation, we actively learn and practice the right way to do things. This keeps us highly engaged in practicing behaviors and thought processes that we can easily transfer from the simulated environment to real life. Research supports the effectiveness of game-based learning in virtual environments—for example, according to a meta-analysis of flight simulator training effectiveness, simulators combined with aircraft training consistently produced training improvements compared to aircraft-only training[vii].

In contrast, traditional, passive training approaches drill us on certain narrow procedures, and then evaluate us on our memory of what we were told. Even when we successfully retain the lesson's facts and procedures, our behavior in true-to-life situations remains untested. In addition, even the most comprehensive training program cannot cover procedures for every complex eventuality that we will encounter—no matter how thick the binder is. In game-based environments, we learn not only the facts, but also the important, underlying hows and whys. This understanding of deeper, more abstract principles prepares us to perform consistently and effectively, even in new and unexpected situations.

Game-based Learning vs. Traditional Training

The effectiveness of hands-on learning isn't new—for example, the apprenticeship system traces a rich history from ancient times to the present day. But well-designed game-based learning has several advantages over traditional experiential learning methods. It is cost-effective and low-risk (unlike, for example, safety training using live machinery). Perhaps even more important, there are significant learning advantages. Learners can re-enact a precise set of circumstances multiple times, exploring the consequences of different actions. In addition, well-designed games permit learning experiences that aren't possible in real life—for example, "designing" a dolphin to find out how body size and fin position affect how far it can swim[viii], or deliberately causing the biggest possible virtual explosion to understand why gas line disasters happen.

Figure one compares three approaches: passive training methods such as classroom lectures and online "click through" tutorials; hands-on training such as apprenticeship programs; and game-based learning.

	Traditional Training (lectures, online tutorials)	Hands-on Training	Game-based Learning
Cost-effective	X		X
Low physical risk/liability	X		X
Standardized assessments allowing student-to-student comparisons	X		X
Highly engaging		X	X
Learning pace tailored to individual student		X	X
Immediate feedback in response to student mistakes		X	X
Student can easily transfer learning to real-world environment		X	X
Learner is actively engaged		X	X

Fig. 1: Comparison of Traditional Training, Hands-on, and Game-based Learning

How We Learn

All games are not created equal. The games we give up on are the ones that let us down with regard to learning. They do a bad job of structuring our learning experience, leaving us bored or frustrated. To be effective, game environments must be structured around how we learn.

Carnegie Mellon's Eberly Center for Teaching Excellence has amassed a set of basic principles that describe the learning process[ix]. Following are four of these key principles, with examples of how each plays out in traditional training and in game-based learning.

Principle 1: Students' prior knowledge can help or hinder learning. Obviously, learners who have accurate prior knowledge of a given subject matter tend to have a leg up. But what about a learner whose prior knowledge is wrong? As an example, consider an experienced worker who is practicing loading dock safety procedures. He may "know" that he's supposed to look behind him when backing up in a forklift—but if he's worked on mostly quiet loading docks in the past, he may have developed the bad habit of merely listening for potential rear obstacles. In a traditional lecture-based setting, his buried misconception might surface only at test time, if at all—rendering unreliable his related "learning" up to that point. With game-based learning tools, misconceptions about core learning goals are quickly apparent. For example, in-game, his failure to look behind him before backing up would result in an immediate, negative consequence (e.g., crashing a forklift, hurting his virtual self or striking a pedestrian). As a result, he could rapidly self-correct and move on to more advanced learning based on a sound foundation.

Principle 2: Students' motivation determines, directs and sustains what they do to learn. The digital generation that makes up a large part of today's workforce is notoriously unmoved by traditional, lecture and tutorial-based training approaches. On the other hand, they are very comfortable with videogames and game-based learning. According to game-based learning experts, learners tend to be highly motivated by in-game feedback such as scores and evaluations. For example, many learners using the loading dock safety game play again and again until they achieve a perfect safety score. In the process (and sometimes without consciously realizing it), they learn how to operate within the game environment; actively think, experiment and learn how to safely accomplish their work; and practice their "lessons learned" to develop consistent and productive thought processes.

Principle 3: To develop mastery, students must acquire component skills, practice integrating them, and know when to apply what they have learned. Learning is a process that happens in bite-sized chunks, each learner working at a different pace. Thoughtfully designed, passive training programs follow this process, but primarily do so on a group basis. This means that slower students often struggle, and faster students become bored. The focus tends to necessarily be on learning facts or rules, with limited opportunities to apply them. In contrast, good game-based learning is tailored to each learner. For example, in the loading dock game, a learner begins with basic concepts such as putting on protective gear. She cannot advance in the game until she performs this step correctly. As she chooses actions that demonstrate her mastery of interim learning goals, she moves on to more advanced challenges. Even more important, because the game represents an active, realistic learning environment, the focus is on learning, through consequences, to apply the right knowledge at the right time.

Principle 4: Goal-directed practice coupled with targeted feedback enhances the quality of students' learning. As discussed, traditional training cannot provide a constant, individualized and highly motivating level of feedback. In addition, traditional classroom and tutorial-type training methods do not give learners the opportunity to repeatedly practice thought processes and skills in a realistic

environment. An effective game for loading dock workers establishes motivational goals relevant to actual loading dock work. As learners progress, when they make a mistake, they experience immediate in-game consequences (e.g., failure to put on a hard hat results in a falling beam to the head). Additional feedback, which comes through alerts, scores, and post-game reports, motivates learners to continue practicing until they master the game's learning goals—and provides the information they need to get there.

Characterizing Good Game-based Learning Environments

Linked to the general principles of how we learn are more specific principles that describe how we learn in the context of effective game environments.

James Paul Gee, author of *What Video Games Have to Teach Us about Learning and Literacy*[x], describes 36 learning principles that well-designed games embody. Following are four:

Subset Principle: Learning, even at its start, takes place in a (simplified) subset of the real domain. For example, the setting for the loading dock game should represent an actual loading dock, so that players can easily map their in-game behavior to on-the-job performance. However, it must be a simplified version that omits unimportant details, so that players can focus on aspects of the simulation that are relevant to the learning objective—things like crosswalks and pedestrians.

Active, Critical Learning Principle: The learning environment must encourage active and critical, not passive, learning. In the loading dock example, this means players do not merely watch correct and incorrect examples of loading dock behavior, followed by a quiz—they actually think, act, experience consequences and pursue goals in a variable game environment.

Probing Principle: Learning is a cycle of probing the world (doing something); reflecting on this action and, on this basis, forming a hypothesis; re-probing the world to test the hypothesis; and then accepting or rethinking the hypothesis. For example, an effective loading dock game must present a functional environment in which players may choose from and evaluate many different actions. The goal is to find the right course of action via experimentation—making choices and experiencing the consequences.

Practice Principle: Learners get lots of practice in a context where the practice is not boring (i.e. in a virtual world that is compelling to learners on their own terms and where the learners experience ongoing success). For example, to encourage practice—and thus, development of good habits—the loading dock game must gradually increase the difficulty level of the in-game challenges. This keeps players engaged and encourages them to continually hone their skills.

Why Now?

Digital game-based learning tools are becoming widely accessible. With the demonstrated effectiveness of game-based learning vs. traditional, passive learning approaches, why have many organizations waited until now to adopt game-based education and training? Two factors are driving this adoption:

A Changing Workforce

Schools, office buildings and other worksites are filled with people who have never known a world without videogames, cell phones, and the internet. In the four years between 2006 and 2010, nearly one in five US workers is expected to retire[xi], to be replaced primarily by 18-40 year-olds who grew up with videogames.

People habitually divide their attention among several things at once. Competition for the fractured attentions of trainees, students and audiences in general is tougher than it's ever been. For example, the *New York Times* recently reported that a third of people in one poll said that they frequently check email during business meetings[xii]. In this environment, unidirectional training and communication approaches such as lectures, manuals, workbooks, videos, and online, click-through reading material can quickly "lose" their preoccupied target audiences.

The chronic problem of how to win students' attention in order to teach has become acute. Well-designed digital games—complete with realistic settings and compelling narratives—are to this and future generations what adventure novels like Robinson Crusoe were to previous ones. Used for learning, well-designed games are able to cut through distractions and engage this audience in a way that few other methods can. As a result, increasingly organizations are seeing how funding highly engaging game-based approaches will bring significant returns.

Technological Advances

In the past, game-based learning environments were prohibitively expensive for most organizations. Traditional game- and simulation-based learning applications have typically entailed mainframes, special interface equipment, and a years-long design, development and implementation process. Only a few sectors—most notably, aviation and the military—were able to justify the cost, because the quality of training was a life-or-death issue. More recently, health care organizations and medical schools have begun to rely on games and simulations, and practice on these tools is now encouraged or even required. For example, the FDA now requires virtual reality training for placement of some stents[xiii], and many medical schools have established centers dedicated to simulation training.

Today, game-based learning is accessible in many different industries, for four reasons:

- The success of game- and simulation-based learning in the aviation, military and healthcare industries provides a powerful proof-of-concept, and an endorsement of learning effectiveness.
- Advances in raw processing power with an attendant decrease in cost have brought game-based learning within reach.
- The development of stable, flexible game engines and toolkits are driving down the cost of development and reducing the need for 100% custom, from-scratch application development.

- A growing crop of designers and developers literate in the medium of games have amassed a critical level of knowledge regarding what works and what doesn't.

There remains an important place for virtual reality simulations that require specialized hardware. When "feel" is important—for example, the sensation of a needle in a certain type of tissue—it's necessary to use motion control devices that provide feedback about how instruments respond to small movements. However, when the learning goals involve thought processes about actions and their consequences, special motion devices such as virtual reality helmets and gloves are unnecessary and potentially even detrimental—they can distract learners from the core objectives. Games that focus on if-then, choice-consequence learning typically run on standard PCs, require no expensive peripherals, and can be downloaded and installed in minutes. Interestingly, while both hardware- and software-based games have become much simpler and more accessible for end-users, the underlying game design has become significantly more sophisticated.

Summary

The ideal of interactive, highly-engaging training and education is ancient. A Chinese proverb says: "Tell me, and I'll forget. Show me, and I may remember. Involve me, and I'll understand." However, the gap continues to grow between antiquated, passive training methods and a workforce that lives an ever more interactive, multimedia, user-controlled lifestyle. With game-based learning tools to bridge that gap comes the promise of vastly more productive and engaged students and workers—ones who embrace learning rather than view it as a disruptive burden.

About the Author

Jessica Trybus is Senior Special Faculty and Professor of the Practice for Carnegie Mellon University's Entertainment Technology Center. She is known as an expert in the development of software that utilizes video gaming and simulation design for more effective learning. Since 2002, Trybus has been an integral part of Carnegie Mellon's renowned leadership in research and development for applying video game design and technology to learning solutions across many different topics and a wide variety of audiences. Trybus is the founder and CEO of Simcoach Games, a Carnegie Mellon spinoff specializing in game-based learning and serious games since 2005. She also serves on the board of The Beckwith Institute (associated with University of Pittsburgh Medical Center), the Andy Warhol Museum and The Three Rivers Workforce Investment Board. Trybus received a B.A. from Cornell University and a Masters degree from Carnegie Mellon University.

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