Policy Insights from the
Behavioral and Brain Sciences
2016, Vol. 3(1) 20–26

DOI: 10.1177/2372732215621311
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What Should Be the Role of Computer Games in Education?

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Abstract

Game advocates call for replacing conventional schooling with educational activities based on computer games. These claims were examined by reviewing published research on games for learning and then drawing policy implications. Value-added research shows that the most promising features of games use conversational language, put words in spoken form, add prompts to explain, add advice or explanations, and add relevant pregame activities. Cognitive consequences research shows that first-person shooter games improve perceptual attention skills. Media comparison research shows that games are more effective than conventional media for science learning. However, an educational revolution based on gaming is not indicated. Policy implications are to use games for targeted learning objectives, align games with classroom activities, avoid confusing liking with learning, and use games to adapt activities to maintain challenge. Research evidence informs decisions about educational games.

Keywords

computer games, video games, educational games, games for learning

Tweet

Research on games for learning does not support calls for an educational revolution based on gaming, but suggests games focused on targeted learning objectives.

Key Points

- Game advocates call for revolutionizing education based on computer games, but research does not call for an educational revolution based on games.
- Game effectiveness is improved by using conversational language, spoken format, prompts to explain, explanatory feedback, and pregame activities.
- Playing first-person shooter games improves perceptual attention skills.
- Games are more effective than conventional media for science learning.
- Policy implications are to use games for targeted learning objectives, align games with classroom activities, not confuse liking with learning, and use games to maintain challenge.

The Issue: Can Game Playing Improve Academic Learning?

Computer games for learning are those intended to promote learning (Mayer, 2014). Can playing computer games (also called video games) help people develop knowledge and skills and, if so, how should computer games be used in education? These are the questions addressed in this brief article.

Imagine a scenario in which school-age children spend their time playing computer games that help them learn academic content and skills. Imagine schools where instruction is supplemented or even supplanted by having students play computer games that help them learn what they need for success in life and work. Imagine students who are motivated to learn and take responsibility for their learning because they enjoy playing computer games for learning.

This is the kind of future envisioned by game visionaries. In the popular book, *Reality Is Broken: Why Games Make Us Better and How They Can Change the World*, Jane McGonical (2011) states, “I foresee games that fix our educational systems” (p. 14). Similarly, in *Don't Bother Me Mom—I'm Learning*, Marc Prensky (2006) writes, “Kids are almost certainly learning more positive, useful things for their future from their video games than they learn in school” (p. 4). Finally, in *Good Video Games + Good Learning*, James Gee (2007) claims, “Good games

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Table 1. Three Genres of Game Research.

Genre	Description	Comparison
Value added	Which game features improve learning?	Play base version vs. same game with one feature added.
Cognitive consequences	Does game playing improve cognitive skills?	Play off-the-shelf game vs. control activity.
Media comparison	Do students learn better with a game than with conventional media?	Play game vs. learn with conventional media.

are problem-solving spaces that create deep learning—learning that is better than what we often see in today's schools" (p. 10).

The common theme running through the claims of many game advocates is that today's schools are failing but tomorrow's video games can pave the way for student learning. The rationale for this call for an educational revolution is based on the idea that computer games are highly motivating (Lepper & Malone, 1987; Malone, 1981; Malone & Lepper, 1987) as evidenced by their huge popularity—for example, computer game players are in more than 67% of U.S. households, and more than US$100 billion is generated in sales worldwide each year (Kapp, 2012). If these claims are correct, the policy implications for educational reform are substantial—we need to make school activities more like computer games.

In spite of the enthusiasm of game advocates, it is worthwhile to ask whether there is sufficient evidence to support their claims for the educational value of playing computer games. In contrast to the claims made by game advocates, researchers are charged with the much less glamorous task of testing the claims in rigorous scientific studies. Over the past decades, there has been a succession of major reviews of scientific research on games for learning (Connolly, Boyle, MacArthur, Hainey, & Boyle, 2012; Honey & Hilton, 2011; Mayer, 2014; Randel, Morris, Wetzel, & Whitehill, 1992; Sitzmann, 2011; Tobias, Fletcher, Dai, & Wind, 2011; Vogel et al., 2006; Wouters, van Nimwegen, van Oostendorp, & van der Spek, 2013; Young et al., 2012), but their overall conclusions have not supported the claims of game advocates for revolutioning education.

For example, Tobias et al. (2011) conclude,

> 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. (p. 206)

In an earlier analysis of game research, O'Neil and Perez (2008) lament,

> While the effectiveness of game environments can be documented in terms of intensity and longevity of engagement . . . as well as the commercial success of games, there is much less solid empirical information about what outcomes are systematically achieved . . . and there is almost no guidance for game designers and developers on how to design games that facilitate learning. (p. ix)

This article explores what the current state of scientific research evidence has to say about games for learning and explores the policy implications of this research base for educational practice. Researchers have a role to play in determining the effectiveness of games as learning environments, and hence in contributing to a research base for drawing policy implications. Thus, this review attempts to apply the science of learning to education (Mayer, 2011a).

The Research: Three Genres of Game Research

What does the research have to say about the effectiveness of computer games as educational tools? As summarized in Table 1, experimental research on learning with computer games can be broken down into three major genres: *value-added research, cognitive consequences research*, and *media comparison research* (Mayer, 2011b, 2014). Value-added research addresses which game features improve learning, cognitive consequences research investigates whether playing various off-the-shelf games improves cognitive skills, and media comparison research seeks to determine whether games are better than conventional media at promoting academic learning. Also, observational studies describing game playing can add rich context to our understanding of games for learning (e.g., Turkle, 1995), but this article focuses on experimental studies because they allow for causal conclusions relevant to educational policy recommendations (Shavelson & Towne, 2002).

Value-Added Research

Value-added research compares the learning outcomes of people who play the base version of a game (control group) with those who play the same game, but with one feature added (treatment group). The value-added approach is encouraged by a recent research review: Adding instructional support to computer games shows overall positive effects from priming appropriate cognitive processing, such as selecting relevant information, organizing it, and integrating it with relevant prior knowledge (Wouters & van Oostendorp, 2013).

Table 2. Five Promising Features for What Works With Educational Computer Games.

Feature	Description	Effect size
Personalization	Put words in conversational style rather than formal style	1.5
Modality	Put words in spoken form rather than printed form	1.4
Self-explanation	Add prompts to explain at key points in the game	0.8
Coaching	Add advice or explanations at key points in the game	0.8
Pretraining	Add pregame activities that describe key components	0.7

In particular, consider the effect size created by adding individual features, based on Cohen's d, which provides a common metric for determining how many standard deviations of improvement were caused by adding the new feature. In educational intervention research, effect sizes of d = 0.4 or greater are considered to be practically important (Hattie, 2009), so this article focuses on game features that produce effect sizes of d = 0.4 or greater.

For example, the Design-A-Plant game is a computer-based game intended to teach environmental science, in which students travel to a distant planet that has specific climate patterns such as heavy rain and high winds, and they must design a plant that will survive there by selecting from eight types of roots, eight types of stems, and eight types of leaves. Next, students get to see how well their plant survived, while a local character, named Herman-the-Bug, explains how their plant functions. Across nine studies, students performed better at solving transfer-of-knowledge problems, if they played a version of the game in which Herman-the-Bug's words were spoken (treatment group) rather than printed on the screen (control group), yielding a median effect size greater than 1 (Moreno & Mayer, 2002; Moreno, Mayer, Spires, & Lester, 2001). This is an example of a value-added study because it compared the learning outcome performance of students who played the base version of the game (i.e., with printed text) versus those who played an enhanced version with one feature changed (i.e., with spoken text rather than printed text). This set of studies allows us to propose the *modality principle*—people learn better in games when explanations are spoken rather than printed.

As summarized in Table 2, a recent review of published game research identified five game features that substantially improved student performance on a test of learning outcome (Mayer, 2014): using conversational style (personalization), presenting words in spoken form (modality), adding prompts to explain (self-explanation), adding explanations or advice (coaching), and adding pregame descriptions of key components (pretraining). These promising features yielded high median effect sizes based on at least six experimental comparisons.

Six other features are not yet promising because they yielded small or negligible median effect sizes based on only four or fewer experimental comparisons: adding competitive features based on ongoing game score (competition), allowing learners to control the order of game activities (learner control), allowing learners to choose the game format (choice), adding an engaging story line (narrative theme), including a static image of game characters on the screen (image), and breaking the screen into parts (segmenting). More research is needed before strong recommendations can be made to include or exclude these game features.

Another important aspect of value-added research is to determine what does not work. In Mayer's (2014) review, one feature yielded a median effect size of $d = -0.1$ across six experimental comparisons: using immersive virtual reality (VR; immersion). Although students reported liking the VR version of the game much better than the desktop version, liking is not learning. However, this finding is limited to only the Design-A-Plant game, which does not rely on highly immersive environments for its instructional objectives. When the instructional objective includes navigating or interacting with a complex environment, such as piloting a ship or performing surgery, games with immersive environments may be more effective.

Finally, adding on-screen printed words to spoken words throughout the game (i.e., redundancy) was ineffective in two of two experimental comparisons, yielding a small negative median effect size of −0.2. These findings suggest that redundant spoken and printed text should be avoided in most game situations; however, redundant on-screen text may be useful under special circumstances, such as when the words are unfamiliar or technical, learners are not native speakers, or the material must be used during the game.

Overall, an emerging research base helps determine how to design effective educational games, so the value-added approach can be useful in specifying policies for what to look for in educational games.

Cognitive Consequences Research

Cognitive consequences research compares the pretest-to-posttest gains on cognitive skill measures of students who play an off-the-shelf game versus those who engage in a control activity, such as playing a qualitatively different kind of game. Although most cognitive consequences studies use commercially available computer games originally intended mainly as entertainment, cognitive consequences researchers may also test games designed to teach specific cognitive skills.

Table 3. Two Promising Cognitive Consequences of Game Playing.

Type of game	Example	Type of test	Effect size
First-person shooter	*Unreal Tournament* *Medal of Honor*	Perceptual attention	1.2
Spatial puzzle	*Tetris*	Mental rotation of *Tetris*-like shapes	0.8

For example, in first-person shooter games such as *Unreal Tournament* or *Medal of Honor*, players must constantly be on the lookout for attackers, who appear at various places on the screen and move in varying trajectories across the screen, and be ready to shoot at them as warranted. Anderson and Bavelier (2011) propose that playing first-person shooter games over extended periods can improve a variety of cognitive skills practiced in the game, mainly involving perceptual attention, as compared with playing non-shooter games.

As summarized in Table 3, a recent review identified two types of games that promoted substantial improvements (i.e., median effect sizes greater than 0.4) in specific cognitive skills across at least six comparisons (Mayer, 2014). The top row shows that playing first-person shooter games such as *Unreal Tournament* or *Medal of Honor* improves a variety of perceptual attention skills, such as useful field of view (Feng, Spence, & Pratt, 2007; Green & Bavelier, 2003; Wu et al., 2012) or multiple object tracking (Boot, Kramer, Simons, Fabian, & Gratton, 2008; Green & Bavelier, 2006). Across 18 experimental comparisons, the median effect median effect size was greater than 1, which is considered a large effect.

The second row of Table 3 shows that playing puzzle games such as *Tetris* improves spatial cognitive skills that are closely aligned with the game, mainly mental rotation of *Tetris*-like shapes. In short, playing *Tetris* improves a very specific spatial cognition skill—mental rotation of *Tetris*-like shapes. Across six experimental tests, the median effect size was 0.8, yielding the second strongest cognitive consequences effect. However, playing *Tetris* had only a small effect on mental rotation of 2D non-Tetris shapes ($d = 0.4$) and did not have a consistent effect on other spatial cognition skills ($d = 0.0$). Thus, *Tetris* playing appears to have a more limited impact than playing first-person shooter games.

In contrast to these two bright spots in the cognitive consequences literature, Mayer's (2014) review did not find substantial evidence (i.e., median effect size of 0.4 based on at least six comparisons) that any other game types improved any cognitive skills. Similarly, there was not consistent evidence that any games improved reasoning or memory skills, including real-time strategy games. Overall, cognitive consequences research does not support claims for broad transfer of game playing to performance on cognitive skill tests, that is, no sufficient evidence supports the claim that playing computer games can improve one's mind in general.

Media Comparison Research

Media comparison research compares the learning outcome performance of students who learn academic content from playing a game (game group) versus those who learn the same content from conventional media such as books and face-to-face slideshow presentations (conventional group). As Clark (2001) eloquently explains, media comparison research that studies differences between game and conventional media may be confounded by concurrent differences in presented content and instructional method. Clark admonishes that when differences in instructional media are confounded with differences in instructional method or content, interpretation of differences in learning outcome is difficult. Thus, the conclusions drawn in this section depend in part on the degree of experimental control in the reviewed experiments.

As an example of a media comparison study, consider learning about wet-cell batteries by playing an action game—*Cache 17*—in which players (game group) must find lost artwork hidden in an old World War II bunker system and at one point must build a wet-cell battery to open a stuck door in route to the artwork. In contrast, other students (conventional group) learn the same information about building wet-cell batteries from a PowerPoint slideshow that uses the same words as in the game. Adams, Mayer, MacNamara, Koening, and Wainess (2012) report that the conventional group performed substantially better than the game group ($d = -0.4$) on a learning outcome test concerning wet-cell batteries. In this case, when the content was the same in both groups, the game medium did not produce better learning than a conventional slideshow presentation.

A recent review of media comparison research (Mayer, 2014) found substantial evidence (i.e., effect size greater than 0.4 based on six or more comparisons) that games are more effective than conventional media for only one content area—science—in which the median effect size was 0.7 based on 16 experimental comparisons. None of the other areas (i.e., mathematics, social studies, language arts, and second-language learning) had a sufficient number of comparisons. In light of the potential for methodological problems with media comparison studies and the insufficient amount of research in most disciplines, it is premature to draw firm conclusions concerning the relative merits of game versus conventional media. The media comparison issue may be too broad and simplistic to be of much value to policy makers because a more important issue concerns the circumstances under which games may be particularly effective. A larger research base and more focused studies are needed to address this issue.

The Implications: Toward Educational Policy on Games for Learning

This review of research on games for learning shows that many games (and game features) are ineffective, so it is important to choose games based on appropriate criteria. Selection of educational games should depend on the available evidence. For example, Table 2 lists some promising game features, and Table 3 lists some effective games for teaching specific cognitive skills. Also worthwhile is selecting games based on an understanding of how learning works, including having sufficient game features to maintain motivation to learn, while having sufficient instructional features (such as feedback) to keep players focused on the learning objective. This review of game research yields several policy implications that warrant further study.

Put the Revolution on Hold

The major policy implication of this review of research on games for learning is that it is premature to call for a major overhaul of schools based on computer games: The research certainly does not warrant extensive replacement of current educational practices with practices based on computer games. Although strong claims are made for revolutionizing education based on computer games, the current state of the research literature does not support these claims.

Use Games for Targeted Learning Objectives

A second major policy implication of this research is that the curriculum likely has a place for small games that focus on well-specified learning objectives. Games should have clearly targeted goals, and the cognitive processing required in the game should correspond closely to the learning objectives. The research on games for learning gives scant reason to hope that game playing will improve the mind in general. Instead, games should be targeted to specific objectives.

Align Games With Classroom Programs and Activities

A third policy implication is that targeted games should fit within the existing educational program. In short, targeted games should be used to supplement and complement ongoing instructional activities rather than to supplant them. Games should not be stand-alone activities that are disconnected from the overall program of instruction, but rather should be used as part of a package of instructional activities to achieve specific instructional goals. An intriguing, but understudied, implication is that games can be used out of class to effectively extend the school day and increase time on task, which has been shown to be a key determinant of learning (van Gog, 2013).

Do Not Confuse Liking With Learning

A fourth policy implication is to focus on game playing that improves learning outcomes, rather than solely focusing on how much students like playing the game. Although students may like to play certain kinds of games, self-reports of liking do not necessarily translate into learning. There are numerous examples in the literature where students liked one version of game best, but did not learn best from it (e.g., Moreno & Mayer, 2002). Games with the most spectacular visual impact or the most excitement, for example, may not be as educationally effective as less glitzy games that focus on an educationally relevant objective. Thus, the most relevant measure for choosing games is the effects on learning outcome, although on balance, it is possible that liking to play a particular game could lead to greater time on task.

Adapt Instructional Activities to Maintain Challenge

An important feature of games is that they can continually adapt to the player's current level of competence, producing an ever-increasing level of challenge that maintains the player's motivation. Using well-designed games to continually create the appropriate level of challenge for each student is a policy implication that is consistent with research on deliberate practice (Ericsson, 2006).

Conclusion

Even before the widespread availability of computer games, Abt (1970) proposed that serious games had potential to improve education and training, but was not able to provide convincing evidence. Subsequently, early analyses by cognitive psychologists (Loftus & Loftus, 1983) yielded hope but not much evidence that video games could be learning devices, epitomized in the comment, "It would be comforting to know that the seemingly endless hours young people spend playing Defender and Pac-Man were really teaching them something useful" (p. 121). Today's computer games are far more sophisticated and are played regularly by millions of people of all age levels, but more important, we now have a preliminary research base concerning the effects of game playing on academic learning. This research base can begin to address the questions and hopes raised a generation ago, and temper the claims of today's game advocates.

The current state of the field yields a growing collection of educational features that improve learning when incorporated into computer games for learning (based on the value-added approach), a short list of off-the-shelf games that promote educationally relevant cognitive skills (based on the cognitive consequences approach), and a tentative indication of the conditions under which learning with games is more effective than learning with conventional media (based on the media comparison approach). What is needed is additional methodologically rigorous research, within each of these three game research genres, aimed at fleshing out the emerging picture of what works with educational games, as well as research aimed at determining the implications for how to successfully implement games for learning in education and training.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This article was supported by funding from the Institute of Education Sciences and the Office of Naval Research.

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