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On the Need for Research Evidence to Guide the Design of Computer Games for Learning

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Computer games for learning (also called video games or digital games) have potential to improve education. This is the intriguing idea that motivates this special issue of the *Educational Psychologist* on "Psychological Perspectives on Digital Games and Learning." Computer games for learning are games delivered via computer that are intended to help people learn academic knowledge and skills. Given the documented commercial success of computer games for entertainment, it makes sense to ask how educators can harness their motivating power to improve academic learning. As with other aspects of technology-supported learning, once again educational psychology is a driving force in contributing to theory and practice concerning the educational use of computer games. This commentary summarizes the four articles in this special issue and then suggests what is not needed and what is needed to move the field of game research ahead.

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EDUCATIONAL PSYCHOLOGY'S CONTRIBUTION TO COMPUTER GAMES FOR LEARNING

This special issue contains four articles, each systematically presenting the insights of leaders in the field of computer games for learning. As with other aspects of technology-supported learning (Mayer, 2009, 2014; Sweller, Ayres, & Kaluga, 2011), once again educational psychology is a driving force in contributing to theory and practice concerning the educational use of computer games. A common theme running through the four articles, as well as recent reviews (Mayer, 2014, in press), is the need for research evidence to guide the design of computer games for learning and to ground theories of academic learning.

In "Foundations of Game-Based Learning," Plass, Homer, and Kinzer (this issue) help organize the field into four perspectives—cognitive, motivational, affective, and socio-cultural—and argue that an understanding of how to design games for learning requires recognition of the contributions of all four perspectives. In short, the authors show how to ground research on computer games for learning in a broad array of theoretical approaches and provide examples of games and game features that tap into these four perspectives. As a next step, research is warranted to assess the effectiveness of game features suggested by each of the four perspectives.

In "Digital Games as Multirepresentational Environments for Science Learning: Implications for Theory, Research, and Design," Virk, Clark, and Sengupta (this issue) explore what research on *multiple external representation environments* (MERS) has to say concerning the design of science computer games aimed at teaching students about models. Based on cognitive research on MERS, they derive a set of game design principles and then examine how well the principles are implemented in a set of exemplary science games. The article calls for evidence-

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based design of computer games and points to the shortcomings of existing games. A useful next step would be to examine whether adding features based on the principles to a game has positive effects on learning outcomes.

In "Constructivist Gaming: Understanding the Benefits of Making Games for Learning," Kafai and Burke (this issue) make the case for allowing students to construct their own video games. They describe some of their own projects in which teams of children build homemade video games using online tools, and they ground these activities within the theoretical framework of constructionism (Papert, 1980). An important instructional issue concerns the degree of guidance that should be provided, in light of evidence that many students show suboptimal learning with pure discovery approaches (Mayer, 2004). In the future, research is needed to pinpoint how best to provide guidance during game-making activities and to assess the effectiveness of game making on learning outcomes compared to a control group.

In "Digital Games and Learning: Identifying Pathways of Influence," Subrahmanyam and Renukarya (this issue) suggest game features that could influence learning and propose theoretical mechanisms—conceptualized as four possible pathways to learning—to justify including them. They call for basing game design on psychological mechanisms of learning, and they propose that different game features can influence the learning process in different ways (i.e., tapping different learning mechanisms). A useful next step would be to derive theory-based predictions concerning which features should be added to games, and then test the effects on learning processes and outcomes of adding each feature to a game as compared to a control group that simply plays the game without the added feature.

WHAT IS NOT NEEDED

On the positive side, the four articles in this special issue provide important insights from experienced researchers in the field of computer games for learning. In some cases, the authors back up their assertions with research evidence by describing research methods and results that are relevant to practice and theory in designing computer games for learning. However, reflecting a field that is in its initial stages, some space in the articles is devoted to describing innovative games and game playing, speculating on the implications of broad perspectives for game design, and offering expert-inspired visions of how games could improve education. Although this material is interesting and potentially useful, as the field matures it would be useful to see more focus on linking game design and theory to research evidence based on students' learning outcomes. In taking an evidence-based approach, the field can move beyond expert visions of the role of games in education, beyond descriptions of games and game playing, and beyond broad theoretical perspectives.

Beyond Untested Claims

Visionaries foresee an educational revolution based on video games, and some of the articles echo this enthusiasm. What is needed in the field of research on games for learning is less advocacy and a better linking between claims and evidence. All of the articles recognize that as the field progresses, the focus should be on what the research evidence says rather than on what experts say.

Beyond Descriptions of Games and Game Playing

The articles in this special issue provide detailed descriptions of some innovative games and describe creative thinking produced by game players. Sometimes missing is a clear link to research evidence showing the impact of playing the game on learning outcomes. As the field progresses, descriptions of games and game playing should be supplemented with corresponding research evidence concerning effects on learning processes and outcomes.

Beyond Broad Perspectives and Isms

Some of the articles in this special issue call for examining the implications of various conceptual positions or broad perspectives, which can be a useful way to generate research ideas. The next reasonable step is to move from broad theoretical frameworks to more focused theories that spell out specific learning mechanisms in a testable way, because a focus solely on broad doctrines (or "isms") has not been a productive path for learning theory during its 100-plus-year history (Mayer, 2001). As the field of game research progresses, broad doctrines should be replaced with testable theoretical models that contain specific learning mechanisms linked to research evidence on games for learning.

WHAT IS NEEDED

What Is Needed: Asking the Right Questions

An important starting point for generating an evidence base concerning games for learning is to ask the right questions. Instead of asking what experts claim about the educational value of games, asking what is exciting about a particular game, or asking what a particular "ism" suggests about games, a clear focus on productive research questions and the empirical evidence that addresses them is needed. Based on an analysis of the existing research literature on games for learning, I propose three major research

TABLE 1
Three Questions to Guide Research on Games for Learning

Question Type	*Question*	*Example*
Value added	Which features improve academic learning from a game?	Does adding a scoreboard improve academic learning from a game?
Cognitive consequences	Do people improve their cognitive skills by playing an off-the-shelf game?	Does playing Tetris improve players' spatial cognition skills?
Media comparison	Do people learn more academic content from a game than from conventional media?	Do people learn more about electrical circuits from playing a game on circuits or from a slideshow containing the same content?

questions to help guide the field, as summarized in Table 1 (Mayer, 2014):

1. Value-added question: Which features make a game more effective? This is a value-added question, because we seek to determine whether adding (or changing) one particular feature of a game will result in improved performance on a learning outcome measure. For example, some researchers may wish to test the idea that adding narrative theme or a scoreboard to a game improves learning.
2. Cognitive consequences question: Can playing an off-the-shelf game improve one's academic skills? This is a cognitive consequences question, because we want to know what is learned from playing an off-the-shelf game that was originally designed mainly for entertainment.
3. Media comparison question: Do people learn academic content better with games than with conventional media? A challenge with this question is that it is somewhat difficult to make sure that the two groups (games vs. conventional media) are equivalent in content and method and differ only in terms of media used to deliver the content.

For each of these questions, we also want to know whether the results apply mainly to certain kinds of learners (i.e., who questions), content (i.e., what questions), and circumstances (i.e., where questions). This analysis is based on the idea that asking the right questions is the key to making progress in the emerging field of games for learning.

What Is Needed: Using Research Methods that Address the Right Questions

To address these three questions about computer games for learning, we need to employ appropriate research methods as shown in Table 2 (Mayer, 2014). I focus on experimental comparisons to answer each of the three questions because experiments have been shown to be appropriate for answering questions about what causes a change in learning outcome (Phye, Robinson, & Levin, 2005; Shavelson & Towne, 2002). Clearly, observational methods have a useful place in the study of other questions about computer games for learning, but my focus is on experimental comparisons because they are best suited to answer the foundational questions listed in Table 1.

To answer value-added questions, we compare the learning outcome performance of a group that plays a base version of the game (control group) with a group that plays the game with one feature added or changed (game group). To answer cognitive consequences questions, we compare the pretest-to-posttest change in a cognitive skill for a group that plays an off-the-shelf game for an extended period (game group) with a group that engages in an alternative activity such as playing a game that does not tap the same cognitive skill (control group). To answer the media comparison question, we compare the learning outcome performance of a group that learns academic content through playing a game (game group) with a group that learns the same content with conventional media (control group). Throughout

TABLE 2
Research Designs to Address Three Questions About Games for Learning

Question Type	*Research Design*
Value added	Compare learning outcome of a group that plays the base version of a game (control group) with a group that plays the same game with one feature added or changed (game group).
Cognitive consequences	Compare pretest-to-posttest gain on a cognitive skill for a group that plays an off-the-shelf game (game group) with a group that engages in an alternative activity (control group).
Media comparison	Compare learning outcome of a group that plays a game (game group) with a group that receives the same content via conventional media (control group).

TABLE 3
Three Criteria for an Experimental Comparison

Criterion	*Description*	*Example of Violation*
Appropriate measure	Main dependent measure focuses on academic learning outcome or skill.	Only dependent measure is self-report of liking the game.
Experimental control	The performance of the game group is compared to a control group.	Only comparison is pretest-to-posttest change of the game group; there is no control group.
Random assignment	Participants are randomly selected for the game and control groups.	Participants get to choose which group they are in.

the four articles we see examples of each of these three genres of game research, although value-added studies are most commonly cited for generating guidelines for game design.

Table 3 lists three criteria for an acceptable experimental comparison: appropriate measures, experimental control, and random assignment. Concerning appropriate measures, the key dependent measure should be a measure of learning outcome. Instead of self-reports from learners or minute details of in-game actions or vague observations, we want to know what was learned. Learning outcomes can include both measures of retention and measures of transfer. Concerning experimental control, experimental comparisons need a control group. Simply showing a pretest-to-posttest improvement in a game group (or showing clever thinking by learners in a game group) is not sufficient, because without a control group it is not possible to attribute the gain or clever thinking to the game. Concerning random assignment, participants need to be randomly assigned to game and control groups. When learners can select which group they want to be in, it is not possible to attribute group differences to game playing. In the four articles in this special issue there are descriptions of research methods and results that adhere to these basic criteria, but overall the field of game research needs more methodologically sound studies.

What Is Needed: Linking Research Evidence to Practice and Theory

As you can see, my main theme is that we need a body of methodologically sound research evidence targeting three fundamental questions listed in Table 1. This evidence can be used to guide the design of effective games for learning and to contribute to evidence-based theories of learning and motivation that contain specific learning and motivational mechanisms relevant to gaming.

CONCLUSION

The authors of the articles in this special issue on "Games and Learning" are to be commended for furthering the conversation concerning how educational psychology can contribute to the field of computer games for learning. I concur with their calls for research studies on games for learning, and in particular I support a focus on methodologically sound research addressing the three fundamental research questions listed in Table 1. If our goal is to contribute to practice (i.e., designing effective games for learning) and theory (i.e., constructing testable learning theories that contain specific mechanisms for learning and motivation), a fruitful approach is to build the research base that addresses foundational questions concerning which game features improve learning, what is learned from playing off-the-shelf games, and whether games are more effective for academic learning than conventional media.

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