Handbook of Research on Serious Games for Educational Applications

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Chapter 2
The Role of Metacognition in Learning via Serious Games

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ABSTRACT

This chapter focuses on three recommendations from the National Research Council (2011) for conducting research that may increase the impact of serious games on student achievement. At the core of these recommendations is an emphasis on the role of metacognition in learning. The first recommendation examines the player's self-awareness as a learner and how a sense of agency can be nurtured by serious games to promote self-regulated learning. The second examines the mediating processes within the individual that influence learning with games. This section describes embodied cognition, which examines the interactions among body, mind, and game environment that can lead to learning. The third examines the problem of transfer of learning. This section offers suggestions on how transfer from gaming contexts to academic contexts can be facilitated. The chapter concludes with an examination of whether research in response to these recommendations can positively impact learning via the serious game.

INTRODUCTION

The popularity of video games in the United States is indisputable. A recent report by the Entertainment Software Association (ESA, 2015), indicated that four out of five households own a device to play video games, 42% of Americans play video games three or more hours per week, 26% or 40.3 million gamers are under 18 years of age, and the popularity is fairly evenly divided between females (44%) and males (56%). In addition, there is an ever-broadening corpus of research showing that video gaming can have strong positive effects on visual processing of spatial characteristics of information, attentional processing, executive functioning, inductive reasoning, mental rotation, memory, and task motivation (Green, 2014)—all necessary characteristics for video gaming. One obvious interpretation of these findings is that high engagement with video games enhances a person's ability to engage in video games. But, other than the self-perpetuating effects of video games, are there other benefits to be gained through playing video games? In the context of the current volume, the question becomes, Do the skills and knowledge

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gained through video games transfer to formal educational settings? The belief that the high engagement engendered by the entertainment value of video games can act as a motivator for children to learn as they entertain themselves has been a strong force behind the development of a genre of video games for academic learning (Ritterfeld, Cody, & Vorderer, 2009). This new genre of video games, called serious games or digital-learning games, attempts to "target the acquisition of knowledge as its own end and foster habits of mind and understanding that are generally useful or useful within an academic context" (Klopfer, Osterweil, & Salen, 2009, p. 21).

Unfortunately, the use of serious games for formal educational purposes has met with mixed results (Blumberg, Almonte, Barkhardori, & Leno, 2014; Chen & Hwang, 2014), and in many cases only limited success has been attained with child and adolescent students (Kato, 2012). Reports from the National Research Council (NRC; 2011), Tobias and Fletcher (2011), Young, Slota, Cutter, Jalette, Mulling, Lai, Simeoni, Tran, and Yukhymenko (2012), and McClarty, Orr, Frey, Dolan, Vassileva, and McVay (June, 2012) have shown that the current state of research on the use of video games for formal educational purposes is inconclusive. Although all four reports are positive about the use of serious games in the classroom and that there are theoretical reasons to believe that serious games could be beneficial for student learning, the reports are in agreement that there are many instances in which game design is not based in empirical theory (van de Sande, Segers, & Verhoeven, 2015) or sound psychological principles, that educational outcomes and entertainment value are not directly tied to one another (Ritterfeld et al., 2009), and that research on the educational value of edutainment is greatly lacking (Ritterfeld et al., 2009; Young et al., 2012). Young et al. (2012) concluded that "Many educationally interesting games exist, yet evidence for their impact on student achievement is slim" (p. 80); and, Graesser, Chipman, Leeming, & Biedenbach (2009, p. 83) agreed that "Unfortunately, at this point in the learning sciences, very few serious games have been developed that would impress experts in education."

What is the disconnect between learning via serious games and academic performance? People are quite capable of gaining knowledge and problem-solving skill within a serious game and yet fail to utilize that knowledge and skill outside of the game, or even to other games that are structurally similar (Barnett, 2014; Lieberman, Biely, Thai, & Peinado, 2014; McClarty et al., 2012; Morris, Croker, Zimmerman, Gill, & Romig, 2013). The disconnect could be as simple—or difficult—as a lack of transfer. Simple in that the problem of learning from serious games could be attributable to a single process; difficult in that the process of transfer is likely the most critical problem in education, and despite nearly a century of research, remains a critical problem. To add to the difficulty, because transfer research has consistently shown that the likelihood of transfer depends on the similarities between the learning context and transfer context, transfer in gaming may be even less likely because typically the gaming context is highly dissimilar from the classroom context (Morris et al., 2013).

The purpose of this chapter is to discuss what is seemingly an intractable problem: How can the characteristics of durable learning that are evident in players of many popular video games, such as high interest and motivation, critical thinking, affective engagement, social feedback, metacognitive monitoring and control, and strategic planning, be fostered in serious games to make them valuable instructional tools? The belief that the high engagement engendered by the entertainment value of video games can be used to motivate academic learning needs to be substantiated. The NRC (2011) report *Learning Science through Computer Games and Simulations* acknowledges that the impact of serious games on academic learning is questionable and provides several recommendations for research that can potentially increase that impact.

This chapter will focus on three of those recommendations, and although the three recommendations focus on the learning of science, there is no reason to believe that they are not applicable to learning using serious games in many content areas. At the core of these three recommendations is metacognition and learning. Therefore, the general theme of this chapter will be on the role of metacognition in learning via serious games. First, metacognition will be defined. Then, the first NRC (2011) recommendation to be discussed is "Research should examine the role of metacognition and awareness of oneself as a learner when an individual interacts with a simulation or game" (p. 122). The focus of this section is on the player's awareness of himself or herself as a learner and how a sense of agency can be nurtured in the player by designing serious games to promote self-regulated learning. This is followed by "Research should examine the mediating processes within the individual that influence science learning with simulations and games" (p. 122). This section describes a psychology of the individual called embodied cognition, which examines the interactions among body, mind, and game environment that can lead to learning within the serious game and beyond the game. The last recommendation is "Future studies should examine transfer of learning from the simulation or game learning environment to other contexts" (p. 123). This section deals with the problem of transfer, with an emphasis on the transfer of learning from the gaming context to the academic context. The chapter concludes with an examination of whether research in response to these recommendations can positively impact learning via the serious game.

WHAT IS METACOGNTION?

An important starting point is to define metacognition. Metacognition is "knowledge of one's knowledge, processes, and cognitive and affective states; and the ability to consciously and deliberately monitor and regulate one's knowledge, processes, and cognitive and affective states" (Hacker, 1998, p. 3). This definition identifies both declarative and procedural components of metacognition. Metacognitive declarative knowledge consists of a person's knowledge or beliefs about: (a) one's cognitive and affective states and the states of others; (b) a task, its demands, and how those demands can be met under varying conditions; and (c) strategies for accomplishing the task and how and when to use them (Flavell, 1979).

Metacognitive procedural knowledge consists of both monitoring and control components. Metacognitive monitoring refers to processes that are "directed at the acquisition of information about the person's thinking processes" (Kluwe, 1982, p. 212). These processes involve a person's ability (a) to identify the task on which one is currently working, (b) to check on current progress of that work, (c) to evaluate that progress, and (d) to predict whether the expected outcome will be attained (Flavell, 1979). Metacognitive control refers to processes that are "directed at the regulation of the course of one's own thinking" (Kluwe, 1982, p. 212). These processes involve a person's ability (a) to allocate his or her resources to the current task, (b) to determine and direct the steps to complete the task, (c) to set the intensity or (d) the speed of the work task (Flavell, 1979). Both declarative and procedural components of metacognition are necessary for students to become "self-regulatory organisms who are capable of assessing themselves and others and directing their behavior toward specified goals" (Hacker, 1998, p. 10), that is, to become agents of their own thinking.

AWARENESS OF ONESELF AS A LEARNER

Research should examine the role of metacognition and awareness of oneself as a learner when an individual interacts with a simulation or game. Prior research on science learning suggests that making learning goals explicit and supporting learners in metacognition—reflecting on their own learning—enhance learning. (NRC, 2011, p. 122)

What does it mean to have an “awareness of oneself as a learner”? How does this awareness change “when an individual interacts with a simulation or game”? Most educational researchers and practitioners would agree that an awareness of oneself as a learner requires the basic components of metacognition that were just described. In short, an aware learner has an understanding of a self as an embodied person who is capable of using that body to perceive the environment in which he or she is enmeshed and of interacting with that environment physically, cognitively, and emotionally. An aware learner not only can comprehend the world but knows that he or she comprehends the world. The aware learner can monitor his or her thoughts, evaluate current cognitive and affective statuses in pursuit of self-imposed goals, and revise those goals in light of feedback from his or her interactions with the environment. The aware learner can develop strategies and heuristics to adapt to changing situations. The aware learner can understand others and use that understanding to assist in gaining a deeper and more complete knowledge of his or her self. All of these characteristics of self-awareness contribute to a sense of agency, that is, people as agents of their own thinking (Hacker, Dunlosky, Graesser, 2009).

This sense of agency has been recognized as one of the most important characteristics of digital games. Van de Sande et al. (2015) believe that executive control (i.e., verbal reasoning, problem-solving, planning, sustaining attention, resistance to interference, using feedback, cognitive flexibility, regulation of social behavior, and decision making; Chan, Shum, Toulopoulou, & Chen, 2008) “is strongly demanded for both the monitoring of information and sustaining effective gaming behavior” (p. 433). Fladen and Blashki (2005; cited in McClarty et al., 2012) named agency as one of three key features of games, along with interactivity and engagement. Norman (2013) identified reflection as “perhaps the most important of the levels of processing. Reflection is conscious, and the emotions produced at this level are the most protracted: those that assign agency and cause… ” (p.53). McClarty et al. (2012) identified agency and choice as “critical elements of a true gaming experience” (p. 8); moreover, McClarty et al. stated that “The most common error in online education activities is a failure to provide the learner with an appropriate level of agency” (p. 11).

The designers of serious games face a major dilemma: There is the need to provide a sense of agency within a game, and yet that very agency is compromised by the need to provide players with explicit guidance for learning. Agency is built into game designs by creating open environments that provide learners interactivity, choice, and control, all of which promote greater motivation to engage in the game (Nietfeld, Shores, & Hoffman, 2014; Sabourin, Shores, Mott, & Lester, 2013). But, open environments place greater demands on the learner (van de Sande et al., 2015): Learners need to track and evaluate their progress, identify goals and change goals in light of what has transpired in the game, maintain interest and motivation in the face of limited success or too easily gained success, and stay cognitively focused and affectively engaged (Sabourin et al., 2013). Ironically, to meet the demands posed by an open environment, the learner requires greater explicitness and scaffolding of instruction, the very antithesis of an open learning environment.

How have serious game designers navigated this irony? Unfortunately, although designers acknowledge the need for open learning environments and for the agency and motivation that they engender in the player, few games have been empirically tested for the presence of these components and for the ways in which they are purportedly supported during game play (Sabourin et al., 2013). In addition, although many serious game designers also acknowledge that metacognition, or executive control, is necessary for sustained interest and motivation and affective engagement in serious games, the role of metacognition in serious games, like the effectiveness of serious games, in general, is uncertain (Morris et al., 2015). This area of investigation has not yet attracted a great deal of attention, and frankly, little empirical evidence exists that can help in designing serious games that incorporate metacognition (van de Sande et al, 2015).

To meet the demands of an open gaming environment and to take full advantage of the learning opportunities offered by an open environment, designers need to conduct more research in these identified areas and they need to identify a theoretical foundation upon which this research can be conducted. Although there are many theoretical directions designers could take, there is a large corpus of research on self-regulated learning that would serve well as this foundation (e.g., Boekaerts, Pintrich, & Zeidner, 2000; Schunk & Zimmerman, 2008). Some researchers have incorporated self-regulated learning in more structured learning environments (e.g., Azevedo & Witherspoon, 2009; Conati & VanLehn, 2000; White, Frederiksen, Collins, 2009); however, the open learning environment remains mainly open for further research.

"Self-regulated learning refers to self-generated thoughts, feelings, and actions for attaining one's learning goals" (Zimmerman & Moylan, 2009, p. 299). The ability to self-regulate one's learning is vital to success in all academic endeavors (Schunk & Zimmerman, 1997), and the goal of formal education should be to equip students with the self-regulatory capabilities to educate themselves beyond the classroom (Bandura, 1993; Zimmerman, 2008). Self-regulated learning hinges on learners' abilities to metacognitively monitor and control their learning and to motivate themselves to learn (Sabourin et al., 2013; Zimmerman & Moylan, 2009), and because metacognitive monitoring and control and motivation are critical in game-based learning environments (Nietfeld et al., 2014), incorporating elements of self-regulated learning within the open learning environment in serious games could potentially lead to effective designs. Learners who can accurately evaluate the extent of their learning and consciously and deliberately direct or redirect their own goals are in a better position to transfer their learning from one context (e.g., the gaming context) to another context (e.g., the academic context) (Bransford, Brown, & Cocking, 2004).

Because the demands of most serious games are both cognitive and social, a good theoretical foundation of self-regulated learning on which to build is the social cognitive model proposed by Zimmerman and colleagues (Schunk & Zimmerman, 1997, 2007; Zimmerman & Moylan, 2009; Zimmerman & Risemberg, 1997). Four levels of development are included in this theory, (a) observation, (b) emulation, (c) self-control, and (d) self-regulation, which are not necessarily locked in that particular order. Although social elements permeate all four levels, the first two are primarily social in nature, and the second two are primarily cognitive (Zimmerman, 2000).

First, the serious game environment must provide the novice player the opportunity to observe an expert model. Observing a more capable player is critical for students (a) to acquire a basic understanding of the serious game and its rules, (b) to learn firsthand the strategies that could be used and how to use them, and (c) to understand how sustained engagement in the game is necessary to succeed, and (d) to observe that sustained engagement in the game leads to motivation, and motivation leads to sustained engagement. The expert model could be a teacher assisting student players, a more adept player who is physically playing along in the game or is connected to the game in a social network, or an agent embedded within the game. The expert model plays a delicate balance between being overly or insufficiently explicit. The model must make clear and unambiguous the knowledge, behaviors, thoughts, beliefs, and goals necessary for the successful play of the game, and must demonstrate the benefits of planning, monitoring, and reflection. However, the expert model cannot steal the game from the player. Too much modeling will leave the player on the sidelines wondering why he or she should play a game that seems to play itself. Too little modeling will leave the player frustrated, believing that the rules and goals are too mysterious and the game is just not worth playing. Determining the optimal level of modeling for a specific learner is a difficult task for even the best of teachers—how much more difficult is it for a computer program?

To add to the challenges of the expert model, he, she, or it also should model for the player a level of emotionality with the game. Successful digital games involve players in a way that leaves them believing they have something emotionally and personally at stake (Gee, 2009). Cognitive involvement is a necessary component of a serious game that the player must maintain, but just as important is an emotional involvement (Balcetis & Cole, 2009; Liberman et al., 2014; NRC, 2011; Ritterfeld et al., 2009; van de Sande et al., 2015; Young, 2012). Emotionality promotes and maintains the player's motivation. Emotion captures attention, enhances memory, and helps to build tension and arousal to keep the player enticed to play. And it is not just the play of the game that must be emotionally engaging. The storyline presented in the game should be entertaining, allowing the player to identify and empathize with the characters (Ritterfeld et al., 2009).

Emulation of the modeled thoughts and behaviors is the second level of Zimmerman's and colleagues' theory of self-regulation. The serious game must provide players with ample opportunities to imitate the modeled thoughts and behaviors demonstrated by the expert model, and with repeated practice develop closer and closer approximations of those thoughts and behaviors (Schunk & Zimmerman, 2007). Players need to get the "feel" of the gaming environment. They need to experience the rules of the game and the rewards or punishments that come with compliance or defiance of them. They need to try strategies and to use them for their own personal advantage to accomplish the goals of the game (Gee, 2009). By emulating the expert model, players begin to understand that sustained engagement in the game is necessary to succeed, and that there is a circular relation between sustained engagement and motivation to play.

As players increase their emulation of the expert model and the expert model relinquishes control of the game, players go beyond simple copying of the model. They acquire and begin to own the play of the game and to develop a general sense of the behavioral, cognitive, physiological, and emotional components of the game. Through their metacognitive monitoring of game play, players begin to experience firsthand the gaps, inconsistencies, anomalies, and discrepancies in their understanding of the game, and they begin to exert metacognitive control by revamping their strategies, changing their goals, refocusing their attention, or increasing the intensity or speed of play. In addition, through emulation of the expert model, players begin to discern the critical elements of the game from the non-critical elements, or as Gee (2009) described it "they see through the 'eye candy' to patterns and rules (what I call effectivity-affordance pairings) that will allow them to solve ever more challenging problems as they move through the game's levels" (p. 70). As will be discussed in the section on transfer, these effectivity-affordances play a critical role in the transfer of gaming elements to contexts beyond the game.

The third level of Zimmerman's and his colleagues' theory of self-regulated development is self-control. Self-control is achieved when students can demonstrate self-regulation while performing tasks that are similar in nature to the task that was modeled. For example, a serious game could have a component that requires players to generate a hypothesis for why some physical event occurs in the game. The expert model would initially guide the player to develop a hypothesis, but would then take a more passive role when the player is asked to make a hypothesis for a similar but different physical event. At this point of self-regulation, players are beginning to acquire the desired thoughts, behaviors, and emotions of the expert model but still have not fully internalized them (Schunk & Zimmerman, 2007), and have begun to form an internal representation of the game (Gee, 2009).

In the well-designed serious game, self-control is gradually developed as supports for the player are gradually removed and players begin to independently engage in the game. Players receive continued scaffolding for their actions within the game, but the scaffolding is far diminished in comparison to earlier levels during the modeling and emulation levels. When moving from observation of an expert model to emulation of the model, players simply assume the goals of the expert model, but when moving to self-control, players begin to develop their own goals within the context of the gaming environment. Another way to conceptualize this level of self-regulation is that students are now able to transfer their knowledge acquired during modeling and emulation of the serious game to a context within the game that is similar to but different from that modeling and emulation.

At this level of the development of self-regulation, players begin to develop a mental model of the game that allows them to move from the concrete experiences of the serious game to more abstract notions of the game (Gee, 2009). Moving from the concrete to the abstract helps the player in his or her transfer of game elements within the context of the game to contexts beyond the game. This abstract modeling of the game helps to deepen the problem solving abilities of the player (Gee, 2009), which are enhanced by the metacognitive processing the player is encouraged to use. Using the abstract model, the player is no longer tied to the concrete experiences of the game, but is better able to reflect on the current progress of the game, evaluate that progress, compare what works with what does not, change or modify existing goals, develop and attempt new strategies, and begin to identify critical from non-critical elements (Bransford et al., 2004). In reciprocal fashion, the metacognitive activities that the player is encouraged to use contribute to the development of more complete and usable mental models of the game that, in turn, contribute to the player's heightened understanding of the game and use of metacognitive activities.

Finally, self-regulation is fully developed when students have fully internalized the game and have developed a complete mental model of it that allows them to independently adapt it to contexts that differ from the context in which it was learned (Schunk & Zimmerman, 2007). At this level of development of self-regulation, players learn to initiate their own goals for the game, adjusting or modifying them based on situational or contextual conditions. Moreover, at this higher level of self-functioning, students can maintain their motivation by developing personal goals and develop a sense of self-efficacy for attaining them. Players can now "psyche out" the rules of the game to accomplish goals for one's own personal and emotional reasons (Gee, 2009, p. 68). Players initially accept and get to know the environment established by the game, but at this higher point of self-regulation that environment can be changed within the constraints of the game to match the evolving goals of the player. At this level of development, support from the expert model is removed, and players become independent, self-regulated users of the serious game.

In sum, what does it mean to have an "awareness of oneself as a learner"? Awareness of oneself as a learner depends on metacognition. Among other things, aware learners comprehend and know they comprehend, monitor and evaluate their cognitive and affective statuses in pursuit of self-imposed goals and change goals in the face of changing conditions, develop strategies and heuristics to adapt and thrive in different environments, and use their understanding of others to gain a deeper understanding of themselves. These metacognitive processes are necessary for people to become self-regulated learners, that is, learners who are able to take stock of their knowledge and skills, monitor and evaluate their online thoughts and feelings, and control their actions necessary for attaining their learning goals. Becoming a self-regulated learner brings about a sense of agency, that is, people as agents of their own thinking.

A sense of agency has been recognized as one of the most important characteristics of digital games, and yet the question remains whether serious games embody this characteristic. Research is needed to examine the development of agency in the open learning environment of a serious game, and research is needed that examines serious games for the presence of metacognitive activities, critical components of agency. Moreover, a strong theoretical foundation on which to build is needed to guide this research, and theories of self-regulated learning could provide that foundation. Examining serious games through the lens of self-regulation could potentially guide the essential research needed to improve the effectiveness of serious games so that learners can take full advantage of the learning potentials offered by these learning environments.

INTERACTIONS AMONG BODY, MIND, AND GAME ENVIRONMENT

Research should examine the mediating processes within the individual that influence science learning with simulations and games. This research would aim to illuminate what happens within the individual—both emotionally and cognitively—that leads to learning and what design features appear to activate these responses. (NRC, 2011, p. 122)

The rise of cognitive psychology in the 1960s and 1970s provided definite advantages over the behaviorist paradigm that had dominated psychology since the turn of the 20th century. Now there was an organism who mediated the relation between stimulus and response. Stimulus-Response (SR) was replaced with Stimulus-Organism-Response (SOR). This addition to psychology was intended to give focus to the person as a thinking agent capable of exerting control over the response to a given stimulus rather than reacting to the stimulus in a mechanistic way. Many cognitive scientists, however, replaced the "empty-headed mechanics of behaviorism with a more sophisticated machine that processes information, but nonetheless follows a simple mechanistic model" (Hacker, Dunlosky, Graesser, 2009, p. 1). Subsequent developments in cognitive science have attempted to go beyond a disembodied information-processing organism that mediates SR relations to an organism that is *situated* in unique social, cultural, and physical contexts, with each context exerting a unique influence on how that information is processed. Situated cognition has done much to promote the idea that knowledge and skills are best learned in contexts that closely resemble the contexts in which they will be used (e.g., Brown, Collins, & Duguid, 1989; Lave & Wenger, 1989). In other words, you cannot understand "what happens within the individual" apart from considering the influence of the context within which the individual is learning.

More recent developments in cognitive science have attempted to go one step further. Embodied cognition makes many of the same assumptions as situated cognition, principally that the environmental context does exert a unique influence on learning. In addition, although there are multiple versions of embodied cognition depending on which discipline is involved (e.g., development psychology, linguistics, philosophy), there is at least one major commonality among them, namely, along with the environmental context, learning must be understood by how the individual learner perceptually and physically interacts with that environment (Varela, Thompson, & Rosch, 1999; Wilson, 2002). The critical thrust of embodied cognition is to explain how the body and mind interact perceptually, physiologically, and psychologically in real time with the environment to achieve goal-directed activities (Morris et al., 2013; Wilson, 2002). Considering the context of digital games, Gee (2008) has argued that games are "action-and goal-directed simulations of embodied experience" (p. 254). Embodied cognition, therefore, appears to be well-suited to explain the dynamic systems involved in game environments and to guide research that "illuminate(s) what happens within the individual—both emotionally and cognitively—that leads to learning, and what design features appear to activate these responses" (NRC, 2011, p. 122).

From an embodied cognition perspective, in the context of a digital game, a player learns both emotionally and cognitively through dynamic interactions among the body, the mind, and the game environment (Morris et al., 2013), that is, the player's learning is embodied in those interactions (Balcetis & Cole, 2009). At the outset of learning a digital game, a player begins to perceive, either as a first-person avatar or a third-person controller, the features of the game, and those features are processed in relation to how his or her body and mind can interact with them. What does each game feature do and how is it physically manipulated? What features are useful or seemingly useless? What features remain a mystery? Through these initial perceptual and physical interactions, the player begins to acquire basic abilities to engage in the game, and ideally, begins to form an emotional engagement with the game.

Emotion plays a critical role in games and has been identified as one of the six essential features of video games (Juul, 2005). At a very basic level, melding physical reactions with emotional responses can serve as a motivating force in a game. At a deeper level, Balcetis and Cole (2009) propose that motor movements can trigger emotional reactions, which can act as signals that shape behaviors and guide self-regulation (Baumeister, Vohs, DeWall, & Zhang, 2007; Frijda, 2005). For example, positive affect can signal that progress in a task is proceeding according to plan and that one should continue the task until completion (Tice, Baumeister, Shmeuli, & Muraven, 2007). Conversely, negative affect can signal that a person is falling short of his or her goals and needs to increase his or her self-regulatory mechanisms (Balcetis & Cole, 2009).

Once basic abilities to engage in the game have developed, the groundwork for the development of higher-order cognitive processes has been established (Thelan, 1995). These higher-order cognitive processes are essential for the further development of game play, and for the serious game, are essential for the transfer of learning to contexts beyond the game. Therefore, from an embodied cognition perspective, the design features of a well-designed gaming environment must first consider how the activities of the game encourage interactions between the player's perceptual and physical systems and how the dynamics of those interactions are enhanced or constrained by the game (Glenberg, 1997; Thelan, 1995). Moreover, because every player's perceptual and physical systems differ, each player will perceive the design features differently and interact with them differently (Varela et al., 1999). Therefore, there must be sufficient flexibility in the game to accommodate the unique dynamics that form between the player's perceptual and physical systems. But for players to go beyond a superficial learning of the game and develop a deep learning of the game, his or her perceptual and physical interactions with the game environment must be linked with cognitive and emotional processes that promote real-time learning of specific conceptual knowledge and skills that can be immediately applied back into the play of the game environment so that higher-order cognitive processes can be acquired.

With the development of higher-order cognitive processes, the player begins to develop a mental model of the game, which, as was described in the section on *Awareness of Oneself as a Learner*, contributes to the player's development of self-control and self-regulation. Recall that at these higher levels of self-regulation, the mental model of the game allows the player to move from the concrete physical and perceptual experiences of the game to a more abstract notion of the game (Gee, 2009). Using the mental model, the player is able to engage in the game metacognitively, that is, reflect on the current progress of the game, evaluate that progress, compare what works with what does not, ask whether the game really works the way it appears, change or modify existing goals based on situational or contextual conditions, develop and attempt new strategies, identify critical from non-critical elements, and maintain motivation by developing personal goals and developing a sense of self-efficacy for attaining them (Bransford et al., 2004; Morris et al., 2013; Schunk & Zimmerman, 2007). At this point of self-regulation, the game environment can be changed—within the constraints dictated by the game—to be used by the player to attain his or her evolving goals. At this level of development, transfer beyond the game becomes possible.

The allure of popular video games is unmistakable. Players are engaged for hours at high rates of attention and motivation, are singularly focused on the game play, are reacting perceptually, physically, and emotionally to the game elements in real time in a matter of seconds, are engaging high levels of inductive reasoning, and are monitoring and controlling their play as they continually update their mental models as to how the game needs to be played for continued success. There is more than information processing going on here. There is more than situated contextual factors influencing their thoughts and behaviors. This is a total mind and body experience of a virtual environment, and "what happens within the individual—both emotionally and cognitively" is best understood by a psychology that considers this total engagement—embodied cognition.

TEACHING FOR TRANSFER

Future studies should examine transfer of learning from the simulation or game learning environment to other contexts. These studies should examine how transfer occurs…, the extent of transfer, and whether including data drawn directly from the real world in simulations and games influences students' understanding of science processes and/or motivates them to make real-world decisions based on evidence. (NRC, 2011, p. 123)

Transfer, simply defined as "using existing knowledge and skills to learn, solve problems, or carry out a new task in a new situation" (Liberman et al., 2014, p. 189), has for over a hundred years perplexed, frustrated, and most importantly, intrigued, scientists from both behavioral and cognitive camps. Perplexed and frustrated because even under very explicit conditions in which learning tasks and transfer tasks can be nearly identical, many people do not perceive the relations between the tasks and fail to extend their learning to the new task. Intrigued because many educational theoreticians and practitioners believe that the mechanisms involved in transfer (e.g., cognitive, social, and emotional) are at the heart of all learning and if more fully understood would be the gateway to more effective learning, more productive classrooms, and to better educated people who are equipped to deal with the world's burgeoning sources of information and ever-changing complexities.

Since Thorndike and Woodworth's (1901a, 1901b, 1901c) early work involving the notion of common elements, to Osgood's (1949) stimulus-response associations, to Gick and Holyoak's (1980) analogical reasoning, to Singley and Anderson's (1989) production rules, the concept of transfer has been extended and expanded. These perspectives, coupled with more recent theorizing (Butterfield & Nelson, 1989), have provided the understanding that transfer can more readily occur when there is greater explicitness in instruction between learning tasks and transfer tasks, when it is directly embedded within the instructional design of specific content, and when elements of metacognition are emphasized, such as engaging learners as active agents in their own thinking and encouraging monitoring, evaluation, and control of learning. More directly related to this chapter, the pertinent question to be asked is to what extent does transfer occur from simulations or game learning environments to influence students' understanding of the real world? Based on what we presently know about serious games, the answer to this question is that transfer to the real world is, at best, limited (e.g., Barnett, 2014; Liberman et al., 2014).

A fundamental question that must be addressed by researchers interested in studying transfer is *What transfers*? For Thorndike and Woodworth (1901a, 1901b, 1901c), the answer was common elements between the learning and transfer contexts. Common elements could take on any number of characteristics, ranging from mental and environmental objects to events (Butterfield & Nelson, 1989). For instance, a mental strategy that is known to be useful in one context could be perceived as useful in another context, or characteristics of an object that are perceived as useful are perceived to be equivalently useful in a different object in a different context. For Osgood (1949), what transfers from one context to the next was stimulus-response relations. More specifically, positive transfer occurred when stimulus-response relations were virtually identical across varying contexts, and negative transfer occurred when stimuli remained similar across contexts but responses differed with each new context. For Gick and Holyoak (1980), what transfers from one context to the next were mental models that serve as analogies. When the concepts and goals presented in a new problem are perceived as similar concepts and goals previously encountered to solve an earlier problem, that earlier problem serves as an analogy within which the new problem can be structured. Successful mapping of elements from the earlier problem onto elements of the new problem leads to positive transfer. Finally, for Singley and Anderson (1989), what transfers from one context to another were production rules as defined by Anderson's ACT theory, in which condition-action rules take the form of IF-THEN pairs. For example, multi-column arithmetic would take the form, IF the goal is to add number 1 and number 2 in a column, and number 1 + number 2 = number 3; THEN set as a goal to write number 3 in that column (Anderson, 1996). For transfer to occur, the production rules in the learning task must be similar to the production rules in the transfer task.

With the exception of Osgood's behaviorist's notion of transfer, these conceptualizations of transfer have been dominated by cognitive perspectives, which focus primarily on learning as the result of a mind representing and manipulating internal symbolic representations. However, these conceptualizations ignore a more complex reality in which we live. As discussed earlier, in that more complex reality, cognition is a consequence of the interactions of the body, the mind, and the environment (Balcetis & Cole, 2009; Morris et al., 2013; Varela et al., 1999; Wilson, 2002; Wilson & Golonka. 2013). Learning is a consequence of a person's unique mental and physical interactions with his or her environment, and those interactions with the environment are determined by how he or she perceives that environment in a goal-directed activity (Varela et al., 1999; Rosch, 1999).

If an embodied cognition perspective seems plausible, then we need to think of how transfer would fit within that perspective. *What transfers* in embodied cognition? An answer to this question is forthcoming by utilizing the concept of affordance that was originally proposed by James J. Gibson nearly 40 years ago in his *The Ecological Approach to Visual Perception* (1979). An affordance is defined as a relationship between a property of an object and a person's capabilities to use that property to achieve a goal-directed activity (Norman, 2013). Gibson originally conceived of affordances as independent of a person's ability to recognize them, that is, there may be a relationship between the property of an object and a person's latent capability to use that property, but a person may not perceive that relationship. Nonetheless, there would still be an affordance. However, Donald Norman (2013) has restricted the meaning of the term in the field of human-computer interaction to only those relationships that are perceivable by a person. Norman (2013, p. 11) provides the following example to illustrate this point:

A chair affords ("is for") support and, therefore, affords sitting. Most chairs can also be carried by a single person (they afford lifting), but some can only be lifted by a strong person or by a team of people. If young or relatively weak people cannot lift a chair, then for these people, the chair does not have that affordance, it does not afford lifting.

When a person encounters a problem within a specified environment, the properties of the objects associated with the problem are perceived to embody specific affordances, that is, the properties are perceived in relation to whether ones' mind and body can interact with them to solve the problem (Balcetis & Cole, 2009). Can the objects be grasped? How can they be manipulated? What properties can be useful? Which are irrelevant? Can the properties be altered? If the affordances perceived are aligned with the person's capabilities, the properties can then be used in his or her goal-directed thoughts and behaviors to instantiate a solution. In some other environment, the very same affordances may be perceived to be useless or are not within the person's set of capabilities and some other solution path must be sought.

To illustrate, in the context of a fictitious video game dealing with the fantasy of Medieval knights, your knightly avatar is presented with a terrible dragon that must be slain. Along with the dragon comes a collection of objects that are perceived to carry with them affordances, but you can only choose one to slay the dragon. Of these objects, one is a long sharp stick that you know you are capable of using to kill the dragon (i.e., there is a relationship between a property of the stick—its sharpness—and your capabilities to use it in a goal-directed activity—stabbing). You select the stick and immediately stab the dragon in the heart. After the dragon is slain, a torrential rain storm follows, and your avatar needs to keep dry or catch his or her death of cold. The same sharp stick is now perceived to have an affordance that is applicable to the new problem—you are capable of using the stick as a pole to hold up a tarp over one's head. Later on in the scenario, two people need to have their height measured so that they can be fitted with proper armor. The same sharp stick is now perceived to have an affordance that is applicable to the new problem—you are capable of using the stick to measure the heights of the two people. Finally, a cold night descends and your avatar needs to keep warm. The same sharp stick is now perceived to have an affordance that is applicable to the new problem—you are capable of breaking the stick up into smaller pieces and use them for fire wood. In each case, a specific property of the stick is identified that can be used to solve the immediate problem, and all other properties, although perhaps still perceivable, are suppressed because they are not germane to the immediate problem.

Each recognition of an affordance represents an example of transfer. Existing knowledge of the various properties of the stick can be used to solve a new problem or carry out a new task in a new situation (Liberman et al, 2014). Whether this is an example of near or far transfer depends on the individual. Near transfer would be illustrated by individuals who see the sharp stick only as a weapon, and the extent of their transfer would be that animals other than dragons can be stabbed with it. Far transfer would be illustrated by other individuals who perceive the properties of the stick beyond stabbing things and recognize perhaps the length property as a means of measurement. The stick and all its properties remain the same. What changes, or what transfers, are the relationships between the properties of the stick and the person's perceptions and capabilities to use those properties to achieve different goal-directed activities.

If learning is viewed as embodied, that is, learning is a consequence of a person's unique mental and physical interactions with his or her environment, and those mental and physical interactions with the environment are determined by how he or she perceives that environment in a goal-directed activity (Balcetis & Cole, 2009; Morris et al., 2013; Varela et al., 1999; Wilson, 2002; Wilson & Golonka. 2013), then we see the possibilities that a player is not simply mentally playing with a video game, but literally becomes a part of the game to solve a problem. "[I]nternalized, game-play induced cognitive processes" become "unique interactions of each player with the affordances (i.e., invitations to action) designed into each game" (Young, Slota, & Lai, 2012, p. 297). The player develops a personal stake in the game in which he or she is personally and emotionally committed to winning (Gee, 2009). And, because emotions can help guide a person's thoughts and behavior, that emotionality becomes an important component of self-regulated learning (Baumeister et al., 2007) and the metacognitive processes that are necessary for it to develop.

In a sense, game and player are mutually specified (Liberman et al., 2014). The designers of the game specify objects within the game that are endowed with pre-given affordances with action potentials that, within the constraints of the game, must be perceived and mastered by the player to win the game. However, the player, who is constrained by his or her unique perceptual, cognitive, and emotional framework, must specify which affordances with their action potentials can be perceived within the game's objects and then used. With any game, to keep the player engaged and motivated to play, the game designer must be concerned with guiding the player so that what the player specifies as affordances and action potentials are those that are in fact specified by the game design. The serious game designer, however, not only must share these concerns, but also must be concerned with whether the player is going beyond the game and perceiving affordances and action potentials that transfer to the real world, that is, "to extend what has been learned in one context to new contexts" (Bransford et al, 2004, p. 51).

An effective serious game would then first focus on scaffolding and guiding the player's learning to generate affordances based on the objects that are specified in the context of the game. The player must be supported within the game, either by aids embedded within the game or by a social network of fellow players, to generate multiple concrete affordances provided by each object within the game (Liberman et al., 2014). These multiple opportunities to observe how different properties can be used in different contexts (e.g., going from spear to pole to measure to fire) build up more abstract and generalized representations of the objects. Moving from the concrete to the abstract is crucial to learning (Gee, 2009); and the transfer literature has convincingly shown that positive transfer is helped by bringing concepts to a higher level of abstraction (Bransford et al., 2004). Learning from serious games must be conscious, intentional, and deliberate—all key components of metacognition: consciously searching for affordances between object properties and one's goal-directed activities; intentionally using the affordances to achieve the goal; and deliberately monitoring and evaluating the output of that activity to determine whether the goal has been achieved and whether new affordances can be generated that go beyond the game.

A simple teacup has specific concrete affordances whose action potentials entail containing tea, possessing a handle that can be grasped, being lifted, and being tipped so that the tea will spill out. Some or all of these affordances may be used within the context of a serious game, and the more of these concrete uses that are used will assist the player in forming an abstract representation of the teacup that is necessary to extend his or her learning beyond the game. For example, the player may be presented with a problem to catch a spider crawling across a table, and an upturned teacup now becomes a trap for containing it. The player may be presented with a problem to help design an aviary, and a more abstracted notion of containment may result in a domed building in which the birds can fly. Or, the player may be presented with a problem to design a fusion reactor, and an even more abstracted notion of containment may result in the design of an electromagnetic field to prevent a hot plasma mass of hydrogen from spilling forth. Moving from the concrete to the abstract is a crucial component that if fostered in a serious game may show promise in transferring learning from the game environment to the real world.

FUTURE RESEARCH AND CONCLUSION

Do the skills and knowledge gained through video games transfer to formal educational settings? Based on the literature reviews available, the answer to this question is "maybe." The inconclusiveness of current research speaks loudly that a great deal of research needs to be conducted before a wholesale adoption of serious games is undertaken by those interested in using them as effective instructional tools. Popular video games have been shown to engender high interest and motivation, critical thinking, affective engagement, social feedback, metacognitive monitoring and control, and strategic planning. But, the question remains whether these characteristics of durable learning can be embedded within serious games.

To give serious games a better chance at playing a critical role in education, this chapter has focused on three recommendations for research that were provided by the National Research Council (2011). At the core of these three recommendations is metacognition and learning. Therefore, the general theme of this chapter has been on the role of metacognition in learning via serious games. The first recommendation focused on the player's awareness of himself or herself as a learner and how a sense of agency can be nurtured in the player by designing serious games that promote self-regulated learning. The second recommendation focused on a psychology of the individual called embodied cognition, which examines the interactions among body, mind, and game environment. The last recommendation focused on the problem of transfer of learning from the gaming context to the academic context.

Because the player's awareness of himself or herself as a learner has such an essential role in learning, research needs to examine how serious games can foster a sense of agency in the player (Fladen & Blashki, 2005; McClarty et al., 2012; Van de Sande et al., 2015). Agency is built into game designs by creating open environments that provide learners interactivity, choice, and control, all of which promote greater motivation to engage in the game. The dilemma to be confronted is how to provide an open environment to players that fosters agency and yet still provides sufficient guidance for players to develop the metacognitive skills necessary to become successful learners of the game and to transfer their learning beyond the game. At a minimum, players need to reason, problem-solve, set and change goals, plan, sustain attention, resist interference, use feedback, regulate game behavior, make decisions, monitor information, and sustain effective gaming behavior. Scaffolding the acquisition of these metacognitive skills in an open environment that encourages choice and control in the player is a difficult task that has not yet been sufficiently pursued by researchers.

The suggestion offered in this chapter is to focus future research on self-regulated learning in the gaming environment. Zimmerman and colleagues (Schunk & Zimmerman, 1997, 2007; Zimmerman & Moylan, 2009; Zimmerman & Risemberg, 1997) have provided a theory of self-regulation that consists of observation, emulation, self-control, and self-regulation. This theory provides a strong theoretical foundation for research of serious games and provides suggestions for design features that can guide players through expert modeling in the use of metacognitive skills. Some research has been conducted that incorporates self-regulated learning in more structured learning environments (e.g., Azevedo & Witherspoon, 2009; Conati & VanLehn, 2000; White, Frederiksen, Collins, 2009), and this research could potentially serve as a model for research of self-regulation in open learning environments. The challenge for researchers is to design a gaming environment that is capable of assessing a player's skills and, based on those assessments, continually reduce the levels of guidance as the player's skills increase. In addition, because each player is different, this cannot be done in some rote fashion, but rather, must be adaptive to the unique skills of each player.

Research motivated by an embodied cognition perspective starts with how a player initially perceives the features of the game and how those features are processed in relation to his or her bodily and mental interactions with them. These initial perceptual, physical, cognitive, and emotional interactions inform the player how to engage in the game. From the acquisition of basic abilities, higher-order cognitive processes develop, including metacognitive processes that are essential for the further development of the game and for the transfer of learning to contexts that potentially go beyond the game. Wilson and Golonka (2013) argue that a research agenda that is guided by embodied cognition will lead to a radical shift in our conceptualization of cognitive behavior:

This shift will take cognitive science away from tweaking underlying competences and toward understanding how our behavior emerges from the real time interplay of task-specific resources distributed across the brain, body, and environment, coupled together via our perceptual systems. (p.1)

Such a shift will require a shift in our methods for studying the design of serious games. Wilson and Golonka (p. 2) provide four questions to be asked to guide a task analysis necessary to examine how embodied cognition can explain a person's behaviors:

1. What is the task to be solved?
2. What are the resources that the organism has access to in order to solve the task?
3. How can these resources be assembled so as to solve the task?
4. Does the organism, in fact, assemble, and use these resources?

Embodied cognition offers a way to conceptualize and investigate the dynamic systems at play within the individual as he or she is immersed in a game environment. Better understanding of these dynamics can only help to identify the design features that can activate these dynamics. Finally, if an embodied cognition perspective is adopted, then thought needs to be given to how transfer would fit within that perspective. Under the best of circumstances, transfer of learning is difficult to achieve. Even greater difficulties are presented when considering the transfer of learning from the gaming context to the academic context. Whether such transfer is practicable still remains to be substantiated.

In this chapter, the notion of affordance was discussed as a way to conceptualize transfer. Within the serious game, the player must be provided with multiple opportunities to generate concrete affordances of objects and from these concrete affordances move to the generation of abstract and generalized affordances that can go beyond the game. To do this, the player must be supported within the game, either by aids embedded within the game or by a social network of fellow players to make learning conscious, intentional, and deliberate; that is, to make learning metacognitive.

In sum, there is much territory to travel before we can arrive at a destination in which serious games have all the allure of a popular video game and all the potential of promoting academic learning. This does not mean that such a journey should not be undertaken. There are many researchers who have the abilities and the interests to undertake the journey. However, it does mean that there are several hurdles that must be jumped before arriving there. First and foremost, there is a tremendous amount of research to be conducted. There simply has not been a sufficient amount of research conducted to determine whether learning within the context of a video game transfers to an academic context. Second, whether there is funding available to conduct this research is questionable. Hundreds of millions of dollars go into the production of video games, and an entertainment hungry population is willing to pay. Hundreds of millions of dollars are not available to go into the design of a serious game. Third, a theoretical foundation needs to be established for the research of serious games. A theory of self-regulated learning has been offered here, but whether this theory has wide appeal is unknown. Fourth, a shift from traditional cognitive science to embodied cognition and the methodologies that it requires could offer a new perspective on learning from serious games. However, there are several versions of embodied cognition depending on the researcher's discipline, and even though embodied cognition has garnered a growing interest among researchers, there has not been a wide acceptance of it. Fifth, embodied cognition has placed a strong emphasis on the role that affordances can play in learning, but the notion of affordance has been around for at least 35 years and has not been widely researched and has not gathered much attention in the context of serious games. There is obviously much to accomplish before we can answer whether it is possible for serious games to contribute to academic learning and hopefully to learning in the greater world.

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KEY TERMS AND DEFINITIONS

Affordance: The relationship between the properties of an object and a person's capabilities to use those properties in goal-directed activities (Gibson, 1979; Norman, 2013).

Embodied Cognition: Is a psychology of the individual that advocates that along with the environmental context, learning must be understood by how the individual learner perceptually and physically interacts with that environment (Varela, Thompson, & Rosch, 1999; Wilson, 2002). The critical thrust of embodied cognition is to explain how the body and mind interact perceptually, physiologically, and psychologically in real time with the environment to achieve goal-directed activities (Morris et al., 2013; Wilson, 2002).

Transfer: Transfer is "using existing knowledge and skills to learn, solve problems, or carry out a new task in a new situation" (Liberman et al., 2014, p. 189).

Self-Regulated Learning: "Self-regulated learning refers to self-generated thoughts, feelings, and actions for attaining one's learning goals" (Zimmerman & Moylan, 2009, p. 299). Effective self-regulated learning depends on the learners' abilities to metacognitively monitor and control their learning and to motivate themselves to learn.

Metacognition: Metacognition is "knowledge of one's knowledge, processes, and cognitive and affective states; and the ability to consciously and deliberately monitor and regulate one's knowledge, processes, and cognitive and affective states" (Hacker, 1998, p. 3).

Situated Cognition: A major thrust of situated cognition promotes the idea that knowledge and skills are best learned in contexts that closely resemble the contexts in which they will be used (Brown, Collins, & Duguid, 1989; Lave & Wenger, 1989). That is, you cannot understand what happens within the individual apart from considering the influence of the social, cultural, and physical contexts within which the individual is learning.

Serious Game: This is a genre of video games, sometimes called digital-learning games, that attempts to "target the acquisition of knowledge as its own end and foster habits of mind and understanding that are generally useful or useful within an academic context" (Klopfer, Osterweil, & Salen, 2009, p. 21).