A Literature Review of Gaming in Education

Research Report

Katie Larsen McClarty

Aline Orr

Peter M. Frey

Robert P. Dolan

Victoria Vassileva

Aaron McVay

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Abstract

The use of simulations and digital games in learning and assessment is expected to increase over the next several years. Although there is much theoretical support for the benefits of digital games in learning and education, there is mixed empirical support. This research report provides an overview of the theoretical and empirical evidence behind five key claims about the use of digital games in education. The claims are that digital games (1) are built on sound learning principles, (2) provide more engagement for the learner, (3) provide personalized learning opportunities, (4) teach 21st century skills, and (5) provide an environment for authentic and relevant assessment. The evidence for each claim is presented and directions for future research are discussed.

Keywords: digital games, education, assessment

A Literature Review of Gaming in Education

The rapid penetration of increasingly sophisticated technologies into every facet of society is causing significant shifts in how, when, and where we work, how individuals, companies, and even nations understand and organize themselves, and how educational systems should be structured to prepare students effectively for life in the 21st century. School-aged children worldwide are growing up immersed in a media-rich, ubiquitous, "always connected" world. Concerns over the need to reform the educational system to effectively prepare students for a much more technology driven, interconnected and competitive "flat world" are being voiced by politicians, educators, parents, and others across the globe (Reimers, 2008; Burke, 2010). Continuing to provide the same types of education to students as the world continues to change will not serve them well. As Bill Gates (2005) noted in his address at the *National Educational Summit on High Schools*, "Training the workforce of tomorrow with the high schools of today is like trying to teach kids about today's computers on a 50-year-old mainframe. It's the wrong tool for the times." For developed nations who have historically enjoyed a comfortable relationship between high GDP per capita and positive educational performance, the 2010 Programme for International Student Assessment (PISA) results, which showed the United States as average in reading and science but below average in mathematics compared with other countries, serve as "…a warning and an opportunity. High income countries cannot take for granted that they will forever keep their comparative advantage in 'human capital'" (Gurría, 2010).

The challenges imposed by the rapid rate of technological change on society are significant, as the skills and knowledge imparted by a classical education are no longer seen as adequate preparation for success in life. The rise of various "21st century skills" taxonomies and

frameworks highlights the growing discrepancy between current educational outcomes and the skill sets needed to succeed in the quickly shifting world. The next generation of jobs will be characterized by increased technology use, extensive problem solving, and complex communication (Levy & Murnane, 2004). These are skills that go beyond typical reading, writing, and arithmetic of years past. It's not only *what* students need to learn that is shifting, but also *how* and *when* they learn. Students of today are growing up with laptops, tablets, cell phones, and video calls, and they expect to use this technology in their daily interactions (NCREL & Metiri, 2003).

One area of significant promise in this regard is a movement toward the use of educational video games as learning tools in schools. In response to this movement, several commercial and custom made video games have been used in K-12 classrooms across the world to enhance students' learning experience (Wastiau, Kearney, & Van den Berghe, 2009). The 2011 Horizon report suggests that augmented reality and game-based learning will gain widespread use in two to three years (Johnson, Smith, Willis, Levine, & Haywood, 2011). Advocates of game-based learning in higher education cite the ability of digital games to teach and reinforce skills important for future jobs such as collaboration, problem-solving, and communication. While in the past educators have been reluctant to use video games or computer games in the classroom, there is an increasing interest across broad and varied parts of the educational establishment to look at the use of digital games as serious learning and assessment tools. In 2005, the Federation of American Scientists, the Entertainment Software Association, and the National Science Foundation brought together nearly 100 experts to consider ways to develop next generation learning games. They found that many of the skills required for success in games such as thinking, planning, learning, and technical skills are also sought by employers

(Federation of American Scientists, 2006). In Secretary of Education Arne Duncan's *2010 National Education Technology Plan*, he calls for research in how "assessment technologies, such as simulations, collaborative environments, virtual worlds, games, and cognitive tutors, can be used to engage and motivate learners while assessing complex skills" (United States Department of Education, 2010, p. 15).

The assumption many are making is that digital games are well suited to improve instruction and differentiate learning while also providing more effective and less intrusive measurement than traditional assessments offer. This paper provides an overview of some of the current thinking about digital games in K-12 education. We first present a definition of digital games for use in this paper. Next we discuss the theoretical benefits of games, grounded in cognitive and learning sciences. Then we summarize the empirical research evaluating the use of games for learning and assessment. Finally, we present a future research and development agenda to fill some gaps in the current research and move the field forward.

What Are Digital Games?

For the purposes of this paper, we will use Salen and Zimmerman's (2004) definition of games, which is a "system in which players engage in artificial conflict, defined by rules, that results in a quantifiable outcome" (p. 80). A digital game, then, further refines the definition by requiring the game system to incorporate technology. Simulations, augmented reality, and traditional video games all fall within this definition; however, purely virtual worlds, such as *Second Life,* would not be games because there is no quantifiable outcome. Elements of "gamification"—the use of game-like mechanisms applied to traditional teaching to increase motivation or engagement (e.g., leader boards, points, badges) or the use of games simply as an extrinsic reward system to increase motivation (e.g., earning game time as a reward for

performance)—are also not considered games under this definition. While improving motivation and engagement by increasing the fun of learning are indeed important, these types of approaches are beyond the scope of the paper.

The Promise of Digital Games

Digital games are considered to be the largest and fastest growing market segment of the multibillion-dollar entertainment industry. The global market is worth billions of dollars (Kirriemuir & McFarlane, 2004), and development costs, revenue, and audiences for digital games are comparable—and often exceed—that of the movie industry (Kirriemuir, 2002). With 97% of US teens playing some type of digital game on a regular basis (Lenhart, Kahne, Middaugh, Macgill, Evans, & Vitak, 2008), it is not surprising that there is a large and growing interest in the applicability of games in education.

Over the last century in the U.S., there has been a broad and consistent interest in harnessing the power of technology to add contemporary relevance and improve instruction (Fladen & Blashki, 2005). A steady stream of technologies from Victrolas, slide and film projectors, radios, televisions, overhead projectors, computers, the Internet, and so on have been employed in an effort to increase student engagement, improve classroom efficiency, solve teacher shortages, and in general "fix the system" (Fabos, 2001). Many of the predictions of these new technologies' ability to change education for the better were no doubt exaggerated, but perhaps not entirely without merit. Digital gaming is eliciting similar high hopes and bold claims. In this paper, we will examine the theoretical and empirical evidence behind five of these claims:

1. Games are built on sound learning principles.

2. Games provide personalized learning opportunities.

3. Games provide more engagement for the learner.

4. Games teach 21st century skills.

5. Games provide an environment for authentic and relevant assessment.

Games are Built on Sound Learning Principles

Play is an important element for healthy child development (Ginsburg, 2007), including learning development. Children learn through imaginative play (Bodrova & Leong, 2003; Hirsh-Pasek, Golinkoff, & Eyer, 2003; Zigler, Singer, & Bishop-Josef, 2004). Because digital games can provide an opportunity for play through simulated environments, these games are not necessarily a distraction from learning, but rather can be an integral part of learning and intellectual development (Ke, 2009). We think and understand best when we can imagine a situation and that prepares us for action. Games present a similar situation through simulation, providing us the opportunity to think, understand, prepare, and execute actions (Gee, 2003).

An attractive element of the gaming experience as a learning tool is that it provides opportunities for continued practice because negative consequences are not typically associated with failure. Rather, failure serves as an integral part of the learning experience (Gee, 2009; Groff, Howells, & Cranmer, 2010; Ke, 2009; Klopfer, Osterweil, & Salen, 2009). This encourages players to improve through repeated practice either by advancing within a game or replaying parts of a game. Failure with limited consequence, agency, and choice are seen as critical elements of a true gaming experience. That said, in the context of education where a game might become a required activity tied to real consequences, there could be a diminution in these key elements that may lead students to be less inclined to practice and realize some of the benefits of gaming.

Games also are built with clear goals and provide immediate feedback (Dickey, 2005). This allows players to change their game play in order to improve their performance and reach their goals. The idea of immediate feedback is also prominent in good formative assessment processes. Students will improve their work when given constructive feedback (Black & Wiliam,

1998). It can be difficult for teachers to translate student performance into constructive feedback or to plan their lessons to incorporate probing questions and subsequent actions (Black, Harrison, Lee, Marshall, & Wiliam, 2002). This type of feedback loop, however, is inherent in well-designed games.

Although a player's actions may demonstrate learning within the game environment, less is known about whether such learning can be applied or transferred to a different context. For example, Gee (2005) describes how the game *World of Warcraft* reflects key 21st century skills such as individual specialization within cross-functional teams working collaboratively to meet goals. Although this type of specialization and collaboration is important within the game, it is still unclear how much these behaviors transfer outside of the game world. Of course there are some situations in which you would not expect behavior from a game to transfer (e.g., jet skiing simulation games), and games cannot be adapted for every possible learning situation (Nagle, 2001).

Although research has shown that skills such as problem solving ability increase within a game and may even transfer or increase across games, it is difficult to transfer that skill outside digital games (Egenfeldt-Nielson, 2006). Curtis and Lawson (2002) found only modest evidence of the transfer of problem solving skills. Skills may be easier to transfer outside of games than specific content; however, content that is transferred outside of games tends to be limited and low level (Egenfeldt-Nielson, 2007).

Games Provide Personalized Learning Opportunities

The idea that education should meet students "where they are" is not a new one, although it has several variations: differentiated instruction (Tomlinson, 1999), whole-person learning (Snow & Farr, 1987), individualized instruction (Switzer, 2004), and personalized learning

(Organisation for Economic Co-operation and Development [OECD], 2006). Personalized

learning is described as the way that schools "tailor education to ensure that every pupil achieves

the highest standard possible" (OECD, 2006, p. 24). The OECD report suggests personalized

learning in schools through five processes:

      (1) knowing the strengths and weaknesses of students,

      (2) developing teaching and learning strategies based on student needs,

      (3) engaging curriculum choices,

      (4) supportive school organization, and

      (5) community, local institution, and social service support.

      However, personalized learning need not only occur at the school level. Games provide

an opportunity to personalize learning for students, meeting at least the first three processes.

Strengths and weaknesses of students can be inferred based on players' actions during the game.

Kickmeier-Rust, Hockemeyer, Albert, and Augustin (2008) describe ELEKTRA, a project

funded by the European Commission. Throughout the course of game play, information from the

players' actions (e.g., turning on or not turning on a light switch) are continually aggregated to

create an updated picture of the players' competencies based on the accumulated play actions.

      Games can also be adapted based on students' needs. Appropriate scaffolding can be

provided in games through the use of levels. Supports are embedded into games such that easier

levels are typically played first, advancing on to more complex levels as the player achieves

mastery. For example, scaffolding is built into the science mystery game *Crystal Island* by

allowing students to keep records of the information they have gathered and the hypotheses they

have drawn (Ash, 2011). Other scaffolding can be achieved through the use of graphics, such as

navigation maps, which can lower a player's cognitive load while playing the game (O'Neil,

Wainess, & Baker, 2005). Researchers de Jong and van Joolingen (1998) concluded that adding appropriate instructional supports and scaffolding to simulations or games may help with challenges students may encounter in this type of discovery learning.

Games also meet the unique teaching and learning needs of students when new concepts are introduced as a logical learning progression. Learning progressions are often described as the path students take to learn a set of knowledge or skills (Masters & Forster, 1996), i.e., the sequence in which these skills are typically developed. Learning progressions are frequently used in education. In traditional classroom settings, a student that does not master a concept could be left with a gap in their knowledge foundation that challenges later attempts to build to more complex concepts. In contrast, digital games inherently force the player to master a concept in order to advance (e.g., the double jump with a dash in mid air to get across the pit of lava). Players are able to repeat the same scenario until they master this concept. The same philosophy could extend to the use of digital games in education. A student cannot, in essence, unlock Algebra until a prerequisite knowledge of previous skills has been mastered. This mastery-based learning, however, may require students to invest ample time in learning each skill before moving to the next.

These scenarios also imply that a student has some curricular choice and control over their learning. This sense of agency and autonomy for the learner is important. The most common error in online education activities is a failure to provide the learner with an appropriate level of agency. Agency refers to the learner's ability to interact with the material and feelings of belongingness and socio-emotional support in the situation (Jalongo, 2007). Dalton (2000) reported that 56% of students who participate in online courses sensed a lack of interactivity; they were not active learners with choice. Well-designed games, however, encourage students to

adapt and design learning and teaching styles most suitable to them, which in turn leads to a

more active role in learning (Klopfer et al., 2009). For example, students playing the science

inquiry game, River City, were able to explore their learning environments independently. They

created their own hypotheses and conducted their own experiments in order to solve the problem

(Ketelhut, Dede, Clarke, & Nelson, 2006).

In general, well designed games—as with well designed education experiences — are

challenging but achievable. Games should present players with challenges that are matched to

their skill level in order to maximize engagement (Kiili, 2005). "The key is to set the level of

difficulty at the point where the learner needs to stretch a bit and can accomplish the task with

moderate support" (Jalongo, 2007, p. 401). This is similar to Vygotsky's zone of proximal

development, which is "the distance between the actual developmental level as determined by

independent problem solving and the level of potential development as determined through

problem solving under adult guidance, or in collaboration with more capable peers" (2006, p.

86). A game is able to provide that opportunity for appropriate guidance or collaboration in order

to help players meet the next challenge. The stepwise increase in difficulty reduces frustration

and allows players to form knowledge and strategies that will be useful later (Gee, 2003). A state

of pleasant frustration—challenging but doable—is an ideal state for learning several content

areas such as science (diSessa, 2000). In a game, however, the price of failure is lower (Gee,

2005). Students can take risks and quickly learn from their mistakes. Effective games provide

feedback that is "(1) clear and unobtrusive, and (2) immediately responsive to the player's

actions" (Rigby & Ryan, 2007, p. 8). The feedback also helps reinforce motivation (Jones &

Issroff, 2005). Students are able to adapt to the feedback, and the game continues to adapt to the

student.

However, learning does not just end with the game. Debriefing is critical to using games in education (Lederman & Fumitoshi, 1995), as it provides the connection between learning in the game and applying those skills to other contexts. Teachers can facilitate the transfer of skills by leading pre- and post-game discussions which connect the game with other things students are learning in class (Ash, 2011). Students can be encouraged to share different ways of approaching a problem. Based on a review of 17 studies focused on game design, Ke (2009) concluded that instructional support features are necessary in order for the lessons learned in computer games to transfer to other contexts. Video games can be used to create deeper learning experiences for students, but they do not provide the entire experience. Games work best when coupled with effective pedagogy (Squire, 2002). As such, Steinkueler & Chmiel (2006) suggest that games will not replace teachers and classrooms, but they might replace some textbooks and laboratories.

Games Provide More Engagement for the Learner

Traditional schooling has often been labeled as boring for many students. In fact, nearly half of high school dropouts said a major reason for dropping out was that the classes weren't interesting, and 70% said they were not motivated or inspired to work hard (Bridgeland, Bilulio, & Morison, 2006). Teachers have long used various approaches including contemporary media and art to increase engagement and motivation in the classroom. Perhaps the unique value of the engagement factor within digital games is the ability to sustain engagement and motivation across time, particularly with more challenging learning tasks and without the teacher needing to be a "superstar" (Gee, 2003, 2008; Rupp, Gushta, Mislevy, & Shaffer, 2010). Digital games can be more engaging than regular classroom activities (Malone, 1981; Rieber, 1996). Although engagement may be just one component, Kirkpatrick & Kirkpatrick (2006, p. 30) noted,

"Positive reaction may not ensure learning, but negative reaction almost certainly reduces the possibility of its occurring."

Students' experiences with game environments are shaping their expectations of learning environments. Students prefer rich graphics and multitasking interfaces (Prensky, 2001). They desire tasks that are "fast, active and exploratory, with information supplied in multiple forms in parallel" (Kirriemuir & McFarlane, 2004, p. 3). Students are also more engaged when a narrative story is present within the games (Barab, Arici, & Jackson, 2005). The narrative is used to piece together the different tasks of the game into a coherent unit (Dickey, 2005) and keep students engaged as they work through the different tasks.

Games contain the pieces necessary to engage students and help them enter a state of flow (Csikszentmihalyi, 1990) where they are fully immersed in their learning environment and energized and focused on the activity they are involved in. When complete attention is devoted to the game, a player may lose track of time and not notice other distractions. Games support many of the components of flow such as clear goals, direct and immediate feedback, balance between ability level and challenge, and sense of control. These components can increase student engagement, and student engagement is strongly associated with student achievement (Shute, Ventura, Bauer, & Zapata-Rivera, 2009). In fact, Naceur and Schiefele (2005) have shown that student interest was a better predictor than student ability in challenging reading comprehension tasks, and that interest was also related to persistence in reading difficult texts and in long-term retention of reading material.

Motivation is another benefit of games. It is driven from our belief about how good we will be and our interest in and the value of the goal (Jalongo, 2007). Players are more motivated when they feel a personal attachment to the goal (Gee, 2009). Some games are based on external

motivation, where students receive particular rewards for playing the game to entice them to continue practicing learning. These types of games have had some success in the health care industry and with short term content memorization (Egenfeldt-Nielsen, 2006), but they tend to reinforce rote memory of low level content rather than deep understanding. However, if the goals of the game and the learning outcomes are closely tied together, students tend to be more intrinsically motivated, and the rewards are in solving the game challenges and learning.

A year long pan-European study that included over 500 teachers found that the great majority of the teachers surveyed confirmed that "motivation is significantly greater when computer games are integrated into the educational process" (Joyce, Gerhard, & Debry, 2009, pp.11). Teachers in Scotland gave similar reports where the use of game-based learning consoles in the classroom significantly increased student motivation and engagement (Groff et al., 2010).

Although motivation clearly seems to be important, there is not clear agreement on what makes a game or learning task motivating. Dickey (2005) argued that the three main elements of engaged learning are clear goals and tasks, reinforcing feedback, and increasing challenge. Successful games are also marked by limited negative consequences for risk-taking and opportunities to apply choice. Fladen and Blashki (2005) listed the three key features of motivating games to be interactivity, agency, and engagement. Rigby and Ryan (2007) created yet a different set of needs that are satisfied by engaging games through their Player Experience of Need Satisfaction (PENS) model: competence, autonomy, and relatedness. Each of these models could be used to evaluate games, student motivation, and the impacts on subsequent learning and achievement.

Games Teach 21st Century Skills

Game designers and scholars argue that games capture the player's attention and engage them in complex thinking and problem solving (Barab & Dede, 2007; Gee, 2003, 2005; Jenkins, Clinton, Purushotma, Robison, & Weigel, 2006). For example Gee and Shaffer (2010, p. 3) state:

> Games require the kind of thinking that we need in the 21st Century because they use actual learning as the basis for assessment. They test not only current knowledge and skills, but also preparation for future learning. They measure 21st Century skills like collaboration, innovation, production, and design by tracking many different kinds of information about a student, over time.

Games are frequently cited as important mechanisms for teaching 21st century skills because they can accommodate a wide variety of learning styles within a complex decision-making context (Squire, 2006). The skills and context of many games take advantage of technology that is familiar to students and use relevant situations (Gee, 2003; Spires, 2008). These can all be used to highlight the 21st century skills that are necessary for success in a global economy (Spires, Row, Mott, & Lester, 2011). There is a growing awareness that teaching and assessing 21st century skills "frequently requires exposing learners to well-designed complex tasks, affording them the ability to interact with other learners and trained professionals, and providing them with appropriate diagnostic feedback that is seamlessly integrated into the learning experience." (Rupp et al., 2010, p. 4) This is what well-designed games do.

Games foster collaboration, problem-solving, and procedural thinking (Johnson et al., 2011) which are important 21st century skills. Multi-player role playing games can also support problem-based learning, allowing players to see the results of their actions play out much faster than they could in real time (Khoo & Gentile, 2005) and allowing them to experience situations

rather than simply reading descriptions (Shaffer, 2004). According to Gee (2007), high quality immersive games require players to think systemically and consider relationships instead of isolated events or facts. The abundance of options and possible decision points within games forces players to not only apply their knowledge but to adapt their knowledge to varying situations. They must think abstractly because they are playing abstractly. This helps to develop their skills in decision-making, innovation, and problem-solving (Johnson et al., 2011). Although games can provide learning of these important 21st century skills, teachers may be less interested in using them in the classroom because those skills are not currently tested or explicitly valued in educational systems (McFarlane, Sparrowhawk, & Heald, 2002).

Games Provide an Environment for Authentic and Relevant Assessment

It is important to note that by definition, games are inherently assessments. Games and traditional assessments share underlying characteristics that provide a means for quantifying knowledge and abilities. The two environments use complimentary technologies that can combine to create more accurate models of student knowledge, skills, and behaviors. For example, games provide opportunities for authentic and appropriate knowledge representation of complex ideas, many of which seem under-represented in traditional assessments (Behrens, Frezzo, Mislevy, Kroopnick, & Wise, 2007). In games, the assessment process occurs as the game engine evaluates players' actions and provides immediate feedback. Players make progress or they don't; they advance to the next level or try again. Assessment occurs naturally in a game. The challenge is assessing the *appropriate* knowledge, skills, or abilities (Ash, 2011).

Methodologies have surfaced as a means for designing games for assessment and quantifying the knowledge and abilities within game environments. Evidence Centered Design (ECD; Mislevy, Almond, & Steinberg, 1998; Rupp et al., 2010) creates a framework for assessment by combining competency, evidence, and task models. This framework defines the attributes being assessed and behaviors that represent such attributes, and most important, it identifies the activities that connect what is being assessed to what players do within the game (Rupp et al., 2010; Shaffer, Hatfield, Svarovsky, Nash, Nulty, Bagley, Franke, Rupp, Mislevy, 2009; Behrens et al., 2007). This connection between learning, behavior, and setting provides support for the validity of what is being assessed.

However, analytic tools are still needed to "score" the observations and update the competency model (i.e., the belief about the player's knowledge or abilities at each point in the game). Koenig, Lee, Iseli, and Wainess (2010) developed a conceptual framework for analyzing

the data from interactive games that relies on dynamic Bayesian networks to represent students'

real-time actions and decisions. This representation can feed both formative and summative

assessments of student performance to provide information about their knowledge, skills, and

abilities. Epistemic Network Analysis (ENA) is another tool for translating the elements of ECD

as they occur in the game into a knowledge network map. As such, ENA provides snapshots of

the player's competency trajectory through the game, which can be continuously quantified,

analyzed, and updated to assess the player's development and to inform selection of game task

and activities to be presented (Shaffer et al., 2009).

Games, as experienced by players, can then be adapted based on this information.

Kickmeier-Rust, Marte, Linek, Lalonde, and Albert (2008) found that including adaptive features

in games resulted in better learning performance and also superior gaming experience than non-

adaptive control groups. Quellmalz, Silberglitt, and Timms (2011) developed science simulation

software and demonstrated its efficacy in six states. The results from the assessments were

reliable, valid, of sound technical quality, and were suitable for inclusion in a multilevel state

accountability system.

The opportunity for games to be used as assessments is greatly enhanced because of their

capacity to collect deep, rich data about students and then to analyze—through advanced

methods (Baker & Yacef, 2009)—their fine-grained interactions. Games can therefore serve as

"non-invasive assessments" that provide continuous information which can be analyzed

according to several probabilistic techniques (Kickmeier-Rust, Marte, et al., 2008).

Shute (2011) refers to this embedded gathering of information about players as "stealth

assessment," an evidence-based process by which assessment can be integrated directly with

learning environments. Shute and Kim (2011) demonstrate how assessments can be embedded

within a commercial game to examine learning of educationally relevant knowledge and skills. In this study, the authors adapt ECD to the game environment and use it to assess problem solving and causal reasoning skills demonstrated during the game session.

Application of games can encourage—or require—students to apply deeper levels of knowledge and skills (Bloom, Englehart, Furst, Hill, & Krathwohl, 1956; Marzano, Brandt, Hughes, Jones, Presseisen, Rankin, et al., 1988; Webb, 1997). Unlike traditional assessments, which typically tap students' recall or basic demonstration of skills, games and simulations can present students with more authentic environments to demonstrate strategic and critical thinking. For example, Millis, Forsyth, Butler, Wallace, Graesser, and Halpern (2012) have developed a game-based, intelligent tutoring system designed to teach scientific inquiry skills to high school and college students. Students engage in natural language "trialogs" with artificial intelligence agents and are continually evaluated on their application of higher-order thinking skills as demonstrated by their responses to the agents.

The relevance of the game situation can further be enhanced by changing the point of view (Dickey, 2005). By having students experience the game firsthand, as if they were truly in the situation or by having a tutor speak directly with them, students were able to learn more than being in neutral, 3rd person situations (Moreno & Mayer, 2000). Relevance can also be increased by building realistic characters (Dickey, 2007) or placing the game within familiar environments (Warren, Dondlinger, & Barab, 2008).

Steinkueler & Chmiel (2006) analyzed *World of Warcraft* postings and translated them into evidence of scientific literacy including scientific discursive practices, model-based reasoning, and understanding theory and evidence. The authors stopped short of coding and creating measurement of specific individuals, but this does provide an example of using gaming

data that students are already providing in order to draw conclusions about student learning and the process of scientific inquiry. Similarly, Dolan, Goodman, and Strain-Seymour (2012) developed a prototype, game-based performance task and evaluated the utility of applying frameworks for collaboration and problem solving in evaluating the game's potential efficacy for measuring students' collaborative problem-solving skills.

Gaming presents unique opportunities to support the formative process, which is the process by which data about students' knowledge and skills are used to inform subsequent instruction (Heritage, 2010). In order for formative assessments to be useful to instructors and learners, the assessment data must be valid. However, in low stakes assessments students are typically less motivated. Consequently, information gathered about students' knowledge and skills under such circumstances tend to be less valid (Sundre & Wise, 2003; Wise & DeMars, 2003). The increased motivation brought about by games may have the potential to increase the validity of formative assessments. Delacruz (2011) evaluated games as tools to support formative assessment and examined how varying the level of detail about a game's scoring rules affected learning and performance in mathematics. Her research found that combining elaborated scoring explanation with incentives for accessing game feedback resulted in higher learning gains.

Summary

Despite the strong debate on how games can improve education and how useful they can be for teaching complex concepts and skills, very little research has been performed on the relationship between games and academic performance (Ke, 2009; O'Neil et al., 2005). Most of the available studies consist of descriptive analysis of the impact games have on students' attitude towards the subject being taught and their motivation to attend and engage in class. The data from these studies are typically limited to surveys filled out by teachers and students after

using games in the classroom for several weeks or months (Wastiau et al., 2009).

In rare occasions when researchers have attempted to investigate the relationship between learning within digital games and academic performance, the results are mixed because of differences in definitions and methodologies. Games may not be the most effective tool for all content and in all situations (Ke, 2009). In fact, some have suggested that content areas such as mathematics, physics, and language arts are well suited for gaming (Hays, 2005; Randel, Morris, Wetzel, & Whitehill, 1992), but this result has not been replicated by others (Ke, 2009). Ke found that games seemed to foster higher-order thinking skills such as planning and reasoning more than specific content knowledge.

In order to really evaluate the efficacy of games, researchers need to consider more nuanced features such as the length of game play and the content, structure, and mechanics of the games (Khoo & Gentile, 2005). Identifying an agreed upon set of features such as gaming genres, difficulty levels (from the perspective of game mechanics), delivery platforms, interfaces (e.g., joy stick, touch screen, mouse), and delivery environments (e.g., classroom, lab, home) would be a huge step forward. In addition, creating definitions and models for many of the attributes that are considered integral parts of the power of games (e.g., motivation, engagement, agency) would, in concert with the clarifying principles above, allow for a more coherent research approach.

Perhaps what is most unique about digital games—as opposed to any other learning innovation—is the combination of motivation, engagement, adaptivity, simulation, collaboration, and data collection that can't be achieved at scale any other way. As a result, simply measuring increases in standardized test scores or similar traditional measures of achievement after the introduction of digital games may miss some of the broader learning opportunities that games

present (Shaffer, Squire, Halverson, & Gee, 2005). While there may well be some intangible benefits of digital games in the classroom, unless there is an "investment in evaluation and the accumulation of clear evidence of impact, there will be a tendency to dismiss game environments as motivational fluff" (O'Neil et al., 2005).

In general, the research supports that digital games can facilitate learning, but it is difficult to draw stronger conclusions about the educational impact of digital games at this point because relatively few games have been tested against other teaching and learning approaches (Egenfeldt-Nielsen, 2006). Research, however, should continue to explore the effectiveness of digital games for learning and instruction. Evaluations should no longer focus on *whether* games can be used for learning. Because of key differences in specific features between games, attempts to generalize the effect of one game to all games may be unhelpful (Kirriemuir & McFarlane, 2004). Instead research should prioritize *how* games can best be used for learning.

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