Assessing Problem-Solving Skills in Immersive Environments

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Introduction to the Problem

Over the past couple of decades, developed and developing countries are increasingly relying on a knowledge economy to help solve complex problems arising from globalization such as issues related to global warming including the depletion of the Ozone layer and the scarcity of natural resources in the environment. Solving complex problems requires one to think critically, creatively, and systemically when planning solutions (Shute & Torres, 2012). This type of problem solving involves cognitive processes aimed at achieving a goal when the solution is hidden from the problem solver (Mayer & Wittrock, 2006). Educators consider the development of problem-solving skills a primary goal of teaching and learning (Jonassen, 1997; Ruscio & Amabile, 1999).

Problem solving is also becoming increasingly desirable in 21st century workplace environments (Partnership for 21st Century Learning, 2016; Shute & Wang, 2016). One of the challenges in teaching problem-solving skills in formal education settings stems from limitations with providing authentic problem-solving contexts. That is, in formal learning settings, students are typically required to solve well-structured problems that have limited transfer after instruction (Jonassen, 2000). A well-structured problem is one that can be solved with a particular sequence of steps that leads to a correct answer. Most classroom textbook problems—particularly in STEM areas—feature well-structured problems that have correct answers. However, an ill-structured problem possesses a claim and a justifying argument without a
specific correct answer. An example of an ill-structured problem would be to figure out a viable solution to a problem like what can be done when the population of a community is growing but the current water supply will not support many new people.

Instruction designed on specific principles of learning related to solving a variety of problems—from well-structured to ill-structured—in an authentic context is important for initial and long-term learning as well as promoting problem-solving transfer to novel contexts (Van Eck, Shute, & Rieber, 2017). But again, there is a gap in the kinds of problems being taught in schools with those being required in the workplace. Recent survey data indicates that only 24% of employers who hired recent college graduates stated that the graduates were able to analyze and solve complex problems in their workplace environments (Hart Associates, 2015).

Facilitating learning by using immersive environments, such as well-designed video games in educational settings, is one promising way to bridge the aforementioned gap between school-based vs. workplace or real-world problem-solving skills. Immersion in this context refers to the subjective impression one experiences when interacting with a realistic, digitally-enhanced environment like a video game (Dede, 2009; Lessiter, Freeman, Keogh, & Davidoff, 2001; Stanney, 2002). This feeling of immersion enhances learning by allowing multiple perspectives, offering players a situated learning experience, and promoting transfer (Clarke, Dede, & Dieterle, 2008; Dede, 2009). In general, immersive environments support the following: distribution of knowledge across a community through situated learning, acquisition of fluency in multiple media, and interactions with different human or computer characters with different skills and abilities within authentic and novel problem-solving scenarios (Dede, 2005).

Multiple perspectives in immersive environments allow for egocentric and exocentric frames of reference. Egocentric frames of reference engender motivation through embodied
learning, whereas exocentric frames of reference promote abstract symbolic insights that are gained at a distance from the context of the environment (Dede, 2009). In addition, immersive learning environments help learners practice as well as understand how to apply facts, principles, and concepts in context rather than abstractly. Learning abstractly via memorizing certain facts as well as abstract principles and concepts is how knowledge is typically taught in school (Barab & Dede, 2007). But there is an alternative (and considerably more engaging) pedagogical approach to support learning. According to the recent report entitled “Essential Facts About The Computer and Video Game Industry” published by the Entertainment Software Association (ESA, 2016), video games are played by 65% of U.S. households and consumers spent over $23 billion dollars in the video game industry in 2015. Given the success of the video game industry, education researchers are exploring how well-designed video games can be used to support learning and assessment, referred to as game-based learning (GBL).

Over the past decade, researchers have been examining and testing various ways to deeply embed valid assessment for learning directly into video games with a technology called stealth assessment (see Shute, 2011; Shute & Ke, 2012; Shute & Ventura, 2013; Shute, Ventura, Bauer, & Zapata-Rivera, 2009). Establishing validity is key; herein referring to the psychometric quality of the assessment relative to its accuracy in measuring what is intended to be measured (also known as construct, or convergent validity). Stealth assessment is grounded by an assessment design framework called evidence-centered design (ECD; Mislevy, Steinberg, & Almond, 2003). In general, the main purpose of any assessment is to collect information that will allow the assessor to make valid inferences about what people know, can do, and to what degree (collectively referred to as “competencies” in this chapter). ECD defines a framework that consists of several conceptual and computational models that work in concert. The framework
requires an assessor to: (a) define the claims to be made about learners’ competencies, (b) establish what constitutes valid evidence of a claim, and (c) determine the nature and form of tasks that will elicit that evidence.

In this chapter, we first review the literature on problem-solving skills followed by a brief review of the theoretical foundations of GBL. Next, we discuss current methods for measuring problem-solving skills, and suggest an alternative approach to address some of the issues by using an example of stealth assessment in a research project. We then address the benefits and challenges of using video games in formal education settings. Finally, we explore alternative accreditation measures and assessments such as badges, massive open online courses (MOOCs) and industry certification in informal contexts, and conclude with ideas for next steps in this field of research.

**Problem-solving skills**

Early research on problem solving included Thorndike’s (1898) experiments on cats tasked with escaping a puzzle box. Thorndike determined that the cats were able to escape by mere associations and habits, or essentially by trial and error. The seminal work of Thorndike’s research is regarded as significant in contributing to early behavioral learning theory in psychology, but many scholars regarded problem solving as an unexplainable human behavior before Newell, Shaw, and Simon’s (1958) theoretical work on the mechanisms of thinking and learning related to problem solving (Simon & Newell, 1971). The gap in research on problem solving directed scholars to correct the antiquated narrative on the topic from unexplainable thinking to analyzing how human beings behave, and what cognitive processes engage this critical aspect of thinking and learning (Newell & Simon, 1972).
In general, problem solving can be defined as cognitive processing aimed at finding a solution to a goal when the solution is not known to the problem solver (Mayer, 1992). According to Mayer and Wittrock’s (2006) definition, problem solving consists of four interrelated elements: (1) occurs within the problem solver’s cognitive system; (2) requires the problem solver to theorize and manipulate information; (3) is goal oriented; and (4) relies upon the intellect and skills of the problem solver to establish the order in which each obstacle is handled before finding a solution.

While the elements of problem solving seem straightforward, can problem-solving skills be fostered and improved? Polya (1945) argued that problem solving is not an innate skill, but rather something that can, in fact, be developed, “Solving problems is a practical skill, let us say, like swimming… Trying to solve problems, you have to observe and imitate what other people do when solving problems; and, finally, you learn to solve problems by doing them.” (p. 5). Students are not born with problem-solving skills. Instead, these skills are cultivated when students have opportunities to solve problems proportionate to their knowledge.

Polya (1945) went on to identify a four-step problem-solving technique: understand the problem, devise a plan, carry out the plan, and review/extend. Later, Bransford and Stein (1984) integrated the collection of problem solving research and proposed the IDEAL problem solver. Each letter of IDEAL stands for an important part of the problem-solving process: Identify problems and opportunities; define alternative goals; explore possible strategies; anticipate outcomes and act on strategies; and then look back and learn. Two years later, Gick (1986) presented a simplified model of the problem-solving process including the construction of a representation, the search for a solution, the implementation of the solution, and monitoring the
outcome of the solution. Around that time, the focus of research had been shifted toward a knowledge-based representation such as schemata (Gick, 1986).

How domain-general versus domain-specific are problem-solving skills? Unlike the aforementioned work on identifying general problem-solving models, the study of problem representation recognizes the importance of domain-specific knowledge in solving problems. The representation of problems refers to how a problem solver perceives and understands a phenomenon within the problem-solving environment. Jonassen concluded that “problem solving is not a uniform activity” (2000, p. 65). Instead, problems vary in terms of their structuredness, complexity, and the requirement for prior knowledge (Jonassen, 2003). For example, the types of problems associated with driving a truck are quite different from those needed when negotiating a business deal. Thus, how well a person can solve a problem depends on the accuracy of the person’s representation of the problem scenario.

Jonassen (1997) noted that people confront various types of problems that differ according to the problem scenario, the cognitive processes required to find a solution, and the problem structure. As mentioned earlier, the structuredness of a problem can range from very well-structured (i.e., facts, rules, and principles) to very ill-structured (i.e., poorly defined, inconclusive or conflicting solution paths). Providing students with repeated practice on solving various ill-structured problems can be beneficial in formal education settings because students of all ages experience ill-structured problems that arise naturally from daily interactions with other people and the environment. Trying to solve these types of problems requires students to define (and sometimes re-define) the problem and develop a solution pathway based on the skills needed to reach the solution (Jonassen, 2002).
Recent research indicates problem-solving skills involve two facets: rule identification and rule application (Schweizer, Wustenberg, & Greiff, 2013; Wüstenberg, Greiff, & Funke, 2012). “Rules” in problem solving refers to the principles that govern the procedures, the conduct, or the actions in a problem-solving context. Rule identification refers to the ability to acquire knowledge of the problem-solving environment, and rule application is the ability to control the environment by applying the knowledge acquired. Typically, it is difficult to directly collect data on students’ rule identification ability. However, since rule application is the outward expression of one’s rule identification, the measurement of rule application may be used to reflect students’ ability to identify rules.

Complex problems usually combine a mix of basic rules with rules that require cognitive flexibility—the ability to adjust prior thoughts or beliefs and explore alternative strategies in response to changes in the environment (Miyake, Friedman, Emerson, Witzki, Howarter, & Wager, 2000). Cognitive flexibility is the opposite of functional fixedness, which is the difficulty a person experiences when he or she is required to use objects (or strategies) in uncommon ways (Duncker, 1945). Many researchers have targeted functional fixedness as the major obstacle to successful problem solving (e.g., Anderson, 1980). Moreover, problem-solving skills play an important role in everyday life and in many professions. Gagné (1980) believed that the central point of education is to teach people to become better problem solvers, and as noted earlier, problem solving is recognized as one of the most important skills demanded in the job market (Partnership for 21st Century Skills, 2016). Therefore, research on problem-solving skills and how to improve them are essential to prepare students for upcoming challenges in life and work. In the next section, we discuss how video gameplay can support the development of problem-solving skills.
Theoretical foundations of game-based learning

Advocates of GBL argue that video gameplay supports the development of problem-solving skills through situated learning (Eseryel, Law, Ifenthaler, Ge, & Miller, 2014; Gee, 2008; Greenfield, 2010). Situated learning implies that knowledge and skills are tied to the specific context in which they are learned (Lave & Wenger, 1991). The theory encompasses the following instructional design principles: authentic learning activities, cognitive apprenticeship, and legitimate peripheral participation (Bransford, Brown, & Cocking, 2000; Herrington & Oliver, 1995). Through gameplay, beginning players can develop their skills by exploring, interacting, and practicing with expert player characters (PCs) or non-player characters (NPCs). The learning that takes place during gameplay between novice players and expert PCs or NPCs is similar to cognitive apprenticeship between, for example, professors and emerging scholars in academia.

In addition, well-designed video games can provide a learning environment with internal instructional support features, such as tutorials to help game-players master skills, organize knowledge, and adjust strategies to solve problems (Ke, 2009). Certain well-designed video games that apply instructional design principles to reinforce skill acquisition through gameplay may do so via gaining players’ attention with a compelling video sequence and informing players of the game (or learning) objectives (Gagné, Wager, Golas, & Keller, 2005). To illustrate these principles, we discuss the well-designed massive multiplayer online roleplaying game (MMORPG) called World of Warcraft (WoW; Activision Blizzard, 2016). For example, the immediate starting zones in WoW introduce players to the basic gameplay concepts, mechanics, and procedures within the game after an introductory video sequence immerses players in the game environment with an overview of the starting zone.
Gameplay experiences in WoW stimulate players with novelty, uncertainty, and surprise in the game as they interact with one another and learn new information and skills, such as advanced combat techniques, quest objectives, profession and trade skills, as well as transportation options. This is directly in line with the methods described by Gagné, Briggs, and Wager (1992) for gaining learners’ attention (i.e., via stimulation with novelty, uncertainty, and surprise). After the initial orientation in WoW, and at the beginning of gameplay, players are initially directed to seek out NPCs that have a yellow exclamation point located above their head. NPCs guide each player from one location to the next in the game environment. These NPCs are pedagogical agents that offer quests to guide players in their actions. As each quest is completed, players are given a reward. A pedagogical agent is a computer animated character that exhibits life-like behaviors, speech, gestures, and movements of the body (Dehn & Van Mulken, 2000). In addition to granting rewards, quest givers inform players of objectives that, upon completion, allow players to progress in the storyline, as well as help players transition to new zones and quest givers as seen in Figure 1.

Figure 1. An example of a quest giver NPC that informs players of quest objectives in World of Warcraft (Dragon, 2016).
GBL researchers have also argued that well-designed video games often include — whether intentionally or not — good learning principles, such as the provision of ongoing feedback, interactivity, and active participation. These learning principles (or focal aspects of the gameplay experience) can lead to improvements in knowledge and skill acquisition (Gee, 2003; Ifenthaler, Eseryel, & Ge, 2012; Shute, Ke, & Wang, 2017).

Video gameplay is popular across all gender, ethnic, and socioeconomic lines (Entertainment Software Association, 2016), and good games provide a visually rich gameplay experience. So, *good games* are broadly engaging, and engagement is important to learning. The challenge is validly and reliably measuring learning in games without disrupting engagement, and leveraging that information to bolster learning. Towards this end, researchers have been examining games as effective vehicles for assessment (diSessa, 2000; Shute, Ke, & Wang, 2017; Shute & Ventura, 2013; Shute, Leighton, Jang, & Chu, 2016). The goal is to blur the distinction between assessment and learning while maintaining engagement.

**Measuring problem-solving skills—Challenges and a promising solution**

Key measurement challenges for complex constructs like problem-solving skills include (a) lack of a clear and consensual definition and/or operationalization of the construct, (b) theoretical multidimensionality of the construct where certain dimensions may have internal as well as external sources, (c) difficulty disambiguating trait from state (e.g., where some people tend to be generally good problem solvers, and others are can only solve problems in certain settings or domains), (d) difficulty disambiguating the generality of the construct (e.g., is there a single “problem solving” variable, or is it solely dependent on the context), and (e) reliance on outdated multiple-choice and self-report measures, the former narrowly focused and the latter flawed. Self-report measures in particular are problematic as they are subject to “social
desirability effects” that can lead to false reports about behaviors, attitudes, and beliefs (see Paulhaus, 1991). In addition, test takers may interpret specific self-report items differently (e.g., what it means to enjoy solving “hard problems”) leading to unreliability and lower validity (Lanyon & Goodstein, 1997).

Innovative and valid performance-based assessments of problem-solving skills are needed that assess how students apply this skill in the solution of complex, real-world problems. One way to approach this problem is to use video games or similarly immersive environments, to simulate a variety of problems for performance-based assessment (Dede, 2005; DiCerbo & Behrens, 2012; Gobert, Sao Pedro, Raziuddin, & Baker, 2013; Quellmalz, Timms, Silbergitt, & Buckley, 2012; Shute, Wang, Greiff, Zhao, & Moore, 2016).

Early approaches to performance-based assessment in GBL included using serious games as tools to improve skills as seen in Marine DOOM, a modified version of the game DOOM, designed to improve military thinking and decision-making skills (Krulak, 1997). New developments in GBL include the use of virtual reality (VR) technologies to promote collaboration and deep learning across a range of educational areas and for a broad swath of students (Greenwald et al., 2017). And while some researchers have attempted to design specific games to promote problem-solving skill (e.g., Van Eck, Hung, Bowman, & Love, 2009) there are various commercial video games on the market that may be used for this research, such as Portal 2 (Shute, Ventura, & Ke, 2015) and Plants vs. Zombies 2 (Shute & Wang, 2016). Such game-based environments can provide meaningful assessment by supplying students with scenarios that require the application of different facets of problem-solving skill.

Stealth assessment provides a way to embed valid assessments directly into immersive environments like video games, extending the evidence-centered assessment design framework
by delineating specific gameplay behaviors (specified in the evidence model) and statistically linking them to competency model variables (Shute & Ventura, 2013). Stealth assessment thus complements the use of serious games to measure and improve skills by eliciting and aggregating student data during gameplay that can be used to provide real-time inferences about knowledge and skill states that can inform policies relevant to a range of stakeholders (Cukier & Mayer-Schoenberger, 2013).

The results of this analysis are data (e.g., scores) that are passed to the competency model, which statistically updates the claims about relevant competencies in the student model. The ECD approach combined with stealth assessment provides a framework for developing assessment tasks that are explicitly linked to claims about personal competencies via an evidentiary chain (i.e., valid arguments that serve to connect task performance to competency estimates), and are thus valid for their intended purposes. The estimates of competency levels can also be used diagnostically and formatively to provide adaptively selected levels, feedback, and other forms of learning support to students as they continue to engage in gameplay.

To illustrate, Shute, Wang, Greiff, Zhao, and Moore (2016) developed a stealth assessment of problem solving skill and embedded it in a game called *Use Your Brainz* (a slightly modified version of *Plants vs. Zombies 2*). The game was then tested with a sample of middle-school students. The research team began by developing a problem solving competency model based on a review of the relevant literature. Problem-solving skill was divided into four primary facets: (a) analyzing givens and constraints, (b) planning a solution pathway, (c) using tools and resources effectively and efficiently, and (d) monitoring and evaluating progress. The first facet maps to “rule acquisition” and the remaining facets map to “rule application.” They then identified in-game indicators that would provide evidence about students’ levels on various
problem-solving facets—specific actions a person would do while engaged in gameplay that would provide evidence (positive and negative) towards one or more of the facets.

The problem solving model was then implemented in the game via Bayesian networks. A Bayesian network is a probabilistic graphical model that represents a set of random variables and their conditional dependencies via a directed acyclic graph. Each of the 45 levels in the game had its own Bayesian network, reflecting the specific indicators of the level, as well as its particular difficulty and discrimination estimates. To validate the stealth assessment, data were collected from middle school students who played the game-based assessment for three hours and then completed two external problem-solving measures (i.e., Raven’s Progressive Matrices and MicroDYN). Results indicated that the problem solving estimates derived from the game significantly correlated with the external measures, which suggests that the stealth assessment is valid. Next steps include running a larger validation study and developing tools to help educators interpret the results of the assessment, which will subsequently support the development of problem solving skills. In the ensuing section, we explore the benefits and challenges associated with using video games in a classroom environment.

**Video games in formal education settings**

Given the gap in problem-solving skills being taught in schools and those required in workplace environments, we suggested the integration of video games into formal learning curricula with the goal of improving problem-solving skills, and to prepare students with the skills necessary to succeed in a globally-interconnected society. Similarly, Schrader, Zheng, and Young (2006) argued that gameplay experiences with video games can promote team collaboration and problem-solving skills for students through immersive game environments. However, while many students and teachers clearly enjoy video gameplay, the majority do not
fully understand how video games can be used to support learning outcomes (Selfe & Hawisher, 2004).

Well-designed video games can support higher-level learning via offering players practice across multiple and varied problem solving scenarios (Gee, 2007; 2008; Van Eck, 2006). Repeated practice with novel problems can improve problem-solving skills within a domain (Gagné, Wager, Golas, & Keller, 2005). In K-12 settings, video games have been shown to improve creativity, recall of facts, and problem-solving skills when compared to computer-assisted instruction (Chuang & Chen, 2009; Jackson et al., 2012). Overall, there seems to be consensus that video games can support changes in affect, behavior, knowledge, and skill acquisition for learners (Clark, Tanner-Smith, & Killingsworth, 2016; Ifenthaler, Eseryel, & Ge, 2012; Mishra & Foster, 2007; Shute, D’Mello et al., 2015; Sitzmann, 2011; Wouters, van Nimwegen, van Oostendorp, & van der Spek, 2013).

While well-designed video games can help improve cognitive competencies, there is also a need to bridge the gap between in-game knowledge and school knowledge (i.e., game-based learning and formal learning). One possibility involves the design of scaffolds that are both engaging and meaningful to instruction, such as presenting concepts that are directly tied to in-game performance and readily identifiable during gameplay (Barzilai & Blau, 2014). As an example, avatars in World of Warcraft (i.e., the digital embodiment of a player in the game) communicate with each other to solve problems such as how to use given tools and resources to travel from one zone to another. Using tools and resources efficiently is a facet of problem-solving skill (Shute & Wang, 2016). Introducing a problem-based scenario in World of Warcraft that requires students to learn how to reduce travel time from one zone to the next using
resources (e.g., map and transportation hub) efficiently is one way to teach problem-solving skills in formal education settings.

In addition, reducing travel time is also a relevant concept that can transfer from the game to the natural world. In this approach, designing scaffolding challenges students to think critically during gameplay and provides students with meaningful connections between gameplay and educational concepts (Gee & Hayes, 2011; Salen & Zimmerman, 2003). Instruction that weaves gameplay concepts with educational content by using scaffolds can inform stakeholders and policy makers that video games are effective learning tools in formal education settings. Well-designed multiplayer video games like World of Warcraft also provide opportunities for collaborative learning and problem solving that has relevant implications in workplace environments.

Certain well-designed video games that emphasize multiplayer interactivity during gameplay can also help players develop skills that are desirable in 21st century workplace environments. As an example, Symantec’s former Chief Operating Officer (COO), Stephen Gillet, included the roleplaying video game World of Warcraft as one of his achievements on his résumé to highlight his experience in organizing large groups of individuals to solve difficult problems, demonstrate confidence in solving these problems through natural and immersive video game environments (i.e., analyzing different strategies and gameplay tactics with peers in-game and through social media platforms like Twitter), and distribute resources (i.e., gold, crafting components, weapons, and armor) to in-game friends (Pagliery, 2014). These gameplay practices may lead to improvement in planning and executing strategies that can be applied to similar workforce-related collaborative projects in the natural world. Next, we discuss alternative
assessments in practice and professional settings as well as future directions of game-based learning and alternative assessments in academic research and practice.

**Alternative accreditation measures, assessments and future implications**

In a competitive global market, people are always looking for ways to improve their status, lifestyle, or wage earnings. Educational achievement via academic degrees is generally considered to be the best and most common way to improve personal status. Yet current research on alternative educational credentials (e.g., certificates, badges) indicates that they also can have labor market value. Thus, the implications for career advancement and earning potential of these alternative credentials are significant (Ewert & Kominski, 2014).

In the U.S. and other developed countries, certifications are very common in the following fields: aviation, construction, technology, environmental sciences, and other industrial sectors, as well as healthcare, business, real estate, and finance. Various government bodies (e.g., the Institute for Credentialing Excellence in the U.S.) set rigorous standards for accreditation of certification programs based on the Standards for Educational and Psychological Testing (APA, AERA, NCME).

When discussing alternative credentials, it is important to distinguish between educational certificates—typically earned within an academic institution (i.e., similar to, but more specialized than an academic degree), and industry-based certifications (e.g., Microsoft certification)—completed after reaching a certain level based on performance assessments (Carnevale, Rose, & Hanson, 2012). Both of these are equally marketable. That is, the growing demand for skilled laborers to solve complex problems in a knowledge-based economy suggests that there is a market for individuals that possess knowledge and skills associated with particular educational certificates and industry-based certifications (Noack, 2001; Ray & McKoy, 2000).
This demand coincides with an 800% increase in the number of certificates awarded over the past 30 years, with a majority (71%) being awarded by the government (Carnevale, Rose, & Hanson, 2012; Ewert & Kominski, 2014).

Current changes to industry require people to develop new skills and demonstrate their understanding through industry-certification, while educators are also exploring ways to provide assessments that can promote knowledge and skill acquisition and reduce the negative effects of inaccurate or over-assessment on learner motivation (Abramovich, Schunn, & Higashi, 2013; Shepard, 2000; Stiggins, 2002). Education reformers are drawn to alternative assessments as a way to capitalize on the benefits of assessment while mitigating negative effects. One particular type of assessment that is trending among educational technologists is badges (e.g., Alberts, 2010; O’Byrne, Schenke, Willis, & Hickey, 2015). Badges are defined as a visual symbol of achievement that can be viewed online to verify the context in which the badge is earned through process or activity (Gibson, Ostashefksi, Flintoff, Grant, & Knight, 2013). Badges represent an alternative assessment method that extends student learning and achievement beyond formal education settings.

Universities and professional networking sites such as LinkedIn are experimenting with badges to signify achievement (Chauhan, 2014). Badges shift the focus from measuring achievement via rubrics to personalizing achievements, thus validating learning experiences inside and outside of the classroom environment (O’Byrne et al., 2015). When embedded into a curriculum and/or an immersive environment, digital badging systems validate the process of learning and specific skill development that may be missing from traditional learning assessments and evaluations.
Overall, the growth of certification programs—in education and industry contexts—can be viewed as a reaction to the changing employment market. Because such certifications are portable, they do not depend on one school or company's definition of a certain skill or job. Certification then becomes salient on one’s résumé by being an impartial, third-party endorsement of an individual’s professional knowledge and experience. However, critics of these types of alternative assessment indicate that without proper implementation and an underlying theoretical learning foundation, the alternative assessments can produce negative effects on learning, such as: decreasing intrinsic motivation, overemphasizing game/environment design compared to the learning activity, and increasing one’s desire for extrinsic awards and attention (Deci, Koestner, & Ryan, 1999). In other words, earning badges or video game rewards can distract learners from achieving goals other than earning the reward itself (Abramovich, Schunn, & Higashi, 2013). Research on performance assessments indicates that prior knowledge can be very influential in determining learner assessment outcomes, and proponents of badges need to further research the motivational impact of badges on learning between different types of learners and badges (Abramovich, Schunn, & Higashi, 2013; Dochy, Segers, & Buehl, 1999).

Discussion

The demand for skilled workers who can solve complex problems in 21st century workplace environments requires a shift in how to measure and assess problem-solving skills in formal education settings. In this chapter, we defined problem-solving skills and explored the theoretical foundations for GBL to explain how interactions within immersive environments can promote the development of problem-solving skills. We outlined some of the challenges associated with assessing problem-solving skills in formal education settings (e.g., the prevalence of flawed assessment methods such as multiple choice type of items and self-report
surveys) and highlighted the importance of using performance-based assessments as well as alternative accreditation measures in 21st century workplace environments. This suggestion coincides with the growing labor demand for multi-skilled workers in a constantly changing global economic landscape.

In addition, we proposed a possible solution to reduce the gap between school-based and real-world problem-solving skills via integrating immersive environments like video games into formal education settings to help students improve their problem-solving skills by preparing them with repeated problem-solving scenarios through immersive gameplay. To illustrate, we included an example of an in-game problem-solving stealth assessment (for more details, see Shute, Wang, Greiff, Zhao, & Moore, 2016). Furthermore, recent research on the effects of immersive gameplay on cognitive and noncognitive skills demonstrates that learning does occur—for problem-solving skills, persistence, visual-spatial skills, and attention (e.g., Green & Bavelier, 2012; Rowe, Shores, Mott, & Lester, 2011; Shute et al., 2015; Ventura, Shute, Wright, & Zhao, 2013). Some researchers, however, have reported null effects of immersive gameplay on cognitive skill acquisition (Ackerman, et al., 2010; Baniqued, Kranz, et al., 2013; Boot, Kramer, Simons, Fabiani, & Gratton, 2008) so clearly, more research is needed.

One future GBL research thread may aim to bridge the gap between the world of commercial vs. educational video games. Towards that end, we need a systematic approach to designing game-based assessment that produces engaging video games and valid assessments. This will involve an interdisciplinary team (e.g., experts in assessment, game design, content, instructional design, psychometrics, and learning sciences). Sound research methods are needed to explore how well-designed video games can be used as reliable and valid assessments of multiple and diverse competencies. From an assessment standpoint, research is needed to
determine the value added of game-based assessment over traditional assessment relative to the quality of the assessment (i.e., validity, reliability, and generalizability) and the impact on learning, engagement, and transfer. This research should also include analyses on how game-based assessment data predict important external criteria (e.g., high school or college graduation, state test scores, and so on) better than traditional assessments.

The ECD framework provides a systematic approach to assessment design and also provides a transparent way to reason about student performance. And while there are other ways to develop assessments, they often lack transparency as well as specification about the competencies, and tend to focus on tasks that are too simple or inauthentic. This can result in creating assessments that measure unintended competencies and thus damage the reliability and validity of the assessment. In addition, using an ECD approach for the design of game-based assessments can provide a clear research and communication framework for assessment/learning experts and game designers who want to design and develop new educational and engaging game-based assessments that accurately measure important traditional and new competencies.

One final hurdle to surmount, to weave such immersive video games into classrooms concerns the need for these games to provide easy-to-interpret reports to stakeholders—such as students and teachers. There are many ways an assessment can accumulate data (e.g., tallying frequency counts of events, automatically logging player information then mining the logfile to make estimates of competency states via Bayesian networks). Regardless of the methodology for accumulating evidence, the ensuing estimates can be reported at various grain sizes (e.g., general problem solving skill or specific facets) for diagnostic purposes (see Almond, Shute, Underwood, & Zapata-Rivera, 2009). And with regard to validity issues of game-based
assessments, when embedded assessments are not only ongoing, but also invisible, this can remove test anxiety, again leading to a more valid assessment (Shute et al., 2009).

In conclusion, we believe that conducting research with the goal of improving 21st century competencies like problem-solving skills for learners through immersive video gameplay environments is relevant and important to pursue given the emerging challenges of a globalized economy (i.e., renewable energy, pollution, climate change).

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