Game-Based Learning and Digital Game-Based Learning:

A Comprehensive Literature Review

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Abstract

Research indicates that preadolescents play digital games, on average, between four to six hours per day (Homer, Hayward, Frye, & Plass, 2012). Worthy of exploration is the notion that if such gameplay had a serious educational context at its foundation, then students could engage in serious gaming (Djaouti, Alvarez, & Jessel, 2011) and, thus, experience an increase in engagement (Huang, Huang, & Wu, 2014; Ninaus, Moeller, McMullen, & Kiili, 2017; Núñez Castellar, All, De Marez, & Van Looy, 2015) and quantifiable learning outcomes (Byun & Joung, 2018; Clark, Tanner-Smith, & Killingsworth, 2016; Jagušt, Botički, & So, 2018; Ninaus et al., 2017; Pasnik & Llorente, 2015; Shin, Sutherland, Norris, & Soloway, 2012; Takeuchi & Vaala, 2014; Tokac, Novak, & Thompson, 2019; Van Eck, 2015). This paper introduces game-based learning and digital game-based learning results from various studies on student engagement and learning outcomes, as well as a discussion of how these findings affect the development of Prodigy Math Game, the supplemental math platform.
It has been hypothesized and widely accepted that a child’s involvement in games can have a profound impact on development (Piaget, 1962). Research on digital game use found that as recently as 2012, preadolescents were found to play digital games, on average, between four to six hours per day (Homer et al., 2012; Ofcom, 2016). This is less surprising when one considers that, worldwide, digital gameplay averages 7.11 hours per week for those aged 18 and older, with the United States averaging the highest amount of time at 7.61 hours per week, and India at 6.92 hours per week (Limelight, 2019). With such a large market and call to action for the creation and development of games that lead to academic development (Richards, Stebbins, & Moellering, 2013), there has been no shortage of academic games entering the market.

Researchers’ published work broadly supports the notion that teachers are utilizing digital games in the classroom. In a survey of 700 teachers conducted by Takeuchi & Vela (2014), they found that 74% of K-8 teachers implement digital game-based learning (DGBL) to augment instruction, 80% of whom have their students play at least monthly and over half (55%) of whom have their students play weekly. These academic games often fall into one of a few types, as outlined in Table 1.

Table 1: Types of Games (Blamire, 2010)

<table>
<thead>
<tr>
<th>Type</th>
<th>Basis for Learning</th>
<th>Key Games</th>
<th>Key Texts</th>
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<tbody>
<tr>
<td><strong>Active games</strong></td>
<td>• Promotes physical activity</td>
<td><em>Wii Sports</em></td>
<td>-</td>
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<tr>
<td></td>
<td>• Early learning skills (hand-eye, motor-skills)</td>
<td><em>Wii Fit</em></td>
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<tr>
<td>Category</td>
<td>Examples</td>
<td>Authors/References</td>
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| Alternate reality games       | • Embodied play experience  
• Authentic real-world experience  
• Social collaboration | Savannah Uncle Roy All Around You 
| Authoring games               | • Understanding of games’ structure, production, effects and audiences  
• Media literacy | Mission Maker Adventure Author 
Burn, A and Durran, J (2007) Media Literacy in Schools |
| Creative games                | • Creative production  
• Collaboration and sharing | Spore LittleBigPlanet 
- |
| Epistemic games               | • Professional practice | Pandora Digital Zoo Urban Science 
| Massively multiplayer online games | • Distributed thinking  
• Collaboration | World of Warcraft Everquest 
| Military games                | • Authentic professional training | America’s Army Full Spectrum Warrior 
Prensky, M (2002) Digital Game-Based Learning |
| Mobile games                  | • Authentic real-world contexts  
• 21st century skills | Virus Newtoon 
| Persuasive games              | • Critical skills  
• Critical reflection | Oil God Activism 
Bogost, I (2007) Persuasive Games |
| Role-playing games            | • Understanding character and identity  
• Problem-solving | Deus Ex Tomb Raider 
Gee, JP (2004) What Video Games Have to Teach Us |
Two terms are commonly utilized in this domain: *game-based learning* and the *gamification of learning*. In game-based learning (GBL), there is a delicate balance between gameplay and the necessity to cover desired subject matter (i.e., education content). When GBL comes in the form of a digital game, it is often referred to in research as digital game-based learning. In the gamification of learning, elements of a game are added to traditional learning activities that might not be traditionally exciting for students. Game-like elements added to such learning activities include the attainment of points, mastery of levels, awards, and other features commonly observed in digital video games (Plass, Homer, & Kinzer, 2015).

Games that have been designed with an inherent purpose to help teach content or a skill have been often cited in research as *serious games*, a term coined by Abt (1970) to separate them from games created purely for entertainment (De Lope & Medina-Medina, 2017; Tsekleves, Cosmas, & Aggoun, 2016; Zhonggen, 2019). Figure 1 depicts this separation where “video
“game” refers to games developed purely for entertainment, and where “serious game” refers specifically to games that were created with the intention of teaching content or a skill (Ratan & Ritterfeld, 2009). While video games are intended only for fun, teachers can utilize them for educational purposes, which shifts the purpose of the intended use from gaming to serious gaming. In comparison, serious games can combine fun elements of video games with an explicit learning purpose.

Games with a narrative that drive them fall into the category of those referred to as having serious storytelling whereby “the narration progresses as a sequence of patterns impressive in quality, relates to a serious context, and is a matter of thoughtful process” (Lugmayr et al., 2017, p.1509).

Figure 1: The Relationship Between Video Games, Serious Games and Serious Gaming (Djaouti et al., 2011)
This literature review will have an inherent focus on DGBL with a specific emphasis on pedagogical foundations, findings on motivation and engagement, as well as effectiveness and efficacy.

**Pedagogical Foundations of DGBL/GBL**

Informal games, such as “duck-duck-goose” or “ring around the rosy,” are often used as a means of teaching concepts or ideas to children from an early age, since they engage the child and their focus is on having fun even as they learn how to take turns and follow directions. As Piaget (1962) theorized, the play that children engage in shifts as they progress through different stages of emotional growth. As they age, students become able to participate in more complicated games that also contribute to cognitive growth.

Over time, the concept of connecting students with digital games was presented as a means of increasing student engagement (McGonegal, 2011). One of the earliest and most widely adopted education-based games, *The Oregon Trail*, was developed and produced by MECC for release in 1974. The inherent purpose of the game was to help students conceptualize life as a pioneer and allow them to interactively experience the challenges they faced. This revolutionary concept led to a shift in the ability of teachers to immerse students in educational content and a deeper understanding of the facets that come together to make game-based learning work, as outlined below in Figure 2 (Plass et al., 2015).
As the capacity of technology evolved, so did the ability to more closely personalize content — something necessary to help students learn to use a growth mindset (Dweck, 2017). In time, adaptive software became available which allowed the software being used to directly target students’ weaknesses, strengths, and present a balance of both to help increase student engagement and achievement. The algorithms behind the adaptive software work in the background to help students learn at their level or within their zone of proximal development, in support of the concept first presented by Vygotsky (1978). This type of highly-personalized and engaging learning also helps to develop 21st century skills, including those suggested by Van
Eck (2015) like: increasing motivation, becoming more effective with communication, developing critical thinking and communication skills, and, perhaps most importantly, helping learners develop the ability to become more persistent. Educators who harness the power of highly effective software can engage all students in class with a level of personalization that could never practically be achieved without the support of technology.

When technology, content, and pedagogy (Mishra, 2019) are combined (as outlined in Figure 3 below), digital games can help teachers amplify instruction and deeply personalize instruction for students on a level that was previously next to impossible. In a recent study conducted by Schoology (2017), teachers reported that blended learning was the most impactful method in which student achievement can best be addressed. In addition, these games can help combat student anxiety that can affect students in the earliest grades (Wu, Barth, Amin, Malcarne, & Menon, 2012).

Figure 3: TPACK Framework (Mishra, 2019)
Findings on Motivation and Engagement in Relation to GBL/DGBL

It is of great interest that research outlines various cases whereby GBL/DGBL directly led to an increase in student motivation and engagement (Huang et al., 2014; Ninaus et al., 2017; Núñez Castellar et al., 2015).

As outlined in Figure 2, this increase in motivation and engagement is potentially tied to the various ways in which learners can become engaged via GBL/DGBL — namely, cognitive engagement, affective engagement, and behavioral engagement (Deater-Deckard, Chang, & Evans M. E., 2018; Phillips, Horstman, Vye, & Bransford, 2014), with others additionally including sociocultural engagement (Plass et al., 2015).

When deeply engaged in serious gameplay — and a specific lens toward math — profound attitudinal changes can be detected. For example, research by Phillips et al. (2014, p. 557) revealed that “most [students] reported that playing the game helped them like math more.” Yet, the findings of the study also included the conclusion that students generally prefer to use academic games in tandem with live instruction. This finding helps connect the deep engagement that serious games can provide with the necessity of a teacher who possesses deep foundational knowledge in technology, content, and pedagogy, as outlined in Figure 3 (Mishra, 2019).

Further supporting the conclusion that math-based GBL/DGBL engagement can impact student motivation, work completed by Huang et al. (2014) led to the discovery that students who participated in math-based GBL/DGBL were “positively motivated” while research by Nunez et al. (2015) identified not only increased enjoyment, but, an increase in the capacity of students’ working memory.

Research findings are clear that when students are engaged in math-based games, they
end up more focused on the task at hand. Bragg (2012) conducted a study wherein students were observed in scenarios engaged in tasks that were game-based and tasks that were not game-based. Results of his analyses indicated that lessons rooted in gameplay led to a 93% rate of time on task compared to 72% time on task when the lessons did not include games. Furthermore, Bragg (2012) discovered that the conversation in class was rooted in math 34% of the time when games were utilized compared to just 11% when they were not. This is supportive of the notion that increased social and cultural engagement is evident when gameplay is utilized (Plass et al., 2015).

When reviewing the literature related to game-based learning, widespread implications of research findings are apparent. These findings span not only the domain of academic growth and student engagement. They also incorporate elements of social and emotional learning (SEL). Connections between game-based learning and elements of SEL, which can be defined as programs to support students’ emotional and academic growth (Jones & Bouffard, 2012), are a major source of discussion in the field of education and have shown to consistently have a positive impact on achievement (Corcoran, Cheung, Kim, & Xie, 2018; Durlak, Weissberg, Dymnicki, Taylor, & Schellinger, 2011).

**Findings on the Effectiveness/Efficacy of GBL/DGBL**

Evaluation of research indicating that GBL/DGBL leads to increased motivation, increased engagement, and alignment with SEL themes is critical to understanding the impact of game-based learning. However, in an era of accountability, evaluation of research delineating achievement-oriented outcomes of GBL/DGBL is imperative. To meet such aims, research was reviewed to determine whether GBL/DGBL can lead to sustainable and improved student
achievement. Much research has been done to determine whether or not increased achievement can be detected, and, positive results have broadly been found (Byun & Joung, 2018; Clark et al., 2016; Jagušt et al., 2018; Ninaus et al., 2017; Pasnik & Llorente, 2015; Shin et al., 2012; Takeuchi & Vaala, 2014; Tokac et al., 2019).

A meta-analysis on the broad impact of DGBL for K-16 students found that “digital games significantly enhanced student learning relative to nongame conditions” (Clark, Tanner-Smith, & Killingsworth, 2016, p. 79). When two separate groups of researchers examined GBL/DGBL specific to mathematics, researchers found there was a statistically positive achievement correlation for those exposed to this type of learning activity (Byun & Joung, 2018; Tokac et al., 2019). In their published research, Tokac et al. (2019, p. 407) explicitly stated: “Mathematics video games contributed to higher learning gains as compared with traditional instructional methods.”

As a means of better understanding how DGBL affects student mathematics outcomes in the primary grades, a study was conducted. Though the sample was small, the researchers looked to determine which type of gamified learning experiences would provide the highest level of academic gains for students. Ultimately, findings revealed that “significantly higher performance levels appeared in a gamified condition combining competition, a narrative, and adaptivity with individual performance game elements” (Jagušt et al., 2018, p. 444). This combination seems to provide the blend that best captivates students’ imaginations and allows for the highest level of skill development.

As researchers noticed mounting evidence that digital mathematics games can help improve student academic outcomes, they sought to confirm this growth and to learn what variables related to DGBL were causing this. Ninaus et al. (2017) conducted a small sample size study to
determine how students’ acceptance of game-based learning, intrinsic motivation to learn math, and the quality of the game experience affected student outcomes. Researchers found that game-based learning was an effective method and that all three tenets explored had an impact on student outcomes. It was perhaps the unexpected findings, though, that stood out most. The researchers found that “students with higher self-reported interest in math and better math grades were not as successful in improving their rational number knowledge as compared to those with lower interest in math and worse math grades” (Ninaus et al., 2017, p. 23). While there are variables such as the style of questions or the flow of the algorithm that could have affected the outcomes for students with higher self-reported interests and higher grades from developing, the findings related to those who were less interested and had worse grades are critical ones. It is perhaps here that the power of DGBL is most evident, since even those who may not have a passion for the subject matter are more apt to participate since they enjoy the game. With students who are intrinsically motivated by the learning platform, and thus end up learning at a greater pace via a DGBL platform, they may realize greater gains.

In 2012, Shin et al. conducted a quasi-experimental study of 50 second-grade students to determine the efficacy of DGBL. It was ultimately found that “when students used or played the technology-based game more, their performance was higher than that of students who did not use the technology-based game or who played it less often” (Shin et al., 2012, p. 548). This supports research by Mishra & Kohler (2006) that indicated that teachers can amplify their impact on achievement outcomes by allowing students to utilize DGBL tools. Beyond that, it was also discovered that critical populations such as low-performing female students and high-performing males benefitted in terms the development of their arithmetic skills as a result of their work on the DGBL platform. This implies that populations who might not typically benefit from
traditional types of instruction may garner deeper development specifically as a result of the use of DGBL and its highly personalized approach to learning.

In an effort to better understand the landscape of DGBL and its impact on the American education system, personnel from the Janz Cooney Center implemented a survey of nearly 700 teachers from across the United States. One among their many findings was that 74% of teachers report that they were utilizing DGBL platforms and that they are primarily learning how to implement and use these platforms through their peers. Results specific to math-based DGBL were very encouraging with “nearly three quarters (71%) of digital game-using teachers report that games have been effective in improving their students’ mathematics learning” (Takeuchi & Vaala, 2014, p.5). As a result of this study, we know teachers are embracing the DGBL movement and willing to teach themselves how to implement them — 75% of whom say that the games help students to learn math.

The DGBL movement has been so broad that even PBS Kids created a DGBL platform and conducted a randomized control trial to determine whether DGBL produced increased outcomes in mathematics learning for four- and five-year-old students. Their target population, including those who spent time in early childhood education centers primarily serving economically disadvantaged populations, is of particular interest in outcomes evaluations due to research surrounding socioeconomic status and student achievement. They found that “children in the … [game-based supplement] condition learned significantly more mathematics than children in … [other] conditions (Pasnik & Llorente, 2015, p.3). In addition to the positive academic impacts observed among this at-risk population, the authors also established that children can profit from using DGBL platforms as early as age four.

Perhaps the most telling set of results, researchers found that teachers who adjusted the
instruction they provided to students based on feedback they received from the game ultimately saw higher achievement compared to those who did not (Faber, Luyten, & Visscher, 2017). This finding is further supported by the research of Ysseldyke and Bolt (2007) and Callaghan, Long, van Es, Reich, and Rutherford (2018). Excitingly, this positions GBL/DGBL as a helpful tool when the data made available to teachers is harnessed for targeted improvement in achievement.

**Application for Prodigy Math Game**

Prodigy Education was founded on the notion that learning math should be as fun as playing a video game. With preadolescents playing multiple hours of digital games daily (Homer et al., 2012) and a clear connection with the ability of GBL to positively impact student achievement across various meta-analyses (Byun & Joung, 2018; Clark et al., 2016; Tokac et al., 2019), Prodigy has taken the call to action (Richards et al., 2013) and developed a platform, denoted in Figure 5 below, that can help change student perceptions of their math ability, empower teachers to deeply personalize instruction, communicate achievement with parents/guardians, as well as enable administrators at both the school and district level to review student progress, strengths, and areas of opportunity.

Prodigy Math Game is a serious game that falls into the MMORPG category as outlined by the definitions found in Table 1 by Blamire (2010) and can be identified as a game that has been intentionally designed to include both serious and video game features as delineated in Figure 1 by (Ratan & Ritterfeld, 2009). It encompasses all four of the primary categories of engagement as proposed by the model developed by Plass et al., (2015) found in Figure 2. Even so, the Prodigy Math Game team believes that software cannot stand on its own and be deeply effective, which is congruent with the TPACK framework proposed by Mishra & Koehler (2006). Rather, it takes an excellent teacher who has a deep foundation in content, pedagogy, and
technology to really exploit the full benefits of adaptive serious games.

To clarify, Figure 5 outlines the Prodigy Math Game platform that is designed to facilitate student outcomes. It all begins with a foundation in DGBL rooted in research demonstrating the efficacy of this model (Clark et al., 2016; Jagušt et al., 2018; Ninaus et al., 2017; Pasnik & Llorente, 2015; Shin et al., 2012; Takeuchi & Vaala, 2014; Tokac et al., 2019).

Figure 4: Prodigy Math Game Platform

**Prodigy Platform**

![Prodigy Platform Diagram]

**Conclusion**

Capturing the spirit of play to help children grow through serious games (Abt, 1970) as a means of increasing student engagement, with the goal of increasing student achievement, has become a common trend — one that has produced tangible positive results when broadly studied in various meta-analyses (Byun & Joung, 2018; Clark et al., 2016; Tokac et al., 2019; Zhonggen, 2019). It is evident that children widely play digital games (Homer et al., 2012; Limelight, 2019).
and the advantage of capturing that energy can be used to benefit learning.

Deep research continues to be in need and there are researchers who are focused on ensuring that research and evidence-based best-practices for DGBL are available to those who wish to utilize them (All, Nuñez Castellar, & Van Looy, 2015, 2016). The field of GBL/DGBL has substantial room for continued growth with continuous improvements in technology. It is becoming easier to imagine a world where content is continuously tailored specifically to students’ strengths and areas of opportunity. By and large, this means the work of teachers, who are central student learning (Mishra & Koehler, 2006), can have their instructional work enhanced by technology enabling them to deeply personalize learning more than ever, while allowing students to continuously learn in their zone of proximal development (Vygotsky, 1978).
References


Zhonggen, Y. (2019). A Meta-Analysis of Use of Serious Games in Education over a Decade.