Digital games-based learning. Time to adoption: two to three years?

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Digital games-based learning. Time to adoption: two to three years?

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Abstract

Digital games-based learning (DGBL) has repeatedly been identified as an educational technology likely to be adopted within the next two to three years. Yet, in spite of the promise and hype, DGBL remains relatively uncommon in classrooms. There are many possible reasons, but this chapter focuses on the reluctance of many DGBL researchers and developers to take advantage of insights from the learning sciences and education research. The promise of DGBL remains, but it is unlikely to be realised until the complexities of learning and classroom practices, as well as the complexities of the technology, are more properly understood.

Keywords: digital games-based learning, learning sciences, design approaches, knowledge construction, retrieval practice.

Introduction

It is now more than fifteen years since the publication of Marc Prensky's seminal book 'Digital Game-based Learning' (2001), in which he argued persuasively that computer games will soon be 'how everyone learns'. More recently, in seven of the ten years up to 2014, the influential NMC Horizon Report on emerging technologies for teaching and learning (NMC 2004-2015) repeatedly identified digital games-based learning (DGBL) as a technology likely to be adopted 'within two to three years'. Meanwhile, from 2011, the Gartner Hype Cycle for Education (Gartner 2011-2015) tracked DGBL as it preoccupied developers, policy makers, researchers and many teachers. But then in 2015, despite many research studies reporting positive outcomes (reviewed in Boyle et al. 2016), DGBL slipped unceremoniously into the Hype Cycle's 'trough of disillusionment' while the Horizon Reports of that year did not mention DGBL at all.

Given the extensive research efforts and that many leading scholars have argued that DGBL can provide significant and possibly unique opportunities for learning (e.g., Gee 2004a), with some advocates even seeing it as a silver bullet for much that is wrong in education (Salen 2008), why does DGBL appear to be moving off the agenda? And why, in spite of all of the promise and hype, does DGBL remain relatively uncommon in classrooms (Takeuchi and Vaala 2014)? Unfortunately, this chapter does not have all the answers. Instead, the aim is to explore some core issues, building on insights from the learning sciences that influence whether or not DGBL is used successfully in classrooms. In order to provide a context, the chapter begins with an overview of digital games and the characteristics that make them candidate learning technologies.

Digital games

To understand digital games (computer games or video games) it is first useful to take a step back, to consider what is actually meant by games in general – although defining games is notoriously difficult. For Huizinga (1955), an early games theorist, games constitute a 'magic circle' which separates the experience from that of the real world; while for Caillois (1962), games are light-hearted, non-productive activities, which are bounded in time and place and have uncertain outcomes. However, according to the philosopher Wittgenstein (1968), it is not actually possible to precisely define a game without some games falling outside that definition. Instead, he argues that games should be understood as activities that are ‘recognised as games’ because they share some ‘family resemblances’.

Here, drawing on Wittgenstein’s approach, the family resemblances of digital games will be taken to include the following, all implemented in a digital technology: virtual make-believe environments, rules of play (limitations and constraints), tasks that require effort, explicit aims and objectives, feedback from actions, scored outcomes, virtual or real competition, lack of consequences for the real world, and fun (Whitton 2014). The takeaway is that any digital game might share some or all of these family resemblances.

The many thousands of digital games now available may also be classified by genre. Most agree that core genres include ‘action games’ (such as the first-person shooter ‘Doom’), ‘adventure games’ (such as ‘Tomb Raider’, featuring the character ‘Lara Croft’), ‘god games’ (such as ‘Civilization’), ‘role playing games’ (such as ‘World of Warcraft’), ‘platform games’ (such as those featuring the ‘Mario Brothers’ or ‘Sonic the Hedgehog’), and ‘puzzle games’ (such as ‘Tetris’ or ‘Snake’). Digital games also come in many formats, including complex software packages (such as ‘The Sims’), massively multiplayer online games that require many hours of gameplay (such as ‘Call of Duty’), ‘casual games’, that can be played in just a few minutes (including mobile phone apps such as ‘Angry Birds’ or ‘Candy Crush’), and digital physical games controlled with whole-body movements (such as ‘Dance Central’ or ‘Wii Sport’).

A reason often advanced for using digital games to support learning is that they are so popular. Surveys have consistently shown that around 90% of children play digital games (Lenhart et al. 2015). However, it shouldn't be assumed that the popularity of digital games is universal. Some figures for the number of children who play digital games are based on them doing so for as little as one hour per month (Macchiarella 2013), while other research has shown that some children often prefer other activities, such as playing outside with friends or building with 'Lego' bricks (for those children, digital games are fun but not that important, Holmes 2011).

Before moving on to consider how the family resemblances of digital games are exploited in DGBL, a controversy that should not be avoided will be mentioned. Starting with one of the first digital games, 'Spacewar!', developed in 1962 at MIT, which involved the shooting of enemy spaceships, many popular digital games have involved increasingly graphic violence. Many such games have also been misogynistic or at least have reinforced gender stereotyping. While violent games have frequently been linked to aggressive behaviour (Anderson 2004), particularly towards women (Gabbiadini et al. 2016), the research remains contentious. This is partly because of the methodological challenges, with some identifying links between violent gameplay and real-life violence (Hall et al. 2015), while others suggest that any causal link is very weak (Przybylski 2014). It is unlikely that this debate will be resolved any time soon.

Digital games-based learning

DGBL, also known as educational games, learning games or serious games, has been the subject of academic research for at least 35 years, with Thomas Malone's PhD thesis, ‘What makes things fun to learn? A study of intrinsically motivating computer games.’ (1980), often being cited as one of the first academic studies. Since then, there have been many thousands of published studies and numerous systematic reviews (such as Boyle et al. 2016).

Even casual observation of children playing games inevitably leads to the conclusion that, as they do so, very often they are learning. For many, children’s play is an essentially constructivist activity, the proto-natural form of learning, and learning is intrinsically playful (Bruner 1960). For Gee (1999), entertainment digital games are themselves ‘learning machines’, because their designs comprise various core principles of learning. This learning might be as simple as discovering how to use the game controller to move a character through the game’s virtual space. It might involve learning about the benefits and disadvantages of cooperation, either with in-game avatars or with real people in shared game environments, or the learning of fine visual/ motor coordination and faster decision making. Although this learning “may be more incidental than intentional, more broad than deep...it nevertheless does constitute learning” (Facer et al. 2003: 201).

However, DGBL usually aims to build on and move beyond these foundations, to address learning objectives more useful for, and often aligned with, the demands of formal education. It adapts and applies for educational purposes the mechanisms of digital games designed for entertainment. For example, by responding directly to the input of the player, allowing the player to take action and affect outcomes, digital games can encourage the player to explore a new idea or can reinforce learned behaviour. They can also be designed to adapt to the skills and needs of the individual, just as teachers do – increasing the challenge for players who move rapidly through the gameplay, reducing the challenge for players who are progressing more slowly. Digital game worlds can also be designed to simulate and render safe or make accessible features of the real world (for example, the inside of a volcano), giving learners a more authentic experience than is possible with books or other media. Players in authentic game environments are enabled to 'experience' things, rather than just read about them or watch them, situated in a virtual world that somehow connects to their real lives.

Another reason digital games are promoted as candidate learning technologies is that they can be highly motivating. Many possible motivational mechanisms have been identified (Iacovides et al. 2011), with a distinction often made between 'intrinsic' and 'extrinsic' motivation. At an intrinsic level, digital games can provide compelling narratives and dramatic tensions, using dynamic interactions, high-quality imagery and sounds. Some also offer optimal challenges, choice over actions and goals, adaptive and rapid feedback, and an escape to an alternative reality. Playing digital games might also be pleasurable because doing so offers opportunities to discover new information and to acquire new skills and abilities, or because they can lead to a sense of achievement, mastery, empowerment, and enhanced self-esteem when actions lead to results. Of particular interest is the pleasure gained from overcoming adversity, moving from the negative emotions of frustration or confusion to the joyful emotions of achievement when a gameplay challenge is overcome.

In fact, DGBL often claims to take this one step further. Digital games are candidate learning technologies because motivation to engage with the game, it is argued (e.g. Hoffman and Nadelson 2010), leads almost inevitably to learning, a claim that has been contested elsewhere. While Whitton (2007), for example, found no evidence of a connection between the enjoyment of entertainment games and games to support learning, Calvo-Ferrer's participants (2016) were more motivated by extrinsic factors (such as rewards external to the game). In short, the relationship between DGBL, motivation and learning is complex, such that the ability of games to motivate students is insufficient on its own to warrant their extensive use in classrooms. Instead, the impact of the games on the student's learning, in its widest sense, rather than simply their ability to motivate, ought to be prioritised.

In the last section, a controversy that surrounds digital games was mentioned: digital game violence. The impact of this contentious issue on DGBL should also be considered but again the debate is complex. Here, the precautionary principle (Van Der Sluijs et al. 2005) will be noted, which suggests that whatever the demonstrable effect on learning of a realistic or stylised violent digital game (e.g. Habgood and Ainsworth 2011), because any possible detrimental effects of such a game are unknown, teachers should think very carefully before including them in school classrooms.

The unfulfilled promise

Many reasons for the unfulfilled promise of DGBL have been proposed, not least the fact that using digital games to support formal learning for some remains controversial (Bourgonjon et al. 2013). While, as has been noted, some have argued for a games-based revolution in educational practices, others have rejected the notion that digital games may have a part to play in the classroom, fearing that this trivialises the serious project that is formal learning. In any case, if working within prevailing educational contexts rather than trying to fundamentally disrupt them, it can be challenging to find games that address the intended learning outcomes of existing curricula (while not being weighed down with unrelated or inappropriate content or gameplay), and that appeal to the varied interests of the students who are being invited to play the game (if a student does not enjoy playing a particular game, they are probably less likely to engage with it or to learn the intended outcomes from doing so).

Identifying DGBL that can easily be timetabled, that is not overly-complicated and for which there are appropriate supporting materials, can also be difficult. And even when all of this is achieved successfully, orchestrating DGBL within the constraints of a typical classroom can still be very demanding of both the school and teacher (Dillenbourg and Jermann 2010). There is the need for robust infrastructure, computers and possibly Internet access, and for technical support and contingency plans (alternative classroom activities) for when the technology stops working mid class – all of which can also impact on school budgets. Teachers also are often inexperienced in how DGBL works or might be used to support learning (Takeuchi and Vaala 2014) and thus would benefit from appropriate professional training, which again has serious cost implications. They also need opportunities to familiarize themselves with the game in question, because every game is different and so may affect learning differently, and to plan how that game and the learning that it might afford will fit into their teaching.

Teachers also need to be confident that the game does what it claims to do. This means that evaluations have to go beyond the simple and all too often poorly-constructed quasi-experiments that tend to under-estimate the impact of the DGBL's novelty in the classroom and over-estimate its effectiveness (an inevitable consequence of researcher/developer-conducted evaluations, known as super-realisation bias, Cronbach 1980). Instead, smart evaluations should consider all the reasons a game might or might not be effective in a particular classroom, as well as what 'effective' in this context actually means. In any case, no matter how 'good' the game is shown to be, if no significant benefit is 'perceived', if teachers do not believe that it will reduce their daily workload or enhance student learning, if they fear it will compromise or undermine their usual classroom teaching, or if they are not confident in its pedagogical validity, DGBL is unlikely to become a feature of regular teaching practices.

Another set of reasons why DGBL has not obviously yet fulfilled its early promise centres on the fact that it is itself complex. As has been discussed, what actually constitutes DGBL is open to debate, with very different games being used with very different learners in very different contexts and for very different purposes. Another open question is whether DGBL is appropriate for typical learners, who are mostly well-served by existing pedagogical practices, or are better suited for specific groups of learners such as those who struggle in particular subjects or those who have disengaged (Holmes 2011).

Meanwhile, 'learning', which is after all the core aim, tends to be understood by many DGBL developers in simplistic terms. Rather than drawing on the learning sciences or education research, DGBL researchers and developers all too often assume that their personal experiences of learning and their limited knowledge of some education theory or psychology buzzwords (such as Vygotsky's 'zone of proximal development', 1978; or Csikszentmihályi's theory of 'flow', 1997) are sufficient to inform their approach to pedagogy – an assumption that should be challenged. Perhaps because they are usually enthusiastic digital game players and software developers, they too often tend to focus on the gameplay and the software development, those aspects of DGBL that perhaps they find most interesting, while the learning is more or less taken for granted. In any case, the rich history of learning sciences and education research is mostly ignored while learning is misunderstood "as an activity relatively invariant across people, subject areas, and educational objectives" (Dede 2011: 236).

For example, as already mentioned, much DGBL research focuses on the impact of gameplay on student motivation, without much real understanding of the impact of motivation or of gameplay on learning. As a second example, some DGBL research references somewhat unquestionably so-called individual 'learning styles' that have long been heavily criticised by learning sciences researchers (Krätzig and Arbuthnott 2006). And finally, much DGBL research focuses exclusively on immersive constructivist games, while dismissing games that have been designed to give learners opportunities for deliberate practice, despite repetition and practice repeatedly being shown to be a prerequisite for robust learning (Richey and Nokes-Malach 2015).

Design approaches to DGBL

DGBL has been researched from various perspectives, for example: mobile games-based learning (Koutromanos and Avraamidou 2014), students learning to make digital games (Kafai and Burke 2015), digital games used to help bridge the gap between school and parents (Holmes 2011), DGBL literacy (Burn 2016), and so-called brain training games (although it is worth noting that most brain training games have been shown not to transfer any cognitive benefits beyond playing the game itself, Melby-Lervåg and Hulme 2013). Here, however, the focus will be on three DGBL 'design approaches': games designed for entertainment and repurposed for learning, games designed for structured practice, and games designed for knowledge construction.

Entertainment games repurposed for learning

The first approach to DGBL that will briefly be reviewed involves the repurposing for the classroom of digital games that have been designed as entertainment. Examples of these so-called 'commercial-off-the-shelf' (COTS) games that have been used in classrooms include 'Myst', 'Spore', and 'Wii Play Motion' (there are many others). The fantasy computer game 'Myst' has been used as a stimulus in speaking and writing lessons for primary school students (Rylands 2010), the god game 'Spore' has been used to teach secondary school students about evolution (Schrader et al. 2016), while the 'Wii Play Motion' physical digital game has even been used to support the teaching of statistics to university students (Stansbury et al. 2014).

However, although each of these examples have reported notable successes, the use of COTS games in the classroom is far from straightforward. Even when teachers are experienced in using them, know how they are played, and how they might contribute to desired learning outcomes, they can be difficult to use effectively. Their content might not be relevant, such that it has to be squeezed into the curriculum. And, if it is relevant, it might not be accurate – these games have been designed to entertain and thus often liberally interpret their subject matter (for example, Schrader et al. 2016, found that Spore included too many misconceptions about evolution for it to be especially useful in science classrooms).

Games designed for structured practice

Other DGBL has been designed specifically for use in classrooms, the most common of which usually aim to encourage the structured practice of previously learned educational content. These so-called 'edutainment' or 'drill and practice' games (Shuler 2012), such as the 'Maths Blaster' and 'Reader Rabbit' series, became very popular in many classrooms and family homes during the 1980s and the approach remains common (Takeuchi and Vaala 2014).

In this type of DGBL, the learning opportunity, which is often nothing more than answering a worksheet-style task in a digital context, often occurs *before* the game's gameplay. The playful opportunity is then the reward for a correct response and is usually unrelated to the learning (for example Neurogames, Kahn, and Reed 2012, in which an animated squirrel is the reward for correctly answering a mathematics question). This is a behaviourist approach to learning with *delayed* rewards. In rather more sophisticated structured practice DGBL, the learning takes place *during* the gameplay but still that gameplay is usually but not always unrelated to the learning (for example Timez Attack, West 2010, in which mathematics questions appear as unrelated obstacles to be overcome in order to progress within a virtual battle). This is a behaviourist approach to learning with more *immediate* rewards.

In fact, it is because these structured practice games build upon a behaviourist pedagogy that they are often pejoratively known as 'chocolate-covered broccoli', an attempt to conceal the 'unpleasant but nutritional' learning with the sugary coating of gameplay (Bruckman 1999). Nonetheless, although it is probably true to say that structured practice DGBL games too often "combine the entertainment value of a bad lecture with the educational value of a bad game" (Squire and Jenkins 2003: 8), the evidence is that structured practice games can have a useful role in the classroom because they can encourage the 'deliberate practice' necessary for robust learning (Karpicke 2012).

This use of game-like rewards in response to correct answers has more recently been called a gamified approach to learning. More generally, 'gamification' is "the use of game design elements in non-game contexts..., a software service layer of reward and reputation systems with points, badges, levels and leader boards" (Deterding et al. 2011: 1). The reward mechanisms of entertainment games (rather than the games themselves or their gameplay) are repurposed to heighten the extrinsic motivation of those involved in a range of activities from exercise to shopping (although, in so doing, this might have a negative impact on intrinsic motivation, Mekler et al. 2013). Points, badges, levels and leader boards (PBL) aim to build upon the positive impact of social competition. For example, increasing levels of challenge can help to encourage the player to continue playing, a key aim being to 'level up' during gameplay to higher and higher levels, with leader boards enabling players to see when they have achieved a competitive score and letting other players know that they have done so. From a more pedagogical perspective, they can also provide players a clear medium-term goal, which is known to support learning.

Incidentally, while PBL are used in many educational apps and online DGBL, a more holistic and sophisticated approach to the gamification of learning, using games-based quests and teamwork rather than the more mechanical PBL, has been developed for use in whole classrooms (World of Classcraft, Young 2013) and applied to an entire school to create highly immersive, game-like learning experiences (Quest to Learn, Shute and Torres 2012).

Games designed for knowledge construction

Interestingly, despite the advocacy, there are probably fewer examples of DGBL designed to support the active construction of knowledge than there are of DGBL designed to support the practice and consolidation of knowledge. And for those that do exist, the aim is most often to raise awareness of issues outside core curricula rather than to learn specific curriculum content. For example, a recent review identified eighteen different digital games all of which had been designed to raise awareness and promote behaviours for individuals who have diabetes (to encourage self-management, to promote sensible eating habits, and to increase the frequency of blood glucose checking) (Lazem et al. 2015). Other similar games (Romero et al. 2015) focus on promoting the so-called ‘21st century skills’ (including communication, collaboration and problem solving) which have long been known to be essential for all learners.

Something that often distinguishes DGBL designed for knowledge construction is the intimate relationship between the learning and the gameplay. Rather than the learning taking place before or during often unrelated gameplay (as with games designed for structured practice in which the gameplay is an immediate or delayed reward for the successful review of pre-learned knowledge), in games designed for knowledge construction the learning is *immersed in* and takes place *through* the gameplay thus exploiting the exploratory nature of many digital games. Learning *through* the gameplay situates the learning content in the virtual context of the digital game's world and it does so by means of authentic gameplay tasks.

This might be considered a more constructivist approach. It aims to exploit the various family resemblances of entertainment digital games in order to provide learners with opportunities to construct knowledge about specific educational content. For example, to win the game you need to cross the chasm, to cross the chasm you need to build a bridge, to build the bridge you need to learn about Archimedes' 'law of the lever'. In such a game, players learn the physics in order to play and win the game, they do not play the game in order to learn the physics, even though that is the aim of the educational game developer. Arranging for the learning to take place *through* the digital gameplay (a process also known as 'intrinsic integration', Kafai 1996) also effectively situates that learning in a context potentially familiar to the learner or at least one to which they can relate.

An early example of DGBL designed for knowledge construction was 'Global Conflicts: Palestine' (Egenfeldt-Nelson 2006), an immersive first-person game. In this DGBL the student plays a freelance journalist new to Jerusalem in Israel who is tasked with gathering information about the Israel/Palestine conflict by undertaking various missions and speaking with the locals. A second example is 'Frequency 1550' (Huizenga et al. 2009), a mobile game developed to help students in their first year of secondary school to learn about 15th century Amsterdam by undertaking assignments around the medieval streets in order to discover various historical information, the gameplay goal being to gain citizenship of the city. A third notable example is 'The Mystery of Taiga River' (Barab 2013), which takes place in a 3D immersive world in which students are environmental scientists undertaking an investigation with the aim of saving a park where ecological problems are causing all the fish to die. The game provides students with opportunities to explore issues of water quality (pH, dissolved oxygen and nutrient run-off) and how to adopt a structured approach to weighing evidence and making valid decisions.

DGBL and educational practice

The various practical challenges around integrating DGBL successfully in classrooms have already been mentioned. However, an often forgotten issue still needs to be addressed. While classrooms are fundamentally social environments, all too often DGBL is designed to engage learners as separate individuals. Typically, each student sits with their own digital screen (desktop, laptop or tablet), playing their own bounded digital game (there are relatively few multiplayer DGBL), and while there is often a classroom hubbub it is unclear whether or how these fractured and unstructured conversations are contributing to the student's learning.

In short, the game developer has focused on the software and has not fully addressed the social interactions that might occur around the game, what has been called the game's 'affinity space' (Gee 2004b), and has not leveraged important socio-constructivist opportunities for learning. Indeed, research into a prototype platform game designed to be played by individual children (who were low-attaining in mathematics) has revealed that the game was most useful when, in addition to supporting individual learning, it was also a focal point for social interaction between the children and between the children and the supporting adults (Holmes 2013). Those children who sat next to each other as they played talked about what they were trying to achieve in the game, swapped hints about the gameplay, and discussed how best to answer the mathematical problems. In other words, by encouraging a dialogue about the mathematics embedded in the game and by providing a pedagogically robust scaffold for that conversation, the game helped the children to construct and enhance their own mathematical understanding. Their collaboration and conversations around the game also provided the adults with opportunities to recognise individual needs so that they could give appropriate and timely guidance.

Gee (2011) formalises the distinction between the game as software, what he refers to as the 'small g game', and the social system of interactions that players engage in around the game, what he refers to as the 'Big G Game'. This meta level includes opportunities for dialogue with peers, for making connections to other aspects of the lesson being taught and for interactions extended beyond the classroom. The argument is that, while well-designed 'small g game' experiences involving solving complex problems can lead to learning, the ‘Big G Game’ “acts as a force multiplier on the impact potential of bounded game-play experiences” (Barab et al. 2013: 2) leading to deeper learning and enhancing transfer of that learning to the wider context. Accordingly, although developers all too often focus wholly on the individual bounded ‘game’, it is in fact the entire meta-level ‘Game’ that must be considered when developing, implementing or evaluating the impact of DGBL.

The DGBL mentioned earlier, ‘The Mystery of Taiga River’, developed over more than a decade (Barab et al. 2013), exemplifies a ‘Big G Game’ approach. Beyond the game itself, ‘Taiga River’ involves a learning platform, on which the game is hosted and which connects several games together to provide a learning journey, a data and analytics dashboard to allow teachers and students to inspect and learn from their learning trajectories, social network functionality which might enable discussion and reflection, and a gamification layer of carefully designed extrinsic rewards. It is this ‘Big G’ infrastructure that contextualizes the ‘small g game’ into a flexible affinity space connected with the real-world and extending beyond the classroom.

However, although ‘The Mystery of Taiga River’ and its ‘Big G’ approach is self-evidently engaging and powerful, it is not without issues. To begin with, it has required many thousands of hours of development time, and hence has probably been relatively costly, yet it addresses only a very small part of the science curriculum (although the underlying game engine has been designed so that the game is modifiable for other curriculum areas). It can also be time consuming to implement in classrooms. It requires teachers to devote some hours to understanding both the ‘game’ and the ‘Game’ and how they might best be used to complement their teaching and to address their intended learning outcomes. And it can require a significant amount of student time (learning how to play the game, the gameplay itself and the important post-game debriefing, helping the students to make connections back to other classroom learning), which can be out of balance with the relative importance of this small area of the science curriculum.

There are various other issues that impact on the design and implementation of effective DGBL in educational practice. Picking again on the sophisticated example of 'Taiga River' (if only to emphasise quite how difficult the DGBL project actually is), what happens if the students who are asked to engage with the game either do not like this particular gameplay, or prefer to protect game playing from the classroom (Facer et al. 2003), or do not like playing digital games much at all? Just because the designers have designed a game that they, as experienced gamers, find engaging, it should not be assumed that their enthusiasm will be shared by all students. For example, the reality is that many students prefer casual games (like 'Angry Birds') to adventure games (like 'Tomb Raider'), and they might be disadvantaged if an adventure game becomes the only opportunity to learn a specific area of curriculum content.

A last issue to be mentioned here refers to the fact that games like 'Taiga River' prioritise knowledge construction opportunities, exploration and discovery, effectively to the exclusion of structured practice opportunities. This begs the question whether, by being so critical of games routinely dismissed as chocolate-covered broccoli, a necessary part of the learning process is being overlooked: "it is not that behaviourism, or constructivism, is wrong; indeed, they are both right in their core ideas but they are incomplete and, on their own, make an inadequate basis for design" (Burkhardt 2006: 131).

DGBL and the learning sciences

A refrain in this chapter has been the complexity that surrounds digital games and how they might be used in and beyond classrooms, a challenge that is only amplified when the implications of the learning sciences on DGBL are considered (Connolly et al. 2014). Learning has been a core focus of psychological and neuroscientific research since at least Ebbinghaus's experiments on memory (1913). Since that time, research into the cognitive and social psychology of learning and the neuroscience of learning has been extensive and has involved constructs as wide ranging as executive function, metacognition, self-regulation, affect and social cognition. Here, having acknowledged that there have been numerous studies involving DGBL and each of these concepts, the earlier discussions of structured practice and motivation will be concluded from a learning sciences perspective.

DGBL, structured practice and the learning sciences

As has been noted, DGBL games that have been designed for knowledge construction tend to be more engaging, because they are more like immersive entertainment digital games, which is perhaps why they are frequently preferred by researchers and developers over games designed for structured practice. However, as has also been suggested, enabling the construction of knowledge on its own is insufficient for robust learning, and deliberate retrieval practice is also a prerequisite (Rummel et al. 2016). Robust learning involves "deep, connected and comprehensive knowledge about a domain that lasts over time, accelerates future learning, [and] transfers easily to new situations" (Mazziotti et al., 2015: 2). It comprises three closely coupled types of knowledge: factual knowledge (knowing 'what'), procedural knowledge (knowing 'how') and conceptual knowledge (understanding 'why'); and it includes three closely coupled processes: knowledge and skills acquisition, consolidation and storage, and recall (mostly conscious recall, for declarative knowledge, and often unconscious recall, for skills).

The often ignored reality in much DGBL research and development is that, while constructivist opportunities might be more engaging and is essential for the acquisition of conceptual knowledge, deliberate practice is also necessary for being able to consolidate and store (encode into long-term memory) and then later recall and apply almost all types of knowledge. Put another way, while immersive games-based experiences might enable students to construct an in-depth understanding of a particular topic, a process which is a fundamental component of learning, if they do not also have opportunities to practise what they have learned, they are likely soon to forget it. The importance of structured deliberate practice for learning is also supported by neuroscience research, which has identified various possible neural mechanisms for learning (such as synaptic plasticity, Löwel and Singer 1992; and axonal myelination, Mabbott et al. 2009), each of which requires some form of repeated activity.

The design-based research mentioned earlier of a platform game to support children low-attaining in mathematics set out to build on this psychology and neuroscience research by combining knowledge construction and structured practice in the one DGBL (Holmes 2013). This game provided guided constructivist opportunities, problems that could only be solved by thinking mathematically, in which the child was able to discover and construct their own mathematical knowledge; which were integrated with behaviourist opportunities, repeated practice to help the child encode their newly-constructed mathematical knowledge into long-term memory, to help ensure that that knowledge became automatic and without error, the aim being to free their working memory for other cognitive demands.

DGBL, motivation and the learning sciences

As noted earlier, the relationship between DGBL, motivation and learning is complex. However, the learning sciences provide some insight. For example, cognitive neuroscience suggests that our brain's response to rewards in games increases when players are in the presence of their peers (Chein et al. 2011), which refers back to our earlier discussion of the impact on DGBL of social context. In addition, parallel research suggests that players actually respond to a competitor's loss as if it were their own gain (Howard-Jones et al. 2010), which emphasises the potential impact of competition on enjoyment and self-efficacy.

In the brain, motivation is associated with the generation of dopamine, a neurotransmitter which also has links to learning. Within limits, the larger the reward, the larger the motivational signal and the bigger the potential impact on learning. However, Howard-Jones (2011) explains that the anticipation of rewards can be as important or more important than the reward itself, and that perhaps counter-intuitively the use of uncertain rewards, anticipated rewards that might or might not be given depending on chance, actually increases the overall dopamine release. This additional dopamine helps explain why uncertain rewards can be enticing (a fact not lost on the developers of mainstream digital games) and provides a potential neurobiological explanation for our attraction to games involving an element of chance (consider, for example, sporting fixtures where the teams are well-matched and thus the result uncertain, which are typically much more engaging than one-sided games). Of particular importance, anticipation of an uncertain reward is also likely to generate an extended window of enhanced attention, an opportune teachable moment during which students are especially receptive to encoding long-term memories, which the design of DGBL or its use in classrooms might exploit (Holmes et al. 2013).

However, although children appear to prefer the inclusion of chance-based uncertainty in learning tasks (Howard-Jones and Demetriou 2009), the use of uncertain rewards is counter to much educational practice. In classrooms and other educational contexts, teacher consistency tends to be valued and uncertain rewards are usually thought to be unfair and de-motivating, which is perhaps why chance-based or uncertain rewards are rarely featured in DGBL. Nevertheless, the research briefly reviewed here demonstrates a clear link between increased motivation and improved deep learning in response to chance, such that researchers and developers should consider using uncertain rewards more often in DGBL.

Coda

Despite all of the research, advocacy and hype over thirty-five years, DGBL remains relatively uncommon in classrooms – and, for some, using digital games to support formal learning remains controversial. Nevertheless, there are many examples of ‘well-designed' DGBL that have been shown capable of supporting 'some' aspects of learning in 'some' contexts. However, as has been argued in this chapter, if DGBL is to realise its demonstrable potential, a clearer understanding of digital games, learning and classroom practices in all their complexity is necessary. For example, researchers and developers need to consider combining core approaches to DGBL (games designed to support structured practice and games designed to support knowledge construction), rather than prioritising one to the exclusion of the other. They need to draw on insights from the learning sciences, by working with learning scientists, and move beyond simplistic understandings of what it actually means to learn and what conditions best support learning (for example, recognising the importance of retrieval practice and the impact of uncertain rewards on learning). And, if DGBL is to be seen by teachers as a useful complement to their usual teaching practices, DGBL designers and researchers also need to consider and accommodate the 'Big G' (the affinity space and the classroom context), in addition to the 'small g' of educational games. Only once all that is in place, might DGBL be widely adopted within two to three years.

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