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Press Play for Learning: A Framework to Guide Serious Computer Game Use in the Classroom

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Abstract: Computer gaming is a global phenomenon and there has been rapid growth in 'serious' games for learning. An emergent body of evidence demonstrates how serious games can be used in primary and secondary school classrooms. Despite the popularity of serious games and their pedagogical potential, there are few specialised frameworks to guide K-12 teachers in choosing and using serious games. The purpose of this paper is twofold. Firstly, we draw on recent research to provide an overview of the nature and uses of serious games, current knowledge about their learning efficacy, and the features that teachers should consider when choosing a game. Secondly, we provide a new, practical and comprehensive framework especially designed to guide teachers in making evidence-informed decisions about choosing and using serious games in their classrooms. This framework is organised according to the domains of learning, pedagogy, curriculum, assessment, and technical context.

Introduction

Computer gaming is a worldwide phenomenon, with growth in popularity driven by mobile device uptake, app proliferation and social media engagement (Bohyun, 2015). Globally, there are an estimated 1.4 billion people who play computer games (Spil Games, 2013), with the game market generating more than USD 99.6 billion in revenue in 2016, up 8.5% compared to 2015 (Newzoo, 2016). In Australia, it is estimated that 98% of households with children have video games, 90% of gamer parents play games with their children, and 35% of children have played games as part of the school curriculum (Brand & Todhunter, 2015). As a mode of technology-enhanced learning, 'serious games' (games designed specifically for educational purposes), have been available for several decades. These types of games have sought to harness the enormous popularity of recreational gaming for educative or training purposes (Connolly, Boyle, MacArthur, Hainey, & Boyle, 2012).

The potential of serious games to promote student engagement and deeper learning has attracted much interest. Many classroom teachers find themselves looking for new digital tools to supplement their pedagogical practice. Teachers may be understandably attracted by the marketing of educational games as a means of tapping into the digital interests of their students. There has been much speculation about the potential for serious games to facilitate learning. Serious games can provide the social and cultural context that can facilitate learning (Gee, 2003). In addition, they can offer valuable and frequent feedback to individual learners about their progress. Moreover, serious games have been described as ideally suited to 21st century learning, particularly as they require the development and use of cognitive flexibility and adaptability and other problem-solving skills (Ulicsak & Williamson, 2010).

While there is much debate regarding the beneficial and adverse effects of recreational gaming (e.g. Boyle, Connolly, & Hainey, 2011; Kovess-Masfety et al., 2016; Posso, 2016; Pujol et al., 2016), this paper concentrates on games for learning, with a specific focus on what K-12 teachers need to know about serious games in order to make evidence-informed decisions about their use in the classroom. There is also a growing recognition in the research literature that for a serious game to be effective in achieving learning outcomes, certain pedagogical, curriculum, and technical concerns must be considered along with the characteristics of students. While there are excellent literature reviews and meta-analyses on serious games (Boyle et al., 2016; Connolly et al., 2012; Kirkland, Ulicsak, & Harlington, 2010; Perrotta, Featherstone, Aston, & Houghton, 2013; Wouters, van Nimwegen, van Oostendorp, & van der Spek, 2013), this paper takes a more focused approach to outlining the range of specific issues that K-12 teachers need to consider to promote learning through the use of serious games in their classrooms.

The purpose of this paper is twofold. Firstly, we draw on recent research to provide an overview of the nature and uses of serious games, current knowledge about the effectiveness of serious games for learning, and the types of features that teachers should consider when choosing a game. Secondly, we draw on this literature, and specifically build on the work of Becker (2016), de Freitas and Oliver (2006), and Ulicsak and Williamson (2010), to provide a new, comprehensive and accessible framework designed to guide K-12 teachers in making evidence-informed decisions about choosing and using serious games in their classrooms. While there are detailed holistic models for understanding technology use in the classroom (for example, the SAMR and TPACK models [Puentedura, 2006, 2010]) and complicated conceptual ones designed for evaluation purposes (Mayer et al, 2014), we have chosen to organise the guiding questions in our framework according to the well-established knowledge domains of education: learning (learners); pedagogy; curriculum; and assessment. To further increase the utility of the framework's contribution we have also added the domain of technical context (including its ethical implications) to our framework. This is particularly important given the global networked nature of many serious games today.

What Are Serious Games?

Despite the amount of popular and scholarly interest in serious games, there is no consistent definition used in the field (Susi, Johannesson, & Backlund, 2007; Ulicsak & Williamson, 2010). Serious games are generally considered to be educational games that use digital technology and can be played on desktop computers and video game consoles (Susi et al., 2007), or on mobile computing devices such as tablets and smartphones. The term 'serious game' is often considered synonymous with a 'game for learning'; these generally have knowledge acquisition as their primary focus, although this is sometimes widened to include the acquisition of skills and changes in behaviour (Boyle et al., 2016). The terms 'educational games', 'educational or training simulation' and 'edutainment' are also used as alternative nomenclature (e.g., Alvarez & Djaouti, 2011). Serious games are specifically designed to combine a 'serious' (formal learning) purpose with an entertainment function (facilitated through gaming design elements), and include some of the characteristics of recreational computer games such as the capability to exercise (degrees of) autonomous action and navigation; challenge; competition; progression through levels of difficulty; time constraints; immediate feedback; ranks and rewards; and in some cases, opportunities for sociality, collaboration and user creation of content (Perrotta et al., 2013). Serious games have been extensively used in health, the defence industry, vocational education and employment training, and commerce (DeSmet et al., 2014; Susi et al., 2007; Ulicsak &

Williamson, 2010). Serious games should be differentiated from 'gamification', which is a term that refers to the use of gaming design elements, such as the ones mentioned above, in non-game contexts such as e-learning (Deterding, Dixon, Khaled, & Nacke, 2011; Kapp, 2012).

Like recreational computer games, serious games can also be categorised into different genres based on game design elements. While there is a lack of consistency in the categorisation systems (Ke, 2009), some main types of games include: platform or arcade games (e.g., Super Mario Bros-style games); strategy and logic (puzzle) games; role playing games (where the player takes on a character in a virtual world); realistic simulations (e.g., flight simulations); first-person shooter (where the player sees the game through the eyes of the protagonist); and god games where the player can control an artificial world (e.g. Sims-style games) (Smith & Du'Mont, 2009). There are 2D and 3D versions of these games available for desktop PCs and mobile devices. Increasingly, these types of games are becoming commercially available for new immersive virtual and augmented reality technologies, mediated through head-mounted displays such as Oculus Rift™, HTC Vive™, PlayStation VR™, and in the near future, Microsoft HoloLens™.

Serious games can be available as 'commercial off-the-shelf' (COTS) products, and those designed for a particular educational or training contexts. In addition, there are more hybrid uses for COTS recreational games for educational purposes; for example, Minecraft™ has been used in classroom for learning mathematical concepts (Bos, Wilder, Cook, & O'Donnell, 2014) even though it was not purposively designed as a serious game. In addition, there are a number of game engines that allow teachers and students with some coding expertise to create their own games for leisure and learning (for a case study see Pelletier, 2009).

Serious games can use the internet in different ways. For example, some games only require the internet for a one-off download and any future updates. Other games require ongoing internet connection to support game features, for example those integrated into social media. Certain games are 'download once' and run on individual devices while others can be networked in a closed environment (for example, a school intranet). There are also games that involve a constant internet connection to other players and games resources across the world. Some of these games are known as massively multiplayer online game (MMOG) which are hosted by commercial companies and open to a global player base without restriction. In these types of games, teachers should consider safety and duty of care implications.

What Do We Know About Learners and Serious Games?

Learners in K-12 classrooms in Australia are likely to be somewhat familiar with playing games at home and on mobile devices (Brand & Todhunter, 2015). In 2014-15, 97% of Australian households with children under 15 years of age had access to the internet, with an average of seven different devices being available for this purpose (Australian Bureau of Statistics, 2016). Furthermore, 99% of children aged between 15 and 17 years report that they typically spend 18 hours per week on the internet for personal use, with this representing the highest proportion of users and rate of use in the Australian population (Australian Bureau of Statistics, 2016). For children aged under 15 years, the internet was usually accessed at home for educational purposes (Australian Bureau of Statistics, 2013). While digital inclusion is increasing in Australia, a digital divide still exists, particularly in terms of connectivity and geography (Thomas, Barraket, Ewing, MacDonald, Mundell, & Tucker, 2016).

An estimated 77% of Australian children under 18 years of age play computer games, with average daily gameplay exhibiting gendered patterns: females aged 5-14 years play around 70 minutes daily while those 15-24 years of age play around 80 minutes; and males 5-14 years play around 110 minutes daily while those 15-24 years play around 140 minutes daily (Brand & Todhunter, 2015). This aligns with international research that has shown that video games are likely to be used daily by at least 60% of children between the ages of 8 and 18 years (Rideout, Foehr, & Roberts, 2010).

Despite the statistics about online use and gaming, making assumptions that all learners are 'digital natives' (Prensky, 2001) is unwise. The digital native discourse posits that students who have grown up with digital media display developmental differences in cognition, which is explained via neuroplasticity, and hence they learn differently to previous generations (Thompson, 2013). Although there is no generally accepted profile of the digital native as a learner, they are often assumed to prefer a fast-paced learning environment, along with nonlinear processing of information, multitasking, and collaborative learning (Thompson, 2013). The notion of the 'digital native' generation has gained much popularity and influence in the popular press and in the teaching profession, however there is little research evidence to support this idea of a specific type of young person or learner (Smith, Skrbis, & Western, 2013; Thompson, 2013). Instead, a diversity of technology skills and preferences has been shown to exist within this group (Chandler, 2013; Jones, Ramanau, Cross, & Healing, 2010; Kennedy, Judd, Dalgarno, & Waycott, 2010; Thompson, 2013). Therefore, teachers should not assume that K-12 students will intuitively know how to use digital technology, particularly for effective learning, either in or outside of the classroom. Indeed, Chandler (2013) found that Australian upper primary students are more likely to be introduced to new media, which can include serious games, at school than elsewhere, and the amount and type of experience relevant to engaging with this media varies greatly among students. The onus is therefore on schools to ensure that students develop and refine their digital literacy for effective learning both in and out of school (Wang, Hsu, Campbell, Coster & Longhurst, 2014).

What Do We Know About Learning and Serious Games?

While many students might enjoy playing serious games, teachers will be more concerned about the efficacy of these games as pedagogical tools to enhance learning. There are several decades of research on serious games, however rigorously designed empirical studies that have investigated the effectiveness of serious games in learning are limited in number (Boyle, Connolly, & Hainey, 2011; Girard, Ecalle & Magnan, 2013; Boyle et al., 2016). For example, Connolly et al. (2012) abandoned their plan to conduct a meta-analysis regarding the outcomes of computer games and serious games due to the diversity of the phenomena studied and the theoretical models and research methods that have been used, as well as the lack of published randomised control trials (often considered the gold standard in research). Furthermore, there are a relative lack of studies related to serious games in K-12 education contexts, and so findings in the area should be treated with caution.

Connolly et al. (2012), in their systematic review of 61 studies of serious games with users 14 years of age or older, concluded that generally these games increase motivation, but not necessarily knowledge acquisition. Looking at later studies of serious games for the same age range, Boyle et al. (2016) found a similar pattern of results: serious games are reported to increase students' motivation and engagement in the learning task, but the learning outcomes remain unclear due to disparity in what types of learning outcomes are being assessed and how this is done. In their review of the literature, Perrotta et al. (2013) also found there was

often reference to academic outcomes in studies but little detail which specified what these were and how they were measured. Kirkland, Ulicsak, and Harlington (2010) concluded that video games (including serious games) can have a positive effect on motivation and engagement as well as problem solving skills, but that the extent of the maintenance of these gains over time was unclear. In contrast, one meta-analysis of 39 studies found that serious games produced greater learning gains and better retention than conventional instruction methods, but were less motivating (Wouters et al., 2013).

Providing a possible explanation for the inconsistencies in the findings across systematic and meta-analysis reviews, Wouters et al. (2013) found that learning from serious games was enhanced through other instructional and contextual features of the learning situation, such as the use of supplementary teaching methods, multiple training sessions, and group work. This is supported by Bober (2010, p. 7) who points out that "it is important to distinguish between learning directly from playing the game and learning from teacher-led activities associated with the game". Likewise, Ulicsak and Williamson (2010) suggest that the nature of the game, the circumstances under which it is played, and the type and level of involvement of the teacher will affect the learning outcomes.

While further, large-scale studies on the influence of gender and serious gaming are required, recent research highlighted gendered gameplay and learning preferences. For example, Tan et al. (2013) found that boys wanted more graphics and animations than girls, while Lowrie and Jorgensen's (2011) study of mathematics-based gaming indicated that girls prefer explorative play, but that there are no gender differences in preferences for problem solving or social modes of interaction within gameplay. Girard, Ecalle & Magnan (2013) note that the gender and age of the learner, their stage of cognitive and emotional development, and their socio-economic status should all be accounted for in evaluating learning outcomes from serious games.

The equivocal nature of the findings surrounding the efficacy of serious games for learning are in part due to the emerging nature of the field, but also highlight the ongoing need for game developers to work with educators and researchers to produce robust studies focused on learning, learner attributes, and assessment (Perrotta et al., 2013), and that consider the effect of pedagogy on serious games' effectiveness for learning (Bober, 2010). This has led to recent theoretical work in mapping the relations between learning, 'game mechanics' and pedagogy (Arnab et al., 2013, 2015).

Teachers themselves have touched upon the complexity of understanding learning through serious games, with some expressing the view that students are sometimes unable to make the link between playing the game and wider learning objectives (Ulicsak & Williamson, 2010). Despite this concern, studies suggest that most teachers would like to use games in their classrooms (Ulicsak & Williamson, 2010; Williamson, 2009), with some Australian state education bureaucracies promoting serious games for learning (for example, Victorian Department of Education and Training, n.d.). Indeed, in a study of game-based learning in 38 primary and secondary schools across Victoria, participants reported observing many positive changes in both student and teacher behaviours as a result of implementing serious games in the classroom (DEECD, 2011). Students were observed to be clearly engaged in these serious games, and demonstrated the use and development of higher order cognitive processes, grew in confidence in technology skills, and displayed positive interactions with their peers (DEECD, 2011). Teachers were seen to offer more opportunities for students to take responsibility for their own learning and to engage in peer teaching (DEECD, 2011). Principals were impressed by their staffs' growing levels of confidence, skill, and interest in the application of serious games, and also by the positive influence of this on staff who were not directly involved in the study (DEECD, 2011). Unfortunately, no

objective indicators of learning outcomes – such as assessment results – were made available to provide further support for these observations.

In summary, while research on serious games and learning is currently a work-in-progress, the teaching profession's continued interest in the area warrants a closer exploration of factors to consider when evaluating the appropriateness of a serious game for classroom use.

What Features Should Teachers Look For in a Serious Game?

Dalgarno and Lee (2010), writing about 3D virtual learning environments (one environment used in serious games), explore the unique *affordances* of these environment for learning. Affordance refers to the properties or characteristics that determine the possible uses for a digital object or environment (Dalgarno & Lee, 2010). An adaption of this affordance framework provides one way of understanding what type of learning activities serious games might make possible. For instance, realistic simulations in training games provide a safe and secure environment that allows students to have experiences that in real life would be too dangerous or beyond their resources (Girard, Ecalle & Magnan, 2013; Mikropoulos & Natsis, 2011). Similarly, some types of serious games, particularly those that involve fully realised virtual worlds, allow for 'reification' or the ability to transform or represent abstract ideas beyond the realm of human experience through perceptible representations and interactions; for example, a player might be able to jump through a virtual microscope's eyepiece and into the drop of water and be the same relative size of micro-organisms that live there, and so explore this environment in order to complete learning puzzles (example adapted from Winn, 1993). Size dynamics, where players change their size or the size of virtual objects to experience micro or macro worlds, is a key affordance of virtual learning environments. It is therefore appropriate that when evaluating the suitability of some serious games, such as virtual worlds, that teachers consider the unique properties or affordances of the game and its relevance to intended learning outcomes.

In choosing serious games, teachers also need to consider a number of issues including: socially and developmentally appropriate content; curriculum-alignment; expense and/or licensing issues; the capacity to play the game over short time periods; the suitability of the game for the school's digital platform/s; and the likelihood of high levels of student engagement (Ulicsak & Williamson, 2010). The question of what features of a serious game make them attractive and enjoyable has been of interest to researchers for over three decades. Time, challenge, fantasy, and curiosity have been identified as fundamental components in computer games for children (Malone, 1982). More recently, referring to the literature and to interviews with expert game developers, researchers, and teachers, Bober (2010) concluded that the use of serious games in the classroom should be guided by design principles such as the use of fantasy and narrative to engage students in the learning experience; visual and aural stimulation through multimedia elements; having clear and meaningful goals with challenging and increasing levels of difficulty; incorporating timely feedback mechanisms with a focus on progression; providing students with opportunities to make decisions that influence the learning experience; and encouraging social interaction between learners by providing opportunities for collaboration and discussion – as part of the game, in the classroom and/or online. Finally, as analytics begin to be embedded into serious games, educators will be able to choose games that best allow them to 'harvest' data on student learning behaviour within the game along with formative and summative assessment information (Smith, Blackmore, & Nesbitt, 2015; Smith, Hickmott, Southgate, Bille, & Stephens, 2016).

A Framework to Guide Teachers in Choosing and Using Serious Games in K-12 Classrooms

Ulicsak and Williamson (2010) suggest that the specificity of educational contexts means that there are no hard and fast rules around how to use serious games to support learning. However, research has pointed to the importance of pedagogical support in increasing the efficacy of these games (Bober, 2010; Wouters et al., 2013). Therefore, while teachers do need to exercise flexibility and professional judgement in their selection and use of serious games, we argue that there are a key set of questions teachers can ask when evaluating serious games for classroom use. There are a number of frameworks developed for educators around serious games. For example, while Becker (2016) provides a wide-ranging set of very different models for understanding serious game use for teachers, she does not provide one synthesised guide that teachers might use to inform decision-making. Earlier frameworks or sets of questions from de Freitas and Oliver (2006) and Ulicsak and Williamson (2010) are more focused and accessible, but do not address contemporary aspects of game use in classrooms such as the Bring Your Own Device (BYOD) trend or online gaming. We have however built on the work of these authors to develop a new, comprehensive framework for teachers to use when choosing and using serious games in their K-12 classrooms (see Fig. 1).

Our framework is grounded in established knowledge domains in the field of education (Alexander, 2008; Bernstein, 1975, 1990). These domains are (a) the *learner* and how they learn based on their developmental stage, individual needs and motivations, sociocultural background and experience in gaming; (b) *pedagogy* including planning of learning activities, teaching strategies, and the evaluation of the effectiveness of the teaching approach; (c) *curriculum* or what is being learnt and the various ways of knowing, encountering and investigating this; and, (d) *assessment* or the formative and summative evaluation of how and when students meet learning outcomes; and, (e) *technical context* which includes platforms, connectivity infrastructure, and expertise in the school to support serious game use and content creation (where applicable).

The inter-relatedness of these domains is well documented in educational research (Alexander, 2008). Teachers should consider the domains, and the guiding questions within them, as part of an iterative process when making decisions about the use of serious games in the classroom. For example, the utility of a particular game may be determined in part by whether the teacher's preference is for group work or individual tasks for learning, and the attributes and affordance of the game in fulfilling this pedagogical imperative. Furthermore, these factors will be influenced by a teacher's understanding of the developmental differences for individual learners in their class and, for example, how other related gameplay or activities that are external to the game might scaffold students towards deeper learning.

A teacher's expert knowledge of the learners in their class is critical to the successful implementation of a serious game. Students' self-evaluation of game play experience and skill may or may not be accurate or relevant to a particular game, and so teachers will need to develop ways to gauge students' gameplay skills and identify ways to support those students in bringing their gameplay up to a standard that allows them to maximise their learning from a serious game. Conversely, teachers also need to understand gameplay so that they can assess whether students will be sufficiently challenged by the game or if other learning activities outside of the game are required to extend learning. Teachers should also consider whether the whole game or only a section is relevant to the learning objectives, and how this might affect the time and guidance required to reach the point where students can play independently.

Pedagogical and curriculum-related decisions include the timing and sequencing of the game in the lesson or unit of work. This involves determining whether specified levels of the game are practised to a certain standard, or if ongoing progress throughout the game is expected in subsequent lessons, as well as considering if the game can and should be practiced outside class time. Moreover, teachers should carefully consider how formative and summative assessment of learning outcomes and transfer of knowledge beyond the game will occur. Teachers should devise a brief evaluation mechanism to gauge the student experience of learning and engagement in the game, which will also be of use when reflecting on and evaluating the pedagogical approach. All of these decisions will be affected by the technical context, the curriculum priorities, and the assessment structure of the learning situation.

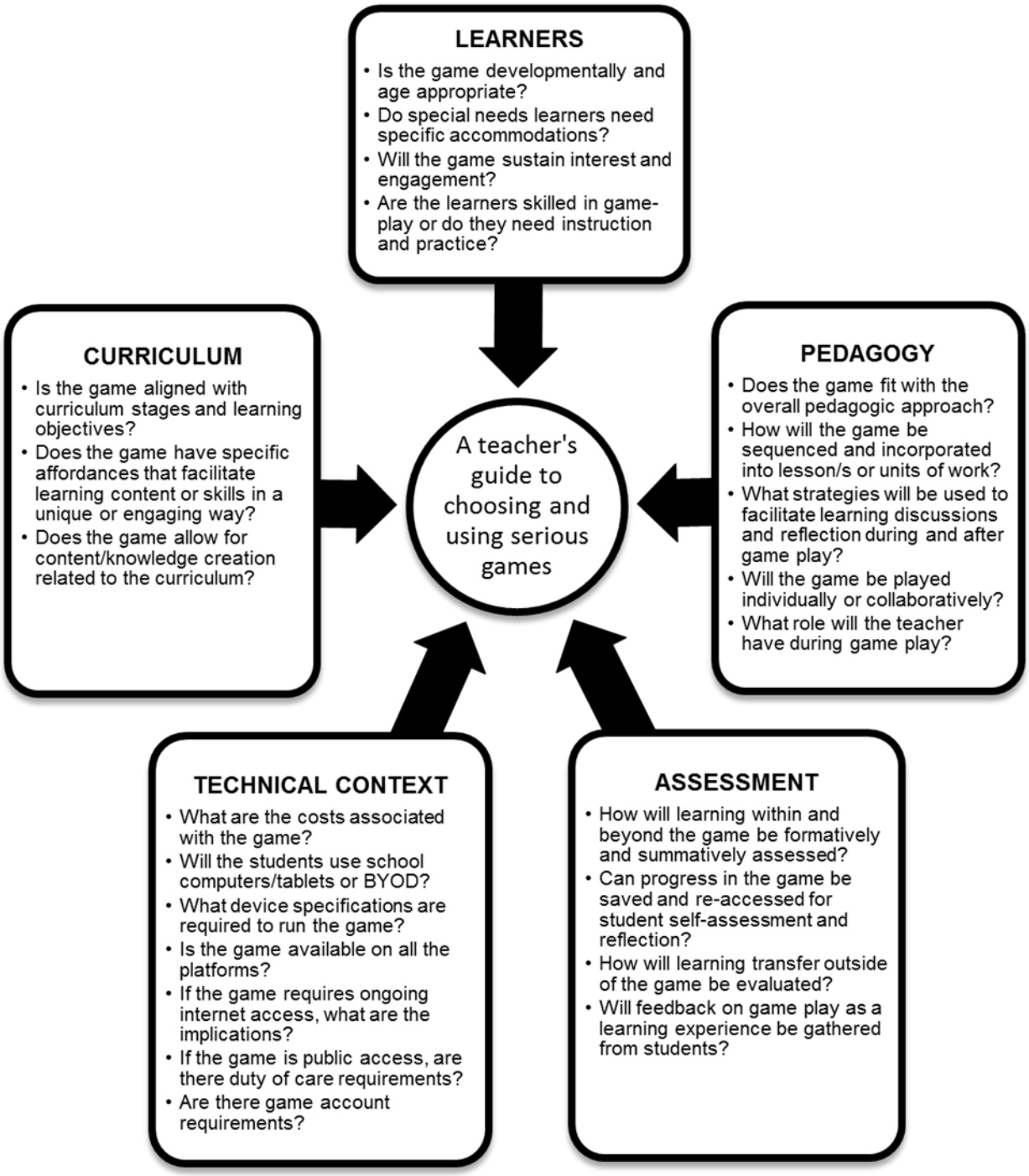

Figure 1. A Framework to Guide Teachers in Using Serious Games in K-12 Classrooms.

Careful preparation to maximise the game's use within the learning context is a priority, and is likely to require the teacher to have reasonably extensive experience of the game before implementing it in the classroom. Familiarity with the game will also increase the teacher's ability to identify and deal with any problems that arise during play, such as those relating to game-related problem-solving or technical glitches. However, it would be wise to have a contingency plan that can be quickly and easily implemented, either for individual students or the class as a whole, if a technical problem arises and game play cannot proceed as planned.

There are a number of key technical and practical issues that must be addressed. Financial considerations include the cost of the game, licensing fees, and the expense of purchasing supplementary content. Teachers should establish hardware availability and the specifications required to run the game, especially if it is a 'Bring Your Own Device' (BYOD) environment, where there can be great variability in the quality and functionality of hardware (Adhikari, Mathrani, & Parsons, 2015). It is especially important in a BYOD environment to make sure that the game is available for a variety of platforms (iOS and Android, for example). If the game requires ongoing internet access, there will be connectivity and security issues to consider. For example, will the school's bandwidth be adequate to run the game? Will the school's network or firewall block access to the game? If it is a public access game, such as if students are in a massively multiplayer online game (MMOG), teachers would need to undertake a safety and risk assessment and determine their duty of care responsibilities. The account settings of games raise not only technical issues (for example, will students need an individual email address to start an account?) but ethical concerns regarding the privacy of data (Chung & Grimes, 2006; Southgate, Smith, & Cheers, 2016). Finally, if games include advertising material, teachers will need to ascertain the appropriateness of this content, how much time it might take away from learning, and its potential to distract from the task at hand.

Thus, before selecting and implementing a serious game in the classroom, we suggest that teachers need to be well prepared by knowing the players, the learning goals, the game and the game platform, how to maximise the game play, and how the game fits into the lesson and overall curriculum. In addition, technical, practical, safety and ethical issues are also key elements when making decisions about using serious games in K-12 classrooms.

Conclusion

There is growing evidence that K-12 teachers can use serious games in a variety of ways to enhance their students' motivation and learning outcomes. However, recent research suggests that the success of serious games in contributing to learning appears to be influenced by the teacher's knowledge of how to choose appropriate serious games for their students and how to implement them effectively in the classroom. This paper has presented a new comprehensive and accessible framework that can guide K-12 teachers in choosing and using serious games in their classrooms. As with all frameworks developed from research literature, the next step is to test its usefulness in actual classrooms in order to adapt and improve it. This framework is intended to encourage teachers to use serious games in an evidence-informed way to complement their existing pedagogical practice and build teacher confidence in using serious games, and increase student engagement and improve learning outcomes.

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