Are Games Effective Learning Tools? A Review of Educational Games
Author(s): Sara de Freitas
Source: *Journal of Educational Technology & Society*, Vol. 21, No. 2 (April 2018), pp. 74-84
Published by: International Forum of Educational Technology & Society
Stable URL: https://www.jstor.org/stable/26388380
Accessed: 04-09-2018 19:16 UTC

de Freitas, S. (2018). Are Games Effective Learning Tools? A Review of Educational Games. *Educational Technology & Society, 21* (2), 74–84.

Are Games Effective Learning Tools? A Review of Educational Games

Sara de Freitas
Birkbeck College, University of London, Malet Street, London, United Kingdom // sara@dcs.bbk.ac.uk

(Submitted December 7, 2016; Accepted January 9, 2017)

ABSTRACT

The literature around the use, efficacy and design of educational games and game-based learning approaches has been building up gradually and in phases, across different disciplines and in an ad hoc way. This has been problematic in a number of ways and resulted in fragmented literature and inconsistent referencing patterns between different sub-disciplines and countries. This is mainly because no distinct single-disciplinary perspective has emerged because of: the cross-disciplinary nature of educational games, a reliance on single-disciplinary contexts for studies, changing terminologies in different contexts and the use of multi-methodological approaches. Distinct perspectives from education science, game science, neuroscience and information science have deepened our understanding of play and games. This research has become more quantitative, rigorous and nuanced as a result of more studies focused upon therapeutic health applications of games, the serious games research movement and more efficacy and comparative studies that examine and quantify utility.

Keywords

Educational games, Serious games, Game science, Neuroscience and games

Introduction

Defining efficacy in educational contexts can be challenging due to the range of variables involved in different learning contexts. Additionally, there are disciplinary restraints that have traditionally meant that cross-disciplinary approaches to data collection and analysis have been broadly discouraged. However to understand education, and in particular questions around efficacy, necessarily we need to adopt more cross-disciplinary approaches. As an example, research emerging from education science is being supplemented by findings from computer science (e.g., interfaces and interactivity), neuroscience (e.g., brain function and activity) and information science (e.g., analytics and user-modelling). Notably these include findings from computer science which allow us to consider usability improvements and human-computer interactions (e.g., Barr et al., 2007), findings from neuroscience which provide a greater understanding of how games impact our brain plasticity (e.g., Bavelier et al., 2012; Kühn et al., 2011; Kühn et al., 2014) and approaches that use analytics in games as a replacement for assessment (e.g., Serrano-Laguna et al., 2012). Together, these findings help provide a broader understanding of how we can model learning experiences in digital, data-rich game environments, and tell us more about how we learn.

The review found that "game science" is emerging as a new term to replace "serious games" which has been a significant term for the game studies research community for the last ten years. Similar to "serious games", the new term aims to link game studies to a greater scientific capability which has the potential to help us model and better understand: the learning behaviours of individuals and groups in game environments, learning design through the metaphor of game design and how games and play work to help people learn.

Establishing the efficacy of games and learning is a complicated endeavour. It needs to be kept within a wider context of understanding how we learn. So how game science fits into the wider disciplinary framework is a critical consideration. When viewed from this educational perspective, the notion of "game science" is part of the field we might call, "education science" and due to its digital nature it is often placed within the sub-discipline of Technology-Enhanced Learning (TEL). However, clearly there is important work to be found across a range of different areas including: human-computer interaction (e.g., Barr et al., 2007), health education and research (e.g., Papastergiou, 2009), neuroscience research (e.g., Kühn et al., 2011; Colzato et al., 2013; Lewis, 2013; Kühn et al., 2014), and across other literature such as business and management (e.g., Pasin & Giroux, 2011), school education (e.g., Hainey et al., 2016), advertising and marketing (e.g., Terlutter & Capella, 2013), military training and simulations (e.g., Hassain et al., 2012), environmental awareness-raising (Rebolledo-Mendez et al., 2009), therapy training (Horne-Moyer et al., 2014), teacher training (e.g., Kenny & McDaniel, 2011) and emergency-response training (e.g., Chen et al., 2008). One challenge with the literature so scattered is that not all researchers acknowledge the breadth of the area and range of applications, and therefore miss vital academic contributions by looking too narrowly at the literature-base. The situation is exacerbated by rifts between US and European research in serious games and between simulation and games literatures, and often you can see researchers will completely ignore critical papers from one "side" of the Atlantic or the other leading

to misunderstandings and incomplete starting points. Despite a number of special issues on games crossing several fields, the continuation of fragmentation of the field has again happened with the split between researchers in serious games and the new area of "gamification". Gamification here is used to mean the application of elements of game-mechanics and/or game-design techniques. To attempt to bring the literatures closer together and to attempt to harmonize some of the terminology, this paper aims to map out the potential new ground for learning as evidenced in the sub-field of technology enhanced learning that defines game-based learning approaches.

To overcome these significant disciplinary challenges, this paper seeks to outline some of the major contributions of the field from different disciplines over time and synthesise these using an integrative approach to a broader education science perspective. The aim is to problematize the current scope of Education Studies and to reposition game science more critically within this educational context and perspective.

Methodology of literature review

This article has adopted a "grounded theory" approach used over a number of years to assess the main themes emerging from the fields that touch on educational games. The method used included a semi-systematic review process with a single-coder, wide literature searches across databases using keywords to collect high impact and cited articles and is supplemented with a journal hand-search. Keywords included educational games, serious games, learning games, web-based games and digital games. Once key texts were identified from the literature search, these were grouped into disciplinary perspectives. The emerging perspectives of education science, game science/studies, neuroscience and information science were distilled and key articles identified were included in this review.

The Review: A recent history of game science

Wave 1: What are games?

Some of the earliest work in the field of game science focused upon, changing definitions and nominations of educational games. For example, work that outlined classifications of games, typologies and ontologies was found in the early literature (e.g., Caillois & Barash, 1961; Sutton-Smith & Roberts, 1971). While the earlier work focused upon structuralist perspectives upon educational games as consistent with the trend for semiotics and structuralist analysis, the theme re-emerged later on in the more recent literature as a theme of consideration (e.g., Elverdam & Aarseth, 2007; Kamii & DeVries, 1980; Salen & Zimmerman, 2004). But the more consistent theme of poststructuralism and postmodernist perspectives necessarily focused more upon notions of play than structure also in line with constructivist and qualitative studies.

It is perhaps ironic that constructivist approaches to learning have become so associated with qualitative approaches as although the work does focus upon individual construction of meaning, the social constructivism of Vygotsky (1980) and others does propose learning in social groups as a central component of learning. But here a split between the American and other literatures can be noted as a de-emphasis of social learning and a greater focus upon Skinnerism and behaviourist approaches as consistent with the individualism and competition of the American ideal. The mode of bringing education theory together with an American individualist twist and its bringing into the paradigm of psychology jointly ensured that the more social focus emphasised by Russian theorist Vygotsky did not become the dominant discourse. The legacy of this can also be seen in the more general sparseness of social learning theory and was compounded by difficulties with researching and analysing group work, a trend that is partially being reversed in studies such as Star where collaboration rather than competition techniques are emerging (Star, 2015).

Wave 2: The serious games movement

Negative publicity around violence in games, in particular entertainment games have attracted popular attention. The robust evidence of games causing violence has overall been inconclusive (e.g., Elson & Ferguson, 2015) – but nonetheless the distinction between games for entertainment and games for non-entertainment was a major driver for why the "serious games movement" occurred in the early 2000s (Blumberg et al., 2013). However, once non-entertainment games could be demonstrably "taken seriously" for purposes such as military training and health education and therapy then the research field gained greater credibility.

Early "serious games" titles, such as America's Army, have set the bar high in terms of the budget ($33 million invested up until 2015 in all titles). Although small budgets next to entertainment games, (e.g., $265 million for Grand Theft Auto 5), America's Army is still considered one of the best exemplars of a serious game today. Having been first published in 2002, it has 13 million registered players who have played 260 million hours. Developed by the US Moves Institute to solve the recruitment problems of the US Army, unfortunately the game has proved to be more of an oddity than a trend. Few large budget serious games have been developed since 2002, and those that have been commissioned have not always enjoyed longevity of support once piloting phases have concluded, e.g., Code of Everand (Dunwell et al., 2014). During this period, although relatively disconnected from the mainstream games literature, the "serious games movement" did gain important contributions from game studies, such as a deeper understanding of the mechanisms of competition as a design component (Cagiltay et al., 2015), how to balance entertainment principles of fun with instructional design and the need to integrate teams of developers, writers and instructional designers.

Wave 3: Technology-enhanced learning perspectives: Out of the wilderness?

The next phase of focus upon educational games borrowed heavily from technology-enhanced learning approaches. There, a focus upon verification and validation of online learning and e-learning was leading to a wide range of comparative learning studies. Again studies were often lacking in robust methodologies, but were beginning to seek a more scientific basis for analysing the efficacy of learning techniques. This approach was driven-out of concerns about the quality of learning in online settings and studies were often more utility-focused. While the early studies had attempted to group games in typologies and genres, these studies focused upon comparisons with other e-learning formats and against traditional learning measures (e.g., Knight et al., 2010).

Out of this work, a movement to understand game design emerged, how could games be designed for different learning contexts? Could commercial off-the-shelf (COTS) games be used? These questions led to a range of studies of games in educational contexts and collections of case studies (e.g., Kim et al., 2009; Michael & Chen, 2005; Prensky, 2005; Shute et al., 2009). This phase of research was dominated by educational perspectives.

However, there were significant difficulties with uptake of games in educational contexts. As Simon Egenfeldt-Nielsen outlined in his thesis (Egenfeldt-Nielsen, 2005), games did not fit into the one-hour lessons, into the single disciplinary focus or into the single-teacher model of traditional learning. Games were disruptive, they demanded greater changes to the traditional delivery and infrastructure of education in schools, colleges and universities. Beyond traditional learning paradigms (see Table 1), game-based approaches required: cross-disciplinarity, longer class durations, mixed student groups, social learning and team-teaching models to come into place to really capitalise on the merits of the game and gameplay as learning approaches (de Freitas, 2014).

Four disciplinary perspectives from the literature

While it is difficult to be too prescriptive with the time periods, the research does seem to fall broadly into four broad disciplinary categories: education science including theory and practice studies and using elements of pedagogy and psychology, game science contextualised through technology enhanced learning, neuroscience that have focused upon brain-function and plasticity and information science-driven studies that focus more upon data analytics and behavioural modelling. The following sections outline these perspectives (see summary in Table 1):

Education science perspective on educational games

Major contributions to understanding learning formed early theoretical and developmental approaches to learning. Through understanding learning as cognitive and developmental sets of processes, theorists and educationalists, such as Jean Piaget, defined ages and stages of development associated with "normal patterns of development" (Piaget, 1971). But Piaget also understood the importance of play in learning (Piaget, 2013). Play has been a theme of the work around games necessarily, but has not been a well-understood aspect of learning. More recent play research by Jean Twenge and others shows how important and developmental play is to learning (e.g., Campbell & Twenge, 2015; Chudacoff, 2007; de Freitas, 2014; Gray, 2011; Twenge & Campbell, 2008).

In the light of the internet, broadened connectivity and mobile access to online educational content, there has been a de-emphasis on content and curriculum and a sharpened focus upon digital literacy and 21st century skills. Employability for the changing global employment market presents new needs for graduates and students (Harlow & Bowman, 2016). The move to a more utilitarian position, driven by education via web-based technologies and digitisation, has reworked how we deliver a university education and even challenged what the role of the university is (Sugden, 2013).

Table 1. Comparing the traditional, new learning and future learning approaches

Traditional paradigm of learning	New learning paradigm	Future learning
Curriculum-based pedagogy	Challenge and activity-led learning	Student developed pedagogy
Tutor-led learning delivery	Peer-focused interactions	Artificial Intelligence (AI) scaffolded learning
Classroom and lecture hall focus	Any-time, anywhere learning	Seamless lifelong learning
Summative assessments	Formative assessment / Peer assessment	No assessments / levelling, points and awards
Age and stage	Competency and personalised learning	Unique learning patterns
Text-focused	Multimedia usage	Adaptive learning
Traditional curriculum e.g., literacy and numeracy	New curriculum e.g., 21st century skills	Hidden curriculum e.g. personalised skills and cognition training
Core curriculum	Work readiness	Blended work and learning

In the author's recent work, she articulates this disruption as a "new learning" paradigm. One that focuses upon problem-, challenge- and active pedagogy, peer learning and is competency-based and personalised (de Freitas, 2014). This differs from the traditional modes of curriculum-based and tutor-led approaches. With the work on games we can begin to see the rudiments of what the author calls a "future learning'" paradigm, which advances to student-led approaches where adaptive learning is scaffolded through AI bots, assessment gives way to in-built levelling-up and the curriculum is hidden (See Table 1).

Game science perspective upon educational games

One of the main stated inhibitors to uptake of educational games and approaches was the lack of robust scientific and evidence-based research. The first randomised and pragmatic randomised controlled trials (RCTs/PCTs) started in the late 2000s. One of the early trials was undertaken by Knight et al. (2010), focusing upon a comparison between traditional and game-based approaches in emergency response training. Arnab et al. undertook an RCT which considered a serious game in a classroom setting. Miller and Robertson undertook an RCT on educational benefits of games consoles in classrooms (Miller & Robertson, 2011). While Star considered a randomised control trial for gamification in StarQuest to identify cooperative and competitive design elements in university students (Star, 2015). Arbogast et al. (2014) were examining the use of an educational game for road crossing in their recent study.

Unsurprisingly most recently RCTs involving games have focused upon health and medical conditions including patients with weight conditions (e.g., Ahola et al., 2013; Maddison et al., 2011; Siervo et al., 2013; Straker et al., 2011; Straker et al., 2013). Fung et al. (2012) considered the use of the Wii Fit for knee rehabilitation. Foss et al. (2013) used their randomised control trial to discover effective use of the i-Bit which is a novel binocular device which uses games and videos to improve patients with a lazy eye. Picherri et al. (2012) looked at the impact of a dance game upon gait. Another popular area for study was the impact of games upon the elderly. An interesting study by Nouchi et al. (2012) explored the positive impact on executive and processing speeds on the elderly of brain training games in their study. While Mayas et al. (2014) explored the plasticity of the brain in the elderly after non-violent game play. A study on Wii Fit games for patient's living with Parkinson's disease was undertaken recently by Pompeu et al. (2012); and one looking at improvements from gameplay with Diabetes sufferers (Kempf & Martin, 2013). Allam et al. (2015) in their RCT on gamification in an online intervention for Rheumatoid Arthritis Patients found that "physical activity increased over time for patients having access to social support sections plus gaming (unstandardised beta coefficient $\beta = 3.39$, $p = .02$)." Patients were also more empowered and used services less as a result.

In addition to more quantitative studies such as RCTs/PCTs, meta reviews have offered important research contributions to overcoming the prevalence of different disciplinary perspectives. Often these reviews have been

cross-disciplinary in scope and dimension, single topic-focused, centred-upon comparative studies or in support of game design improvements. While there was a large group of studies done on violence in games (e.g., Anderson & Bushman, 2001; Anderson et al., 2010), these studies do not have much relationship with educational games which do not use violent metaphors or gameplay. One of the earliest meta-reviews was undertaken by Randel et al. (1992) considered literature 1963-1984, finding that of the 67 studies undertaken over the period, "38 show no difference between games and conventional instruction; 22 favour games; 5 favour games, but their controls are questionable; and 3 favour conventional instruction."

Vogel et al. (2006) in their review included simulations and games, it found that "games and interactive simulations are more dominant for cognitive gain outcomes," it also found that when students were empowered to control access to simulations and games there were significant advantages over when access was tutor-controlled, when no advantage was found. Ke (2009) undertook his meta-review in 2009, reviewing 89 studies finding that there was a need for more longitudinal studies, less fragmentation in the literature and more empirically-based studies. 65 out of 89 studies evaluated the effects of the game upon learning. From the empirically-based studies 34 out of the 69 found positive outcomes from using games, 17 had mixed results, 12 reported "no significant difference" with traditional instruction approaches – and one study found traditional methods more effective.

Wouters and Van Oostendorp (2013) undertook a meta-review on instructor-support in game environments, finding that "instructional support in game-based learning environments improved learning," further that greater improvement was found in skills-based learning. Wouters et al. (2013) also found in another meta-analytic review of literature that "serious games were found to be more effective in terms of learning ($d = 0.29$, $p < .01$) and retention ($d = 0.36$, $p < .01$), but they were not more motivating ($d = 0.26$, $p > .05$) than conventional instruction methods." This refuted much of the educational literature that had found games to have strong motivational gains (e.g., Garris et al., 2002). The study also found that "learners in serious games learned more, relative to those taught with conventional instruction methods, when the game was supplemented with other instruction methods, when multiple training sessions were involved, and when players worked in groups." Sitzman (2011) found that "consistent with theory, post-training self-efficacy was 20% higher, declarative knowledge was 11% higher, procedural knowledge was 14% higher, and retention was 9% higher for trainees taught with simulation games, relative to a comparison group." However she did find evidence of publication bias.

Connolly et al. (2012) undertook their meta-review, in contrast to Wouter et al. (2013), they found improvements in motivation. Their study reviewed 7,392 papers in total and found that "playing computer games is linked to a range of perceptual, cognitive, behavioural, affective and motivational impacts and outcomes." Of the most recent reviews undertaken since 2014, Clark, Tanner-Smith and Killingsworth (2015) have found "results from media comparisons indicated that digital games significantly enhanced student learning relative to nongame conditions (Formula = 0.33, 95% confidence interval [0.19, 0.48], $k = 57$, $n = 209$)."

Neuroscience perspective on educational games and play

Our understanding about how we learn, through brain science and experiment, largely builds upon work of Edelman (1987) and Kandel and colleagues (2000). The specific scientific studies of neuroscientists Daphne Bavelier and Simone Kuhn have helped to shape the field and given great insights into the power of games to support advanced learning. Greater brain volume and plasticity with gameplay (Kühn et al., 2011; Kühn et al., 2014) and greater transferability of skills such as hand eye coordination, memory abilities and visual acuity (Green & Bavelier, 2003; Green & Bavelier, 2008; McDermott, Bavelier & Green, 2014) are amongst the more important findings revealed in recent studies. For example, Green and Bavelier (2008) undertook a review on brain plasticity and learning. They concluded, "possible characteristics of training regimens are proposed that may be responsible for augmented learning, including the manner in which task difficulty is progressed, the motivational state of the learner, and the type of feedback the training provides. When maximally implemented in rehabilitative paradigms, these characteristics may greatly increase the efficacy of training" (Green & Bavelier, 2008, p. 699).

Beyond these studies, it is hoped that we will begin to answer some questions, such as why are games effective learning tools? How can games be used to model social learning behaviours?

Information science perspective on educational games

One of the recent game-changers in the field of education research has been access to large datasets gleaned from learning management systems (LMS), student information systems (SIS), interactive environments and other computer-generated environments, such as digital games. In digital environments, such as games, all data can be collected and analysed relatively easily (Deterding et al., 2015; Loh et al., 2015). In these more data-rich environments the possibility to look at social learning behaviours has emerged (e.g., Gentile et al., 2009; Steiner et al., 2015). The study of social learning behaviour allows for individual and cohort mapping, comparative cohort studies and importantly longitudinal studies. The richness of learning data – or learning analytics – has led to more quantitative and longitudinal studies that involve large student populations (e.g., de Freitas et al., 2015) to supplement the preponderance of qualitative studies. This recent focus upon quantitative study of learning has real potential to inform how we design "new learning" and ensure that our students are suitably engaged and actively partnering in their learning. This is a powerful capability, but not without complex ethical issues in terms of privacy, de-identification of data, informed consent, data management and archiving (e.g., Pardo & Siemens, 2014; Slade & Prinsloo, 2013), some of which may be overcome in time by blockchains (Sharples & Domingue, 2016). Work is needed to ensure that feedback systems are beneficial to the attainment and success of the learner whilst enshrining ethical considerations and transparent approaches.

The notion of game analytics brings together large datasets for analysing human behaviour, supporting learning experiences and supporting individual and group performance and personalisation capabilities (e.g., El-Nasr, Drachen & Canossa, 2013; Drachen et al., 2013; Gibson & de Freitas, 2016).

Table 2. Contributions to game science from four disciplinary perspectives

Contribution from education science	Contribution from game studies/science	Contribution from neuroscience	Contribution from information science
• Importance of play to learning has been confirmed in play studies e.g., identification of importance of play (Piaget, 2013) • Longitudinal studies of examining play patterns (e.g., Twenge & Campbell, 2008) • How patterns of play can impact learning (e.g., Chudacoff, 2007; Gray, 2011)	• Game Studies and Science literature includes insights such as increased motivation (e.g., Star, 2015; Plass et al., 2015; Attali & Arieli-Attali, 2015) • Pragmatic and randomised trials have confirmed that games can be more effective learning tools than traditional modes (advance on e-learning which found no significant difference with traditional modes) (e.g., Knight et al. 2010; Miller & Robertson, 2011; Straker et al., 2011) • Use of combined measures introduced including qualitative and quantitative measures (e.g., Kato et al., 2008)	• Greater brain volume and plasticity with game play (Kuhn et al., 2011; 2014) • Greater transferability of skills such as hand eye coordination and visual acuity (Bavelier, 2003 (with Green) and 2014 papers)	• Data modelling will allow us to map human behaviour more closely by using data interactions in games (e.g., Gibson & de Freitas, 2016) • Analytics allows for personalisation in games (e.g., El-Nasr, Drachen & Canossa, 2013; Drachen et al., 2013)

Discussion and conclusions

This review has aimed to reposition the emergent game science area of research within four inter-related disciplinary contexts of: education science, game studies, neuroscience and information science literatures.

Key challenges for integrating the research base are summarised as:

- The literature is so scattered across different disciplines that not all researchers acknowledge the breadth of the area and range of applications, and therefore miss vital academic contributions by looking too narrowly at the literature-base.
- Beyond traditional learning paradigms (see Figure 2), game-based approaches require: cross-disciplinarity, longer class durations, mixed student groups, social learning and team-teaching models to come into place to really capitalise on the merits of the game and gameplay as learning approaches, which are problematic for traditional formal education systems to incorporate.
- Work is needed to ensure that feedback systems used in educational games are beneficial to the attainment and success of the learner whilst enshrining ethical considerations and transparent approaches.
- Finding the balance between game playability and fun and solid learning design that aligns learning outcomes with assessments (in-game or as part of the blended experience) is a key challenge for effective educational game design.

The overall findings of the studies confirm that a more robust literature-base has grown considerably in recent years and has led to the notion of "game science." Moreover, while the efficacy of educational games is hard to measure, findings from quantitative RCT and more data-driven longitudinal studies are giving us more robust findings to build and improve design of learning experiences, involving gamification and game-based elements and enhancing student success. What we have learnt from the research as well is the importance of using combined measures including qualitative and quantitative measures (e.g., Kato et al., 2008).

Game science is emerging as a robust and dynamic area of research crossing several disciplinary areas and redrawing the scope and research questions that intersect with learning efficacy and design. The future of this sub-field might include bringing together the substantive literatures of simulations, serious games, gamification and education technology. The two issues of cross-disciplinarity and methodology will be key for establishing the lines of the discipline, with the absorption of randomised controls, meta reviews and large dataset analyses combining with the qualitative methods established in education such as content analyses, case studies and ethnologies and with other approaches such as neurological studies and social network analyses to provide a level of granularity that supports better learning design and an improved student experience, through modelling social behaviours.

To the question: are games effective learning tools, the answer from the research is overwhelmingly positive. Going further, the weight of the research findings seems to point to significant improvements in game over traditional methods, and these are further enhanced by blended approaches that utilise game and face-to-face approaches. The work distilled from RCTs is particularly positive and indicates that educators are now challenged with the best ways to implement game-based approaches in their institutions. While it seems that games do enhance student motivation, are engaging and can be associated with behavioural change, more active design studies are needed to ensure that the best interests of the learner are met in different contexts. As educational games enter into a new wave of implementation, it will be interesting to see whether the lessons from across the different disciplines are absorbed into general practice.

It is clearly a challenge for educational institutions, policymakers and practitioners, but with the growing evidence-base advances in quality and overcoming challenges of privacy and design might be forecast. Despite resistance to the adoption of game-based approaches in schools, colleges and universities, like online learning, it will be a matter of time before the cost benefits drive uptake widely and the full implication of the research are fully understood. As the traditional learning paradigm gives way to the new learning and then on to the future learning approaches, game-based learning will become more embedded into practices, be personalised and hide the curriculum in more seamless ways. But researchers, policymakers, managers and practitioners in the field will need to work hard to ensure: distillation of key benefits, join-up of the literatures, harmonising different disciplinary perspectives, methodological challenges and creation of a shared terminology between these four disciplinary perspectives.

References

Ahola, R., Pyky, R., Jämsä, T., Mäntysaari, M., Koskimäki, H., Ikäheimo, T. M., Huotari, M. L., Röning, J., Heikkinen, H. I., & Korpelainen, R. (2013). Gamified physical activation of young men–A Multidisciplinary Population-Based Randomized Controlled Trial (MOPO study). *BMC public health, 13*(1), 32. doi:10.1186/1471-2458-13-32

Allam, A., Kostova, Z., Nakamoto, K., & Schulz, P. J. (2015). The Effect of social support features and gamification on a web-based intervention for rheumatoid arthritis patients: Randomized controlled trial. *Journal of medical Internet research, 17*(1), e14. doi:10.2196/jmir.3510

Anderson, C. A., & Bushman, B. J. (2001). Effects of violent video games on aggressive behavior, aggressive cognition, aggressive affect, physiological arousal, and prosocial behavior: A Meta-analytic review of the scientific literature. *Psychological science, 12*(5), 353-359.

Anderson, C. A., Shibuya, A., Ihori, N., Swing, E. L., Bushman, B. J., Sakamoto, A., Rothstein, H. R., & Saleem, M. (2010). Violent video game effects on aggression, empathy, and prosocial behavior in eastern and western countries: A meta-analytic review. *Psychological bulletin, 136*(2), 151-173.

Arbogast, H., Burke, R. V., Muller, V., Ruiz, P., Knudson, M. M., & Upperman, J. S. (2014). Randomized controlled trial to evaluate the effectiveness of a video game as a child pedestrian educational tool. *Journal of trauma and acute care surgery, 76*(5), 1317-1321.

Arnab, S., Brown, K., Clarke, S., Dunwell, I., Lim, T., Suttie, N., & de Freitas, S. (2013). The Development approach of a pedagogically-driven serious game to support Relationship and Sex Education (RSE) within a classroom setting. *Computers & Education, 69*, 15-30.

Attali, Y., & Arieli-Attali, M. (2015). Gamification in assessment: Do points affect test performance? *Computers & Education, 83*, 57-63.

Barr, P., Noble, J., & Biddle, R. (2007). Video game values: Human–computer interaction and games. *Interacting with Computers, 19*(2), 180-195.

Bavelier, D., Green, C. S., Pouget, A., & Schrater, P. (2012). Brain plasticity through the life span: Learning to learn and action video games. *Annual review of neuroscience, 35*, 391-416.

Blumberg, F. C., Altschuler, E. A., Almonte, D. E., & Mileaf, M. I. (2013). The Impact of recreational video game play on children's and adolescents' cognition. *New directions for child and adolescent development, 2013*(139), 41-50. doi:10.1002/cad.20030

Cagiltay, N. E., Ozcelik, E., & Ozcelik, N. S. (2015). The Effect of competition on learning in games. *Computers & Education, 87*, 35-41.

Caillois, R., & Barash, M. (1961). *Man, play, and games*. Champaign, IL: University of Illinois Press.

Campbell, K. W., & Twenge, J. M. (2015). Narcissism, emerging media, and society. In *The Wiley Handbook of Psychology, Technology, and Society* (pp. 358-370). Hoboken, NJ: John Wiley & Sons.

Chen, Y. F., Rebolledo-Mendez, G., Liarokapis, F., de Freitas, S., & Parker, E. (2008). The Use of virtual world platforms for supporting an emergency response training exercise. In *Proceedings of the 13th International Conference on Computer Games: AI, Animation, Mobile, Interactive Multimedia, Educational & Serious Games* (pp. 49-55). Louisville, KY: CGAMESUSA.

Chudacoff, H. P. (2007). *Children at play: An American history*. New York, NY: New York University Press.

Clark, D. B., Tanner-Smith, E. E., & Killingsworth, S. S. (2015). Digital games, design, and learning a systematic review and meta-analysis. *Review of educational research, 86*(1), 79-122.

Colzato, L. S., van den Wildenberg, W. P., Zmigrod, S., & Hommel, B. (2013). Action video gaming and cognitive control: playing first person shooter games is associated with improvement in working memory but not action inhibition. *Psychological research, 77*(2), 234-239.

Connolly, T. M., Boyle, E. A., MacArthur, E., Hainey, T., & Boyle, J. M. (2012). A Systematic literature review of empirical evidence on computer games and serious games. *Computers & Education, 59*(2), 661-686.

de Freitas, S. (2014). *Education in computer generated environments. Research in education book series*. New York, NY: Routledge.

de Freitas, S., Gibson, D., Du Plessis, C., Halloran, P., Williams, E., Ambrose, M., Dunwell, I., & Arnab, S. (2015). Foundations of dynamic learning analytics: Using university student data to increase retention. *British Journal of Educational Technology, 46*(6), 1175–1188.

Deterding, S., Canossa, A., Harteveld, C., Cooper, S., Nacke, L. E., & Whitson, J. R. (2015). Gamifying research: Strategies, opportunities, challenges, ethics. In *Proceedings of the 33rd Annual ACM Conference Extended Abstracts on Human Factors in Computing Systems* (pp. 2421-2424). New York, NY: ACM.

Drachen, A., Thurau, C., Togelius, J., Yannakakis, G. N., & Bauckhage, C. (2013). Game data mining. In *Game Analytics* (pp. 205-253). Dordrecht, The Netherlands: Springer.

Dunwell, I., de Freitas, S., Petridis, P., Hendrix, M., Arnab, S., Lameras, P., & Stewart, C. (2014). A Game-based learning approach to road safety: The Code of Everand. In *Proceedings of the 32nd annual ACM conference on Human factors in computing systems* (pp. 3389-3398). New York, NY: ACM.

Edelman, G. M. (1987). *Neural Darwinism: The Theory of neuronal group selection*. New York, NY: Basic Books.

Egenfeldt-Nielsen, S. (2005). *Beyond edutainment: Exploring the educational potential of computer games.* Retrieved from http://www.lulu.com/shop/simon-egenfeldt-nielsen/beyond-edutainment-exploring-the-educational-potential-of-computer-games/ebook/product-17534578.html

El-Nasr, M. S., Drachen, A., & Canossa, A. (2013). *Game analytics: Maximizing the value of player data*. Berlin/Heidelberg, Germany: Springer Science & Business Media.

Elson, M., & Ferguson, C. J. (2014). Twenty-five years of research on violence in digital games and aggression. *European Psychologist, 19*, 33-46.

Elverdam, C., & Aarseth, E. (2007). Game classification and game design construction through critical analysis. *Games and Culture, 2*(1), 3-22.

Foss, A. J., Gregson, R. M., MacKeith, D., Herbison, N., Ash, I. M., Cobb, S. V., Eastgate, R. M., Hepburn, T., Vivian, A., Moore, D., & Haworth, S. M. (2013). Evaluation and development of a novel binocular treatment (I-BiT™) system using video clips and interactive games to improve vision in children with amblyopia ("lazy eye"): Study protocol for a randomised controlled trial. *Trials, 14*(1), 145. doi:10.1186/1745-6215-14-145

Fung, V., Ho, A., Shaffer, J., Chung, E., & Gomez, M. (2012). Use of Nintendo Wii Fit™ in the rehabilitation of outpatients following total knee replacement: A Preliminary randomised controlled trial. *Physiotherapy, 98*(3), 183-188.

Garris, R., Ahlers, R., & Driskell, J. E. (2002). Games, motivation, and learning: A Research and practice model. *Simulation & gaming, 33*(4), 441-467.

Gentile, D. A., Anderson, C. A., Yukawa, S., Ihori, N., Saleem, M., Ming, L. K., Shibuya, A., Liau, A. K., Khoo, A., Bushman, B. J., Rowell, L. Huesmann, L., & Sakamoto, A. (2009). The Effects of prosocial video games on prosocial behaviors: International evidence from correlational, longitudinal, and experimental studies. *Personality and Social Psychology Bulletin, 35*(6), 752-763.

Gibson, D., & de Freitas, S. (2016). Exploratory analysis in learning analytics. *Technology, Knowledge and Learning, 21*(1), 5–19

Gray, P. (2011). The Decline of play and the rise of psychopathology in children and adolescents. *American Journal of Play, 3*(4), 443-463.

Green, C. S., & Bavelier, D. (2003). Action video game modifies visual selective attention. *Nature, 423*(6939), 534-537.

Green, C. S., & Bavelier, D. (2008). Exercising your brain: A Review of human brain plasticity and training-induced learning. *Psychology and aging, 23*(4), 692.

Hainey, T., Connolly, T. M., Boyle, E. A., Wilson, A., & Razak, A. (2016). A Systematic literature review of games-based learning empirical evidence in primary education. *Computers & Education, 102*(2016): 202-223.

Harlow, A. J., & Bowman, S. L. (2016). Examining the career decision self-efficacy and career maturity of community college and first-generation students. *Journal of Career Development, 43*(6), 512-525.

Horne-Moyer, H. L., Moyer, B. H., Messer, D. C., & Messer, E. S. (2014). The Use of electronic games in therapy: A Review with clinical implications. *Current psychiatry reports, 16*(12), 1-9.

Hussain, T.S., Roberts, B., Menaker, E.S., Coleman, S.L., Centreville, V.A., Pounds, K., Bowers, C., Cannon-Bowers, J.A., Koenig, A., Wainess, R. and Lee, J., (2012). Designing and developing effective training games for the US Navy. *Military & Simulations Journal*, Spring 2012: 27-44.

Kamii, C., & DeVries, R. (1980). *Group games in early education: Implications of Piaget's theory*. Washington, DC: National Association for the Education of Young Children.

Kandel, E. R., Schwartz, J. R., & Jessell, T. M. (2012). *Principles of neural science* (5th ed.). New York, NY: McGraw-Hill.

Kato, P. M., Cole, S. W., Bradlyn, A. S., & Pollock, B. H. (2008). A Video game improves behavioral outcomes in adolescents and young adults with cancer: A Randomized trial. *Pediatrics, 122*(2), e305-e317.

Ke, F. (2009). A Qualitative meta-analysis of computer games as learning tools. *Handbook of research on effective electronic gaming in education, 1*, 1-32.

Kempf, K., & Martin, S. (2013). Autonomous exercise game use improves metabolic control and quality of life in type 2 diabetes patients-a randomized controlled trial. *BMC endocrine disorders, 13*(1), 57.

Kenny, R. F., & McDaniel, R. (2011). The Role teachers' expectations and value assessments of video games play in their adopting and integrating them into their classrooms. *British Journal of Educational Technology, 42*(2), 197-213.

Kim, B., Park, H., & Baek, Y. (2009). Not just fun, but serious strategies: Using meta-cognitive strategies in game-based learning. *Computers & Education, 52*(4), 800-810.

Knight, J., Carly, S., Tregunna, B., Jarvis, S., Smithies, R., de Freitas, S., Mackway-Jones, K., & Dunwell, I. (2010). Serious gaming technology in major incident triage training: A Pragmatic controlled trial. *Resuscitation Journal, 81*(9), 1174-1179.

Kühn, S., Romanowski, A., Schilling, C., Lorenz, R., Mörsen, C., Seiferth, N., Banaschewski, T., Barbot, A., Barker, G.J., Büchel, C., & Conrod, P.J. (2011). The Neural basis of video gaming. *Translational Psychiatry, 1*(11), e53.

Kühn, S., Gleich, T., Lorenz, R. C., Lindenberger, U., & Gallinat, J. (2014). Playing Super Mario induces structural brain plasticity: Gray matter changes resulting from training with a commercial video game. *Molecular psychiatry, 19*(2), 265-271.

Lewis, S. (2013). Neuropsychology: The Joystick years. *Nature Reviews Neuroscience, 14*(10), 671-671.

Loh, C. S., Sheng, Y., & Ifenthaler, D. (Eds.) (2015). *Serious games analytics: Methodologies for performance measurement, assessment, and improvement.* New York, NY: Springer.

Maddison, R., Foley, L., Mhurchu, C.N., Jiang, Y., Jull, A., Prapavessis, H., Hohepa, M., & Rodgers, A. (2011). Effects of active video games on body composition: A Randomized controlled trial. *The American journal of clinical nutrition, 94*(1), 156-163.

Mayas, J., Parmentier, F. B., Andrés, P., & Ballesteros, S. (2014). Plasticity of attentional functions in older adults after non-action video game training: a randomized controlled trial. *PLoS One, 9*(3), e92269.

McDermott, A. F., Bavelier, D., & Green, C. S. (2014). Memory abilities in action video game players. *Computers in Human Behavior, 34*, 69-78.

Michael, D. R., & Chen, S. L. (2005). *Serious games: Games that educate, train, and inform*. New York, NY: Muska & Lipman/Premier-Trade.

Miller, D. J., & Robertson, D. P. (2011). Educational benefits of using game consoles in a primary classroom: A Randomised controlled trial. *British Journal of Educational Technology, 42*(5), 850-864.

Nouchi, R., Taki, Y., Takeuchi, H., Hashizume, H., Akitsuki, Y., Shigemune, Y., Sekiguchi, A., Kotozaki, Y., Tsukiura, T., Yomogida, Y., & Kawashima, R. (2012). Brain training game improves executive functions and processing speed in the elderly: A Randomized controlled trial. *PloS one, 7*(1), e29676.

Papastergiou, M. (2009). Digital game-based learning in high school computer science education: Impact on educational effectiveness and student motivation. *Computers & Education, 52*(1), 1-12.

Pardo, A., & Siemens, G. (2014). Ethical and privacy principles for learning analytics. *British Journal of Educational Technology, 45*(3), 438-450.

Pasin, F., & Giroux, H. (2011). The Impact of a simulation game on operations management education. *Computers & Education, 57*(1), 1240-1254.

Piaget, J. (1971). *The Theory of stages in cognitive development*. New York, NY: McGraw Hill.

Piaget, J. (2013). *Play, dreams and imitation in childhood* (Vol. 25). New York, NY: Routledge.

Pichierri, G., Murer, K., & de Bruin, E. D. (2012). A Cognitive-motor intervention using a dance video game to enhance foot placement accuracy and gait under dual task conditions in older adults: A Randomized controlled trial. *BMC geriatrics, 12*(1), 74. doi:10.1186/1471-2318-12-74

Plass, J. L., O'Keefe, P. A., Homer, B. D., Case, J., Hayward, E. O., Stein, M., & Perlin, K. (2013). The Impact of individual, competitive and collaborative mathematics game play on learning, performance, and motivation. *Journal of Educational Psychology, 105*(4), 1050.

Pompeu, J. E., dos Santos Mendes, F. A., da Silva, K. G., Lobo, A. M., de Paula Oliveira, T., Zomignani, A. P., & Piemonte, M. E. P. (2012). Effect of Nintendo Wii™-based motor and cognitive training on activities of daily living in patients with Parkinson's disease: A Randomised clinical trial. *Physiotherapy, 98*(3), 196-204.

Prensky, M. (2005). Computer games and learning: Digital game-based learning. In J. Raessens & J. H. Goldstein (Eds.), *Handbook of computer game studies* (pp. 97–122). Cambridge, MA: MIT Press.

Randel, J. M., Morris, B. A., Wetzel, C. D., & Whitehill, B. V. (1992). The Effectiveness of games for educational purposes: A Review of recent research. *Simulation & gaming, 23*(3), 261-276.

Rebolledo-Mendez, G., Avramides, K., de Freitas, S., & Memarzia, K. (2009). Societal impact of a serious game on raising public awareness: the case of FloodSim. In *Proceedings of the 2009 ACM SIGGRAPH Symposium on Video Games* (pp. 15-22). New Orleans, LA: ACM.

Salen, K., & Zimmerman, E. (2004). *Rules of play: Game design fundamentals*. Cambridge, MA: MIT press.

Serrano-Laguna, Á., Torrente, J., Moreno-Ger, P., & Fernández-Manjón, B. (2012). Tracing a little for big improvements: Application of learning analytics and videogames for student assessment. *Procedia Computer Science, 15*, 203-209.

Sharples, M., & Domingue, J. (2016). The Blockchain and Kudos: A Distributed system for educational record, reputation and reward. In *European Conference on Technology Enhanced Learning* (pp. 490-496). New York, NYS: Springer International Publishing.

Shute, V. J., Ventura, M., Bauer, M., & Zapata-Rivera, D. (2009). Melding the power of serious games and embedded assessment to monitor and foster learning. *Serious games: Mechanisms and effects, 2*, 295-321.

Siervo, M., Sabatini, S., Fewtrell, M. S., & Wells, J. C. K. (2013). Acute effects of violent video-game playing on blood pressure and appetite perception in normal-weight young men: a randomized controlled trial. *European journal of clinical nutrition, 67*(12), 1322-1324.

Sitzmann, T. (2011). A Meta-analytic examination of the instructional effectiveness of computer-based simulation games. *Personnel psychology, 64*(2), 489-528.

Slade, S., & Prinsloo, P. (2013). Learning analytics ethical issues and dilemmas. *American Behavioral Scientist, 57*(10), 1510-1529.

Star, K. (2015). *Gamification, interdependence, and the moderating effect of personality on performance* (Unpublished doctoral thesis). Coventry University, Coventry, UK.

Straker, L. M., Campbell, A. C., Jensen, L. M., Metcalf, D. R., Smith, A. J., Abbott, R. A., Pollock, C. M., & Piek, J. P. (2011). Rationale, design and methods for a randomised and controlled trial of the impact of virtual reality games on motor competence, physical activity, and mental health in children with developmental coordination disorder. *BMC public health, 11*(1), 654. doi:10.1186/1471-2458-11-654

Straker, L. M., Abbott, R. A., & Smith, A. J. (2013). To remove or to replace traditional electronic games? A Crossover randomised controlled trial on the impact of removing or replacing home access to electronic games on physical activity and sedentary behaviour in children aged 10–12 years. *BMJ open, 3*(6), e002629.

Steiner, C. M., Kickmeier-Rust, M. D., & Albert, D. (2015). Making sense of game based user data: learning analytics in applied games. In *Proceedings of the International Conference of e-learning* (pp. 195-198). Retrieved from https://files.eric.ed.gov/fulltext/ED562478.pdf

Sugden, R. (2013). Space in an inferno? The organization of modern universities and the role of academics. In M. Valania, & J. R. Wilson (Eds.), *Leadership and cooperation in academia: reflecting on the roles and responsibilities of university faculty and management*. Cheltenham, UK: Edward Elgar Publishing.

Sutton-Smith, B., & Roberts, J. M. (1971). The Cross-cultural and psychological study of games. *International Review for the Sociology of Sport, 6*(1), 79-87.

Terlutter, R., & Capella, M. L. (2013). The Gamification of advertising: Analysis and research directions of in-game advertising, advergames, and advertising in social network games. *Journal of Advertising, 42*(2-3), 95-112.

Twenge, J. M., & Campbell, W. K. (2008). Increases in positive self-views among high school students birth-cohort changes in anticipated performance, self-satisfaction, self-liking, and self-competence. *Psychological Science, 19*(11), 1082-1086.

Vogel, J. J., Vogel, D. S., Cannon-Bowers, J., Bowers, C. A., Muse, K., & Wright, M. (2006). Computer gaming and interactive simulations for learning: A Meta-analysis. *Journal of Educational Computing Research, 34*(3), 229-243.

Vygotsky, L. S. (1980). *Mind in society: The Development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Wouters, P., Van Nimwegen, C., Van Oostendorp, H., & Van Der Spek, E. D. (2013). A Meta-analysis of the cognitive and motivational effects of serious games. *Journal of Educational Psychology, 105*(2), 249-265.

Wouters, P., & Van Oostendorp, H. (2013). A Meta-analytic review of the role of instructional support in game-based learning. *Computers & Education, 60*(1), 412-425.