Virtual Reality (2017) 21:31–58
DOI 10.1007/s10055-016-0298-4

ORIGINAL ARTICLE

Success factors for serious games to enhance learning: a systematic review

Werner Siegfried Ravyse[1] · A. Seugnet Blignaut[1] · Verona Leendertz[1] · Alex Woolner[2]

Received: 6 July 2016 / Accepted: 13 September 2016 / Published online: 20 September 2016
© Springer-Verlag London 2016

Abstract There is no doubt that an abundance of factors exists that makes learning with serious games successful. Research articles reporting on these factors, however, tend to focus on select serious game elements and do not combine all salient factors for successful learning with serious games. Addressing this gap is a necessity for the success of serious games and may even alleviate long-standing debates about pedagogy over enjoyment, how much realism is enough or whether artificial intelligence is worth the cost. This article examines existing academic literature from 2000 to 2015, extracting shared serious game success factors that have had an encouraging impact on gameful learning experiences. As such, we subsequently aim to withdraw the field from a perpetual spiral of does-my-game-work research toward more worthwhile why-does-my-game-not-work research. Qualitative content analysis through the constant comparison method (CCM) analyzed a total of 63 articles from a variety of recognized electronic libraries and databases. Through this analysis, we reveal five central serious game themes: backstory and production; realism; artificial intelligence and adaptivity; interaction; and feedback and debriefing, all of which require deliberate intertwining with pedagogical content to ensure successful learning. This review unravels each of the five themes into their constituent factors and consequently presents the factors as practical guidelines that serious games producers should strive to include in their game productions. Applying these recommendations whenever serious games are considered will provide a foundation for effective gameful learning experiences.

Keywords Artificial intelligence (AI) · Feedback · Interaction · Narrative · Realism · Serious games

1 Introduction

The notion that serious games are more than mere entertainment is a safety definition that does little in the way of stating the exact nature of serious games. The true definition of serious games is an elusive one and varies depending on the application and opinion of the person defining it (Breuer and Bente 2010; Susi et al. 2007). The earliest, and widely used, definition states that serious games have deliberate educational intent without the goal of engaging with them for entertainment only (Abt 1970). The learning intent of serious games has an underlying constructivist rationale with the learner as its central cog (Cheng et al. 2014). Osterman (1998) proposes that constructivist pedagogical strategies should: (a) engage the learner; (b) provide opportunities to explore, articulate and represent knowledge; (c) challenge existing conceptual views and heighten awareness of problems; and (d) allow students to test the efficacy of new ideas. Gee (2005) compliments these pedagogical strategies stating that serious games learning principles include that: (a) nothing will happen without player input; (b) earlier problems encourage the player to build hypotheses, which could be applied to later problems; (c) lateral exploration and thinking allow players to reconceive their goals; and (d) regularly, a new class of problems is thrown at players

✉ Werner Siegfried Ravyse
werner.ravyse@gmail.com

[1] TELIT-SA, Faculty of Economic Sciences and IT, North-West University, Vaal Triangle Campus, Hendrik van Eck Boulevard, Vanderbijlpark 1911, South Africa

[2] Serious Games Institute, Coventry University, Priory St, Coventry CV1 5FB, UK

restarting their cycle of mastery. All-in-all, learning in serious games constitutes allowing learners to apply their current knowledge in a digital environment with the aim of acquiring a new skill set by their own volition to overcome contextual challenges (Boyle et al. 2011).

This does not mean serious games are only about activities that educate, instruct or train, but rather that the addition of pedagogy is what sets them apart from entertainment games (Zyda 2005). The aesthetic design component of the mechanics, dynamics and aesthetics (MDA) framework (Hunicke et al. 2004) encapsulates the fun element of games as a set of "desirable emotional responses evoked within the player" (Hunicke et al. 2004) when engaging with the game. Aesthetics, in a game context, is also sometimes intended to convey the audiovisual (or realism) sensations encountered by players (Niedenthal 2009). The MDA framework also proclaims the importance of mechanics (player interaction with game) and dynamics (progression of the game's backstory or plot).

The challenge facing serious games though, is to find a balance between the ludic and skills or knowledge transfer goals so that neither a dominant game mode (taking away from the learning outcomes) nor learning mode (removing the fun element) is present (Giessen 2015). Some researchers do not agree on this notion of striking an equal balance. Zyda (2005) argues that pedagogy should be subordinate to story and entertainment, while researchers such as Michael and Chen (2006) argue that educating the player should be the primary goal of serious games. Realism (or fidelity) is a root of further confusion. Research shows that fidelity levels and knowledge transfer are not necessarily positively correlated (Feinstein and Cannon 2002). Norman et al. (2012) corroborate this in their review where they found no significant learning advantage from high-fidelity simulators over low-fidelity simulators. The conundrum, however, is that exposure to high-fidelity entertainment games leads target players to ask for serious games to be as audio-visually realistic as possible (Visschedijk and Van der Hulst 2012). No literature unraveling the mystery of the right amount of fidelity for a serious game could be found. Due to unacceptable reliability in operationalizing fidelity, Cook et al. (2013) went so far as to drop the fidelity variable from their comprehensive review on instructional design features for simulation-based education. Moreover, further literature searches revealed that much of the reported design recommendations, development guidelines and assessments of serious games are circumstantial and based on single games within a specific application field. The field of serious games is accused of being disorganized and fragmented across disciplines and geographies (De Freitas and Ketelhut 2014). Undoubtedly, the vast application field of serious games plays a role in this fragmentation, but we feel it most certainly should not be the scapegoat why "quality games designed specifically to promote learning are hard to find" (Mcmahon and Henderson 2011).

Yet, the use of computer games to foster learning has steadily found favor among government policy makers, health professionals, advertisers, training practitioners and educators (Connolly et al. 2012). Also, many researchers (Hyungsup 2014; Mortara et al. 2014; Sacfung et al. 2014; Wiemeyer 2010) keenly report on various games to teach a diverse suite of fields and subjects including sports, resilience among the elderly, fire evacuation and cultural heritage to name a few. The rising popularity and number of application fields make discovering success factors that enhance learning with serious games a worthwhile endeavor.

To meet the objectives of this article, we settled on defining serious games as digital games that have an intended impact on cognition, behavior or motor skills. Also, we refer to success factors as those that positively impact the learning intention of serious games. These success factors may also be taken as practical guidelines that address the economic considerations that commercial serious game producers face. To concretize our view of what constitutes a game, we followed the 12 proposed elements of what makes games engaging by Prensky (2001), thereby excluding (among others) pure simulators, graphic novels and intelligent tutoring systems from this systematic review. We are furthermore cognizant of the long-standing debate surrounding the term serious games and have noted that it is starting to fall out of favor among the field's authors. The founding chairman of Games for Health Europe, Mr J van Rijswijk, suggested the term, *applied games* as a replacement for the aging serious games term during the 2015 Games for Health Finland seminar. The scope of this article does not include identifying an appropriate replacement term for serious games and as such we have elected to stand by this long-standing, and admittedly oxymoronic, term while it is still known among academic authors.

2 Purpose of the article

This article aims to uncover the success factors that enhance learning with serious games by performing a systematic review of prior quality studies. Producing serious games is expensive and time-consuming and much care needs to be taken to ensure that they will be instrumental to aesthetically pleasing learning. Conveying a set of practical production guidelines would contribute to the increased delivery of quality serious games. We aim to address the question, *What practical guidelines can serious game* *producers incorporate to guarantee successful learning with games?* Consolidating the serious games success factors from the wide distribution of literature and conflicting opinions will bring a much-needed veneer of consistency to the field.

Previous summative work in the field of serious games either: (a) provides a perfunctory mention of select serious game requirements (Dondlinger 2007; Van Eck 2006a); (b) focuses on the empirical effectiveness of serious games (Sitzmann 2011; Vandercruysse et al. 2012; Wouters et al. 2013); (c) concentrates on the psychological aspects that cause players to learn from serious games (Dondlinger 2007); (d) lists and compares games within a specific field, without an in-depth analysis or discussion of the game elements (Bhoopathi et al. 2007; Rodriguez et al. 2014); or (e) deliberates on implementation strategies for serious games (Blakely et al. 2009; Webster and Celik 2014). We do not downplay the significance of each of these reviews (and others) carry in the field of serious games, but it is distinctly evident that a comprehensive list and clarification of the factors that make learning with serious games successful is not available. Our systematic literature review on successful learning with serious games addresses this gap and provides such a list as a set of practical serious game design guidelines.

This article is not an exposé on models (Minovic et al. 2011; Peters and Vissers 2004; Sherry 2013), frameworks (Echeverría et al. 2011; Moseley et al. 2014; Westera et al. 2008), theoretical orientation (Kriz and Hense 2006) and other fundamental serious games research or a summary of existing literature reviews on similar constructs (Bedwell et al. 2012; Hainey 2007), but examines and extracts practical matters that researchers who build serious games have encountered. Although the crux of this article is to assist serious games producers with an assimilated set of practical success factors toward enhanced learning through games, we also unavoidably touch on engagement (Whitton 2011), motivation (Garris et al. 2002), gamer demographics (Whitton 2013) and other foundational aspects of serious games.

3 Method

3.1 Databases searched and search terms

This study searched digital databases applicable to computer science, information science and technology, health sciences (the most prominent sector for serious games) education and social sciences. The following databases were searched: Web of Science core collection, Science Direct, EBSCO (comprising of ERIC (Education Resources Information Center), Applied Science and Technology Source, MasterFILE Premier, PsycINFO, SocINDEX, Academic Search Premier, Business Source Premier, CINAHL, E-Journals, MEDLINE, PsycARTICLES, Teacher Reference Center), Electronic Journal Services, JSTOR, and Scopus. The time span was set from 2000 to 2015 and included only academic journal articles.

After consultation with librarians of the North-West University, we chose to employ broad terms for searching the digital libraries. The reason for this was that after several test searches with secondary terms included, we were of the opinion that too few hits for the time period and number of databases in question were present—concern was raised over the possible omission of pertinent work. The following search terms were used: *(serious games; games-based learning; simulation games; gamification; edutainment; educational games; games for learning).* Advergames were excluded as this review is not aimed at games that create awareness, but examine studies targeting (a) knowledge acquisition; (b) behavior change; (c) affective impact; (d) motor; and (e) other skills attainment. Probing the 17 databases resulted in 119 searches with a total of 30 070 hits. All hits were exported to ENDNOTE™ X7 (an electronic reference manager) and stored in 119 distinct subgroups according to a per-search-term-per-database basis. A series of publication removal efforts reduced the number of hits to 1 232 articles.

To further reduce the number of hits (in order to qualitatively analyze a realistic number of articles), we decided to focus only on the most prominent authors from the remaining number of hits. A list of authors from the remaining hits was drawn up, and all authors occurring three or more times were confirmed as prominent by their authorship analytics in the Scopus database. We admit that this was somewhat restrictive and could possibly have led to omitting pertinent work. However, while analyzing the Scopus author analytics, some articles of authors with less than three entries in the researchers' database, due to their prominence in Scopus, were appended to the list for the ensuing inclusion/exclusion process—397 articles remained.

3.2 Selection of articles for inclusion

Three researchers scrutinized each article's title, abstract and conclusion to determine which articles can be excluded on the basis of irrelevance concerning the research question. A number of further conditions then stipulated appropriate studies for the review. The selected articles: (a) concerned digital games with interactive gameplay; (b) had a positive learning impact; (c) contained a description or user feedback of the game; (d) did not evaluate entertainment games for learning potential; and (e) did not discuss EXCEL™-, ACCESS™- or POWERPOINT™-based games. From these inclusion/exclusion criteria, 72 articles were found relevant for this review—during the coding procedure, a further nine articles were removed for reasons including (a) no impact being measured; (b) articles being too similar to others already included; or (c) discussion of a framework as opposed to a game analysis—63 articles underwent in-depth analysis.

3.3 Coding and synthesis procedure

This review utilized ATLAS.TI™, a computer-assisted qualitative data analysis system to amalgamate all the natural language (qualitative) data from the pool of collected literature. Themes and categories were identified a priori during the review's scope determination phase providing a basis for the coding process. As the coding progressed, categories were added, updated or deleted. The pre-identified themes remained unchanged during the coding procedure. Using a partially grounded theory approach and applying the constant comparison method (CCM) (Boeije 2002) enabled us to inductively code the data. The CCM then further facilitated us to refine the network view by categorizing, coding, delineating categories and connecting them as a first instance of serious game success factors (Boeije 2002). Table 1 gives a brief overview of the coding and synthesis steps following the initial theme and category identification.

Abiding by the three steps outlined above led to the clustering of serious game categories around five definitive themes. The *backstory and production* theme pivots around the narrative of the game and how players progress the storyline. The production elements highlight the aspects serious games producers should deliberate regarding the design establishment, various development techniques at their disposal and weaving learning content into the narrative. Fidelity, in all its guises (physical, functional, psychological and interaction), to present learning in an immersive user-appealing way, is the sole focus of the *realism* theme. *Artificial Intelligence (AI) and adaptivity* are not discussed at programmatic or algorithmic level, but are extracted to show which AI (and associated progress tracking) techniques bring about improved fun and learning experiences. The *interaction* theme primarily describes the mechanics (for the purpose of this review, mechanics points to the feedback loop (action-reaction) players experience with game objects) and various other physical properties mediating the engagement between players and the learning content, all the while stimulating their enjoyment. The final theme, *feedback and debriefing*, isolates a deeper account of the communication afforded to players both in-game and from their environment in response to their gameplay activities. The feedback and debriefing theme also points out the learning approaches and support, which should be present for a motivating learning experience, and grants particular attention to reflective and debriefing practices.

Several measures to ensure validity, reliability and avoiding bias of the data extraction method were put into place. The data extraction as themes and categories were derived from existing literature and corroborated by serious game experts. A single author coded two articles on separate occasions (a week apart) with moderate intra-rater reliability (Cohen's kappa = 0.78). Two researchers independently coded randomly selected studies showing a strong inter-rater reliability (Cohen's kappa = 0.83). McHugh (2012) proposed the Cohen's kappa interpretation scale we applied. Given that research with a rich analytical value of the concepts it discusses and a reliability level within or somewhat below the 0.8–0.9 range can go ahead (Riffe et al. 1998), we confidently forged ahead with our review. Duplicate publications of the same data were not included in the review, and the most complete of these articles were selected for the review (Kitchenham 2007). Table 2 presents the 63 articles that underwent analysis and captures each article's data that led to the formation of the five themes. In cases where one article deliberated multiple games, each game's distinct properties were segregated. We also decided to consolidate multiple articles discussing the same game into a single table entry.

Table 1 Steps of the constant comparative analysis process this review followed as adapted from Boeije (2002)

Step and type of comparison	Analysis activities	Aim	Results
1. Comparison within single studies	Open coding; summarizing core of the study; finding consensus on interpretation of fragments	Further develop an understanding of the identified categories	Conceptual profile of serious games success factors
2. Comparison between studies within the same group	Axial coding; formulating criteria for comparing studies; hypothesizing about patterns and types	Conceptualization of the subject; produce a typology	Description of the concepts and an expansion of code words until all relevant themes were confirmed
3. Comparison of studies from groups with different perspectives	Triangulating data sources	Complete the picture; enrich the information	Verification of provisional knowledge from step one with additional information and memos

Table 2 Primary articles and extracted serious game success factors

Author(s) and game purpose	Admiraal et al. (2014); Huizenga et al. (2009); Impart knowledge about medieval Amsterdam (tested by secondary school students)
Backstory and production	Players physically traverse Amsterdam; open-ended progress; learner-centered production suggested for future game development
Realism	Telephone messages with medieval background sounds; real people (no NPCs); act out actual medieval actions; game activities within context
Interaction	Mobile phone; GPS; computer; students enjoyed the higher task load and greater game overview during their head quarter session; zones are introduced by video clips; collaborative and competitive multi-player; present collected media to other groups
Feedback and debriefing	Keywords within video clips; diary entries after video clips; collaborative learning; active learning; city team location shown on map throughout; introductory videos and assignments auto sent when entering zone; immediate feedback of "rat dropping"
Author(s) and game purpose	Alamri et al. (2014); Encourage healthy behavior among obese people
Backstory and production	Find clues to progress; gradual advance; elements relate to game and impact
Realism	Day, night and rain themes; low-polygon visuals; animated avatar; no time limit; player is avatar
Interaction	Heart rate sensors; Wii balance board; push-up bar; walking; devices difficult to handle; instructed how to use devices; proximity of clue textually indicated; 3D
Feedback and debriefing	Self-awareness through immediate bio-metric data; heads-up display (HUD) shown throughout; trend reports; therapists informed of player progress and suggest actions
Author(s) and game purpose	Annetta et al. (2009a); Teach simple machines to elementary school (fifth grade) students
Backstory and production	Retrieve stolen computer parts; solve riddles to progress
Realism	Low-polygon artwork; NPCs have audio voice; textual player-to-NPC communication; players liked hearing NPCs speak
Interaction	Keyboard to move PC; further investigation with Lego® kits; player-to-player text chat; collaborative multi-player; 3D
Feedback and debriefing	Select in-game computer agent when needed
Author(s) and game purpose	Annetta et al. (2009b); Impart knowledge on key genetic concepts to high school students
Backstory and production	Find out who stole the inheritance based on genetic evidence; gameplay and game goals well- aligned with learning concepts; teleport to different scenes
Realism	Authentic scenarios; low-polygon modeling; NPCs present; less emphasis on animation, text and audio that does not aid learning
Interaction	3D; multi-player (collaborative pairs)
Feedback and debriefing	NPCs give content specific help and information; let students question previous knowledge
Author(s) and game purpose	Annetta et al. (2014); Educate pre-service science teachers about laboratory safety
Backstory and production	School laboratory must become safe environment; linear progress; additional scenarios can be added; MSDS sheets from NSTA Web site; users provided content material; user-centered design; play-testing with users
Realism	Scenario mirrors real world; mid-polygon modeling; realistic NPC interaction; time element
Interaction	Point-and-click selection; mouse; 3D; single-player
Feedback and debriefing	Support from mentor and other avatars; inquiry- and problem-based teaching; HUD with score, time and game functions shown throughout; pop-up window with MSDS
Author(s) and game purpose	Arnab et al. (2013); Delivery of relationship and sex education (focus on sexual coercion) to secondary school students
Backstory and production	Narration by game show host character; players role-play coerced and coercer; age-appropriate narrative; all stakeholders involved in content decisions; factual content; end user and facilitator participatory design
Realism	Real-life scenarios; dialogue typical of players; realistic NPCs; mid- to high-polygon modeling; NPCs have audio voice; time pressure; role-play stimulates emotion; lighting elicits emotion; photo-realistic graphics overwhelm some learners; unrealistic NPC features are noticed

Table 2 continued

Interaction	Point-and-click; type in textboxes; smart board (classroom purpose); appealing game show format; effective pause mechanism; dialogue among class members and teachers about scenarios; 2D and 3D; single-player; played as collaborative pseudo multi-player
Feedback and debriefing	Support from classroom teacher and NPC host; scaffolding; blended learning; summary and action points; explanation on responses; immediate sound effects and visuals; audio host NPCs throughout; class dialog during and after gameplay liked; post-session debriefing;
Author(s) and game purpose	Barab et al. (2012); Teach persuasive writing to seventh grade students
Backstory and production	Players use persuasive writing to convince NPCs of their perspective; player actions alter storyline; narrative progress requires disciplinary expertise; open-ended progress; context students identify with; game has real-world usefulness
Realism	Realistic game characters; mid-polygon modeling; textual player-to-NPC communication; NPCs respond to player actions; content to elicit emotion and deeper thought; perceptually rich graphics; first-person role strongly adopted
AI and adaptivity	NPCs treat players according to their game decisions (i.e., indirectly responding to player personal agendas)
Interaction	Point-and-click selection; mouse; keyboard for typing; write persuasive thesis after game; player-to-player text chat; 3D; multi-player environment (gameplay is single-player)
Feedback and debriefing	Teacher-led class discussion; teacher is mother character in game; immediate textual NPC feedback; review previous decisions before final quest (writing a persuasive essay)
Author(s) and game purpose	Baranowski et al. (2011); Thompson et al. (2010); Encourage diet and physical activity behavior change to lower risk of type II diabetes and obesity in (primary school) youths
Backstory and production	NPC teaches people healthy eating and exercise; behavior change woven into storyline; story via pre-rendered cut scenes; players determine own goals for the next week; linear progress; recap of previous episode; game skills related to player lives; user-centered design; new material builds on previous episode
Realism	High-resolution cut scenes; low-polygon interactive scenes; animated sequences; sound and speech; accurate impact of fruit and vegetable consumption on NPCs; natural NPC emotion and response; time pressure in mini-games; no overall time limit; good looks of characters is important; likeable characters are more persuasive
AI and adaptivity	Algorithm converts player information into personalized responses
Interaction	Levels of gameplay and challenge are desirable; identify activities for at home; 3D; single-player
Feedback and debriefing	Support from main NPC; opportunity to replay games and cut scenes; active learning; motivational messages; goal reviews; immediate audio-visual effects; NPCs give specific, realistic and positive feedback; feedback enhances self-efficacy; players liked post-game debriefing; review e-mails
Author(s) and game purpose	Bellotti et al. (2009); Promote best practices in sea-related behaviors (targeted at, but not limited to, high school students)
Backstory and production	Three major settings for sea-related missions; sandbox game; all tasks within game world; knowledge testing to advance narrative; system-initiated events prompting exploration; more surprising events and variation requested; game-world tasks match real-life tasks
Realism	Day/night cycles and weather; realistic people and environment; virtual objects behave as real-life; natural NPC language, emotion and personality; photo-realistic modeling; natural lighting; surround audio; more items, NPCs, events and situations requested
AI and adaptivity	NPCs are controlled by AI; player activity generates events; automatic activation of help-NPC; NPCs should have more depth of knowledge for more compelling dialogue; track player to provide appropriate events
Interaction	Mini-games add stimulation; player-to-player chat interface; instant-messenger applications (only available when game characters are close together); auto-generated help-NPC; 3D; massively multi-player on-line game (MMOG)
Feedback and debriefing	NPCs provide knowledge; score updates throughout; all communication via NPCs or fellow players; continuous monitoring to check compliance and update score
Author(s) and game purpose	Bellotti et al. (2012); promote and develop European cultural heritage (tested by MSc and PhD students)
Backstory and production	Complete missions in European cities; context and narrative are aligned; mini-games enhance exploration; sandbox-style progress; if tasks are meaningful, no user-perceived disruption will exist; short manuscript texts; top-down approach for determining content
Realism	High-polygon modeling; tasks aligned with real-world activity; high NPC interactivity; natural language NPC dialogue; game experience similar to actual city visit; faithful 3D city reconstruction; buildings on map is precise; highly detailed points of interest; 3D exploration has lower detail
AI and adaptivity	User modeling for personal content; adjustment of difficulty level according to player ability; experience engine is responsible for task selection that best matches user model and available task models aligned with a pre-defined pedagogical strategy

Table 2 continued

Interaction	Point-and-click; drag-and-drop; keyboard for movement in mini-games; in-game smartphone for tasks; mouse; keyboard; replay for practice; intuitive mini-games; restart moves task triggers; natural 3D to 2D (and back) transition; uncomplicated interface; first move shown; hint during introductory texts; 3D roaming; 2D tasks
Feedback and debriefing	Brief introductory and concluding texts; task-based learning; player location on 2D map throughout; immediate or post-play feedback; key concepts explained after task; mini-game must provide feedback until correct answer is given; previous clues to answer current questions; tasks require a connection between related items
Author(s) and game purpose	Brom et al. (2010); familiarize secondary school players with political, economical and social issues in united Europe
Backstory and production	Players must drive home their EU policies; non-linear progress; game proceeds in rounds; no abrupt playing-learning transition; students prefer to choose their projects; content is real EU issues; game learning material coupled to real world
Realism	Stylized characters matches environment; sound; game replicates state of affairs in Europe 2008; players enjoy choosing and customizing their avatars; game context matches real-world context; students welcome real data; players like imitation crises and scenarios
Interaction	Hypertext encyclopedia; mouse; keyboard; simple interface assists inexperienced players; easy to understand game; player-to-player bulletin board; multi-player on-line game; cooperative; 2D; digital game is followed by non-digital social role-play game
Feedback and debriefing	Teacher as coach; game not stand-alone; HUD with points and metrics shown throughout; immediate policy effects; students test ideas in a practical and safe setting; game activity lectures; debriefing partially during gameplay; classroom discussion on policy changes
Author(s) and game purpose	Brom et al. (2011); Teach high school students the basics of ethology, behaviorism and animal learning
Backstory and production	Students teach virtual dog to wave its leg on verbal command; two more animals as new levels; context is familiar to students
Realism	Hand-drawn models; basic animations; sound; animal behavior biologically plausible; virtual animal learns quicker than in real life; gameplay has same consequence as real life
AI and adaptivity	*Q-learning* algorithm for animal behavior; simple state space causes learning to appear imitated; complex simulations more suited to advanced courses
Interaction	Point-and-click; micro-games must not require special skills to play; expository lecture; interface and control briefly explained; single-player; 2D
Feedback and debriefing	Teacher guidance; game as lecture supplement; immediate animal response to button selection; post-game debriefing
Author(s) and game purpose	Buttussi et al. (2013); Bolster advanced life support (ALS) knowledge through retraining with a serious game
Back story and production	Lead ALS team to save patient; scenarios are realistic; story should be immersive, engaging and embed tuition; content aligned with national ALS training guidelines; iterative prototyping with end user and instructors; scenarios proposed by ALS instructors
Realism	Realistic 3D graphics; sound; animation; NPC interaction; environment is familiar to players; blood splatter; fidelity of patient alone may not be enough to motivate or engage players; graphics and sound were appreciated
Interaction	Point-and-click for selection and character movement; mouse exclusively; 3D environment was easily learned; task selection was quickly learned; 15-min tutorial on how to play; 3D; single-player
Feedback and debriefing	In-game summary and hints for self-correction; help menu lists apt tasks; opportunity to replay levels; post-scenario debriefing of selections; NPC shows patient location; NPCs provide information; immediate cause-and-effect feedback; game actions debriefing screen
Author(s) and game purpose	Byun and Loh (2015); Modify a COTS game tutorial designed to acquaint players with the Neverwinter Nights environment (tested by college students)
Back story and production	Players explore their virtual homes and progress to the fair where they participate in some events; conversation between players and NPCs progress narrative; open-ended
Realism	Sound; animation; high-polygon modeling; weather effects; audial and textual NPC; sound helps learners grasp the situation; human voice cannot be replicated by text; voiceover affects engagement
Interaction	Point-and-click for PC movement; mouse; tutorial prior to game; 3D
Feedback and debriefing	Map showing player location; HUD with inventory list and list of NPCs spoken to shown throughout; highlight around PC; NPCs provide information; appropriate feedback affects player engagement
Author(s) and game purpose	Cheng and Annetta (2012); Make elementary school (grade six to eight) students aware of the negative consequences of taking methamphetamine and learn basic neuroscience

Table 2 continued

Back story and production	Players drive a car after PC ingests meth; driving game paired with 3D model of a functioning brain; players author own learning event; linear progress; learning material relevant to gameplay; plausible virtual context
Realism	Screen depth dimension causes 3D images to pop out; accurate environment; realistic people; mid- to high-polygon modeling; NPC-to-player is textual; game physics match reality; students want game to match entertainment games
Interaction	Rotate with thumb joystick and select; game controller; students thought about virtual brain while playing driving game; interactive virtual brain exhibit; students help each other to play; 3D
Feedback and debriefing	Peer mentoring; opportunity for replay; immediate feedback when trying to stop the car; post-play feat and rationale for performance; color highlighting; textual description of brain functioning; players monitor own learning process
Author(s) and game purpose	Cheng et al. (2014); Impart knowledge to middle school (grades seven and nine) students about the workings of the body's defense system
Back story and production	Players have to defend the body against invading pathogens; four chapters with increasing difficulty level; authentic context; learning objectives set in advance; content input by subject matter experts; users involved during beta-testing for design
Realism	Characters match real life; animation; narration with text; cartoon-style characters; character attributes and game processes match scientific concepts; time limit; experience should be concrete and direct; students rate fidelity as appealing
Interaction	Drag-and-drop; mouse; students found game easy to use; over-involved gameplay detracts from learning effect; complete a learning worksheet; 2D; single-player; game tutoring to help novices
Feedback and debriefing	In-game explanations of the characters; students sought peer and instructor support; self-directed learning; prior knowledge for new challenges; replay opportunity; game design includes play and tutoring; HUD shown throughout and updated immediately; clear explanations
Author(s) and game purpose	Cheng et al. (2015); Assist junior high school (grade seven) students comprehension of biological evolution
Back story and production	Players keep certain species alive so that its next evolution can take place; must adhere to PC traits; cut-scenes convey major events; game context for exploring cause-and-effect; subject matter experts suggested and validated content
Realism	Characters appropriately visualized to reflect their actual morphology; animation; flat art characters; sound; players experience activities as they would in real life; random events or character mutations
AI and adaptivity	Adaptive feedback based on empirical game data to assist gaming-learning interaction is required; database to record student interaction with game (used for analysis and scoring purposes)
Interaction	Point-and-click on PC and make selections from the subsequent menu; mouse; brief introduction character features and habits; help function; single-player; 2D; turn-based
Feedback and debriefing	In-game information of characters always available; score improved with replay; HUD with PC status always shown; map for PC locations; pop-up window communication; trial-and-error for low achievers without affecting course mark
Author(s) and game purpose	Chittaro and Buttussi (2015); Educate passengers on aviation safety and how to survive aircraft emergencies
Back story and production	Players must survive airplane water landing; obey emergency procedure to progress; return to last safe point after fatal mistake; surprise events boost attention and knowledge gain; emotionally arousing narrative remembered better; game based on actual emergency steps
Realism	Sound; high-polygon modeling; NPCs are life-like; lighting effects; accurate aircraft replica; cause-and-effect of gameplay actions replicates real life; blood splatter, NPC facial expressions; sound becomes muffled as player drowns; time challenge suggested
Interaction	Point-and-click selection; mouse only for desktop; Nintendo Nunchuck, swivel chair and head tracker for VR version; puzzle elements and scariness control for future version; desktop version interaction is simplistic and interface is easily learned; 3D; VR version
Feedback and debriefing	NPC prompts corrective behavior; immediate NPC reactions to selection; negative visuals for incorrect actions; textual advice for persistent or irreversible errors; brief description of action before selecting; immediate feedback can result in attitude and conduct change
Author(s) and game purpose	Chittaro and Sioni (2015); Provide recommendations about emergency evacuation of a train station after a terror (bomb) attack
Back story and production	Players must evacuate bombed train station; linear progress; six dangerous situations to negotiated; context must match real-world experience; in-game safety recommendations taken from civil defense materials; protection motivation theory
Realism	Realistic environment; weather effects; NPCs are realistic; audio coupled to visual stimuli; fire special effect; user self-identification with PC; simulation of temporary blindness, tinnitus and dizziness; realistic vocal sounds of distress
Interaction	Nintendo Nanchuck for controlling PC; Wii remote for interaction; controls are easy to learn; practice scene to learn game controls; direction guides for moving PC also present in the practice scene; 3D

Table 2 continued

Feedback and debriefing	Audio-visual negative consequence of player actions; player health shown throughout and updated immediately; immediate textual cause of death messages shown for ten seconds; suggestions must be kept simple; NPC suggestions more effective textual recommendations
Author(s) and game purpose	Connolly et al. (2011)
Back story and production	Gameplay techniques must have real-life value; enable players to take risks with minimal real-world consequence; games are being developed without underlying coherent learning theories
Realism	Aim for authentic social situations; time pressures improve the time it takes for players with intellectually difficulties to make decisions; players should be allowed to choose and customize own avatars
AI and adaptivity	Process learner speech; interpret and evaluate player actions to determine appropriate NPC reactions; AI can assist to provide timely hints and support
Interaction	Interactive narrative among participants is valuable; skill-builder module as part of the game lessens later frustration
Feedback and debriefing	NPCs are good source of hints; game quests can be documented on the screen; game objects can be labeled; feedback should be appropriate to player actions; feedback could be in the form of additional problems
Author(s) and game purpose	Couceiro et al. (2013); Impart knowledge about the internal workings of a computer to first-year (sport science) university students and increase their motivation to learn about ICT
Back story and production	Players solve computer and network instability; narrative maintains player engagement; introductory cut scenes; linear progress; context aligned with target group; players wanted longer plot; too many dialogues are tiring; game skills match real-life skills; content reflects reality
Realism	Objects are realistic but not very detailed; NPCs are realistic with medium detail; sound effects; music; textual NPC interaction; NPC instills time pressure; avatar customization requested; allow choice of playing female hero; graphical improvement or 3D environment suggested
Interaction	Slide menu inventory; point-and-click; interface must be intuitive, consistent with game narrative and easy to navigate; students wanted increasing puzzle difficulty; students wanted more active involvement; multi-player mode should encourage collaboration; 2D
Feedback and debriefing	NPC puzzles hints and other information; inventory with usable content; NPCs provide scaffolding; constructivist; immediate audio-visual during puzzles; NPC assigns tasks to PC via cut scene dialogue boxes; players can test own ideas; progress tracking for remote inspection in future version
Author(s) and game purpose	Dickey (2011); Foster argumentation and persuasion writing for high school (grades 9–14) students
Back story and production	Players investigate death of rich attorney; learners co-construct the narrative with collected evidence; some players rather explored than follow up evidence; players wanted NPCs present to provide richer suspect backgrounds; evidence designed to aid multiple narratives
Realism	High-polygon modeling; lighting effects; town was put in place to give the sense of a complete island environment; 3D games allow players to experience a story through an imagined physical space
Interaction	Point-and-click; environment must provide affordances aligned with the narrative; argumentation pre-writing activities; player-to-player chat interface; some students spoke aloud to one another; map was provided; instructor did not guide students; 3D; cooperative multi-player
Author(s) and game purpose	González-González and Blanco-Izquierdo (2012); Teach physics and chemistry to secondary school students
Back story and production	PCs have unique skills; player actions construct the game narrative; problem solving to progress; gameplay must not be too brief for social learning to take place; game content must be relevant to the game as well as real life
Realism	High-polygon modeling; simulation of a real situation; natural language dialogue; players create own avatar and give it name that is related to their own; 3D; new technologies provide high levels of realism and interactivity
Interaction	Verbal and gestural tools; tasks are challenging but doable; too much time to learn the interface; time for activities was inadequate; PCs communicate in-game; game tutorial available; 3D; collaborative massively multi-player on-line role-playing game (MMORPG)
Feedback and debriefing	Prior knowledge for later complex problems; HUD and player location map shown throughout; information given within context and as needed; teachers track students as unknown avatar; gameplay log sessions; assess own mistakes and reflect its effect on group performance
Author(s) and game purpose	González-González et al. (2014); Learn different didactic contents collaboratively with other players and to support the socialization of hospitalized (or under home-care) students (9–16 years old) with their classmates
Back story and production	PCs have unique skills; complete mini-games to progress; group progress when individual targets are met; new content linked to prior knowledge; playability evaluation by researchers
Realism	Animation; sound; high-polygon modeling; realistic people; chat is enriched with animations and sound; players create their own avatars

Table 2 continued

Interaction	Keyboard for messaging; learnability of the interface was rated low—tutorial mission developed to address this; chat interface; vocal interaction between those in the same room; toolbar explaining F1 to F12 keys; collaborative MMORPG; 3D
Feedback and debriefing	Teacher in person or as an in-game avatar support; peer mentoring; generating understanding over drill-and-practice; collaborative learning; player locations shown on map throughout; chat monitoring for timely intervention
Author(s) and game purpose	Hämäläinen (2008); Teach vocational education students the design process of surface treatment
Back story and production	Players must design four custom hotel rooms; story keeps player motivated; characters and levels integrated into narrative; linear progress; learning tasks scripted into narrative; scripting must allow for learner's own ideas; game skills are also real-world skills; game content matched curriculum
Realism	Authentic working-life tasks; enhancing motivation should not come from increased fidelity; visual outlining of the game added value; illustrative presentation of material was appreciated; players excited about similarities and differences with the real world
Interaction	Puzzle design so that all players participate; tasks complex enough to motivate gameplay; players enjoyed experimenting; visualization mechanic eased cognitive load; more challenging tasks wanted; students sought to return to task for changes; chat interface; voice-over-IP; 3D and 2D; collaborative four-player
Feedback and debriefing	Scripts for dealing with tasks and how to interact; no teacher intervention; students preferred peer over teacher support; collaborative learning; students enjoyed immediate visual result of their selections; teacher is actively involved in post-game reflection
Author(s) and game purpose	Hämäläinen (2011); Enhance understanding of electrical installation in a house and to support collaborative learning processes in a high school vocational context
Back story and production	Authentic context; problem solving mediates interaction; linear progress; alternate solutions; solve wiring diagram puzzles to progress; failure is an option; working-life stories suit vocational games; game skills match real-life skills
Realism	Actual wiring diagrams; game process replicates real-life procedures; consequence of mistakes lead to the same outcome as in the real world; players exist as avatars
Interaction	Some individual puzzles with others designed to induce collaboration; Skype integration; non-verbal interaction through use/movements of avatars and tools; no written instructions; intro scene for practice; collaborative multi-player; 3D
Feedback and debriefing	Peer support through avatar interaction; task scripts; no teacher assists gameplay; constructivist; collaborative learning; map of game stages available; shock for erroneous wiring; player activities are logged; post-game reflection with teacher
Author(s) and game purpose	Hong et al. (2013b); Enhance cultural cognition among pre-primary school children
Back story and production	Children pair items with related attributes to on-screen picture; editing tool for non-experts to help with content; educational aspects designed by pre-primary school children experts and teachers
Realism	Sound, basic x–y movement animation, 2D pictures not high detail; mid-polygon 3D environment; some lighting effects; timer
Interaction	Webcam that captures body movement; simple interface for children to master; more effective when digital learning is blended with physical learning; post-game physical activity; 2D pictures in 3D environment;
Feedback and debriefing	Instructors motivated reserved children; blended learning; immediate score and sound for actions; total score announced and shown after rounds; encouraging post-gameplay words; no penalty for mistakes; learning is recorded
Author(s) and game purpose	Hong et al. (2013a); Advance secondary school students' abilities to recognize archeological objects and motivate them to visit museum digital archives
Back story and production	Players uncover historical objects with available tools; trade-off decision making; five high-risk guesses per game; digging, puzzle and a combination for progress; actual museum content with teacher input; game obeys school curriculum
Realism	Game objects are actual photos of the objects; selectable tools easily identifiable; NPC is a cartoon-like character; textual input; players make real archeology decisions; each tool's action mimics speed and precision of their real-life counterparts; time constraint
Interaction	*P*oint-and-click; players found interface easy to learn; the researchers want to investigate a team format of the game; 2D; single-player; player-versus-player mode is available
Feedback and debriefing	Clock icon with time in text shows remaining time; points updated immediately and shown throughout; picture becomes clearer with every use of a tool; digging too vigorously breaks the image; information made available to players as they required (just-in-time or on demand)
Author(s) and game purpose	Hong et al. (2015); Teach and explain Chinese idioms to elementary (grades five and six) school children

Table 2 continued

Back story and production	Animated and static game variants are tested; string matching puzzle (static); several answers possible; longer thinking periods improved performance; catch fish to make Chinese idioms (animated); players choose difficulty level; players build idioms until out of time
Realism	Animated fish; fish and decorations stylized; time limit; animation commits idiom to memory; more on-screen game objects increases gameplay anxiety; animation prompts students to react quickly, decreasing thinking opportunity
Interaction	Type with keyboard (static); point-and-click (animated); high degree of learner control positively influences motivation and performance; increased practice time improved performance; students were informed of the nature and rules of the games; 2D; single player
Feedback and debriefing	Students had to come up with their own strategies (static); learn through experimentation; HUD with remaining time, score and current fish in net (animated) immediately updated and shown throughout; players given a list of all the correct idioms they formed for reflection
Author(s) and game purpose	Hwang et al. (2012a); Promote learning performance of elementary school (grades five and six) students in butterfly ecology
Back story and production	Board game links to web-based mini-games; players progress by completing task linked to square they land on; issue to be investigated must be determined first; teachers examine question suitability; content not on the web was manually prepared
Realism	Rudimentary board with spaces to land on; images of birds, butterflies and locusts are copy-pasted onto the board; player avatar is a line drawing representing a person; time limit
Interaction	Drag-and-drop; point-and-click; mouse; students felt game is easy to use; jigsaw puzzles for single concept; matching game for connected concepts; brief overview of learning tasks and gameplay before starting; 2D; turn-based; also played as competitive multi-player
Feedback and debriefing	Leaderboard and player score shown throughout; learning system within game guides players to correct answers; immediate feedback upon answering; task information shown when players land on a board space; post-learning activity; player learning portfolios in database
Author(s) and game purpose	Hwang et al. (2012b), (2013b); Foster elementary school (grade five) student's competence in identifying plants
Back story and production	Players look for plants to counter poisoned water; narrative matches student learning styles; global style have open-ended progression; sequential style progress linearly; storyline motivated learning; content aligns with curriculum; user-designed games recommended
Realism	Color and texturing; low-detail accurate NPCs; learning material actual photographs; authenticity is a characteristic of effective serious games; students felt learning content was provided in a vivid way; role-playing aspect made for more realistic experiences
AI and adaptivity	Adaptive navigation support according to each student's pre-recorded learning style; not done dynamically (game cross-checks database player profile and selects appropriate navigation for gameplay)
Interaction	Point-and-click; game was easy to get familiar with and operate; stages become progressively more complex; learning tasks challenged players; players highly accepted the user interface; introductory stage to show learning tasks, rules and game functions; 2.5D; single-player
Feedback and debriefing	NPC hinting; game provides textual and graphical hints; learn by doing; repertory grid provides a single view comparison; wrongly classifying a leaf prompts game to immediately display a leaf of the erroneous classification and guide the player further
Author(s) and game purpose	Hwang et al. (2013a); Impart knowledge about the butterfly life cycle to elementary school (grade six) students
Back story and production	Players collect pieces of a butterfly life cycle map; mini-games to finish some missions; players take a test to progress; concept mapping must be grafted into scenario to avoid game disruption; game tasks comply with learning objectives
Realism	Low-detail PC; ambient objects are clearly recognizable; texturing; high-polygon 3D modeling for fight scenes; wasps are accurately modeled; enjoyable multi-media adds positively to the learning experience
Interaction	PC walks into the game objects to commence interaction; type; concept mapping did not significantly impact on learning motivation; learning sheet ends each gaming stage; 2.5D and 3D; single-player
Feedback and debriefing	In-game concept map template; revisit content to modify learning sheets; immediate health status updating; instant text feedback for finding object; feedback should be meaningful; database stores player task feats and used as inventory
Author(s) and game purpose	Hwang et al. (2015); Instill financial management principles among elementary school (grade six) students
Back story and production	Players look after families by investing; experiment without real-world effect; recovery from wrong choices; linear progress and exploring within stages; learning material relates to story; content conveys course outcomes; game skills match real-life skills

Table 2 continued

Realism	Color and texturing; people characters are low detail but accurate; authentic outcomes from user actions; role-play leads to authentic experiences; competition prepares students for real life; text-based NPC communication; 2D meets school's computing power
Interaction	Point-and-click; a complex 3D interface may hinder learning in elementary school students; introductory stage to show learning tasks, rules and functions in the game; An opaque textual overlay guides players to their next task 2.5D; single-player
Feedback and debriefing	In-game hints and learning guidance; learn by doing; anytime referencing of learning material; immediate visual investment results; HUD with score shown throughout; score feedback can stimulate reflection; database stores player task feats; reflective activity after the game
Author(s) and game purpose	Johnson and Mayer (2010); Help college students learn how electrical circuits work
Back story and production	Players progress from one puzzle to the next by answering the question and providing a reason for their answer; learning improves with worked examples or visual maps
Realism	Sound; timer (but no time limit); wiring diagram puzzles are identical to real-life wiring diagrams; agent communication should conversational, polite and spoken over formal, direct or textual
Interaction	Point-and-click; drag-and-drop; type; mouse and keyboard; answer elaboration enhances learning; generating reasons for answers caused too much flow disruption; experimenter explained how to play the game; 2D
Feedback and debriefing	Reference sheet; game is not stand-alone; immediate sound and points; HUD (score, time and level) shown throughout; points report after levels; directive feedback may affect learning; button presses recorded; self-explanation induces reflection
Author(s) and game purpose	Ke and Abras (2013); Provide an engaging mathematics learning experience for middle school children with special learning needs; three web-based games were used
	Ker-Splash (KS); Lemonade stand (LS); Lure of the Labyrinth (LL)
Back story and production	Build expression with highest value (KS); earn money with lemonade stand (LS); free a pet (LL); linear (LS and LL); learning content must relate to story and mechanics; adventure story with mysterious characters appealing (LL); players lost interest without internal scaffolding (KS); multiple answers and partial success enjoyed (KS); players enjoy determining their own narrative progress
Realism	Cartoon environment (KS); music (KS); low-detail accurate modeling (LS); sound (LS); stylized environment fits with NPCs (LL); facial expression (LS and LL); NPC utterances (LS and LL); relevant math (LS); excitement about creating avatars and choosing pets; rich game-world distracted children from learning; rich audio-visuals seen as positive feature; speeded challenges not liked
Interaction	Eliminate unimportant tasks; reward skill development; avoid complex games for children with learning difficulty; avoid too many visuals and content partitions in game interface; game strategy and achievement shared with others; pre-game demo and orientation advocated; enough help on game navigation must be available; 2D (KS); 2.5D single-player (LS); 2D single-player (LL); turn-based (KS)
Feedback and debriefing	Mentor and peer support; constructivist; HUDs shown throughout; constant status information; immediate score, visual and auditory feedback; mentors gave feedback between moves; mentoring was sometimes intrusive; simple texts for direction worked well; students suggested informative learning feedback; in-game help should be provided as needed; graphs designed for reflection
Author(s) and game purpose	Ke and Grabowski (2007); Support primary school (grade five) students in learning basic arithmetic and problem solving
Back story and production	Fantasy is contextually relevant
Interaction	Cooperative gameplay favored over competitive gameplay; orientation session for reading guidelines and trying the games; single-player
Feedback and debriefing	Peer cooperation made the mathematics appropriately difficult; cooperative learning approach (Team-games Tournament)
Author(s) and game purpose	Ke (2008); Applying drill-and-practice mathematics games to promote mathematics learning outcomes for elementary school (grades four and five) students; eight games were used
Back story and production	In-game tasks for story progression; interest drops when learning is outside game context; learning embedded within the game story; story must provide scaffolding; game skills match real-life skills; drill-and-practice games more easily integrated into the curriculum than simulation games
Realism	Sound effects, graphics and other sensory stimuli will become familiar and their attention-grabbing properties will diminish; role-playing enhances students' positive attitudes toward math learning
AI and adaptivity	Scaffolding and debriefing to encourage reflection can be attained by informative feedback adapted to individual performances

Table 2 continued

Interaction	Levels become progressively more difficult; mechanics should not encourage guessing; more effort during game tasks within player capabilities; high stakes spurred task effort; compelling goal promotes engagement; basic computer skills taught if required; orientation session to familiarize with games
Feedback and debriefing	Active support for students with lower prior knowledge; think-aloud strategy; right instruction at the right moment; auto-feedback must not hamper gameplay; elaborate over summative feedback; post-game debriefing transforms game event into learning experience; game metrics recorded for analysis
Author(s) and game purpose	Ketamo and Kiili (2010); Teach mathematics concepts to elementary school children
Back story and production	Player teaches pet math; player pets compete against other player pets; competition challenge is automatically accepted; freedom teaching the agent; multiple strategies possible; recovery from mistakes; breaks in gameplay facilitated conceptual change
Realism	Classroom is realistic; sound; mid-polygon modeling; shadows; game replicates human-like guesses; agent is a pet octopus with facial expression and body posture to convey victory and loss
AI and adaptivity	Teachable agent reasons from what it is taught; player shows correctness of agent guess; agent learns inductively; at a given concept size it can conclude; wrong teaching can be fixed; AI network is pruned to limit computational cost
Interaction	Point-and-click; mouse; social dialogue must be part of game design; players need to be engaged as long as possible; players were encouraged to talk to one another during gameplay; 3D models in a 2D environment; competitive multi-player
Feedback and debriefing	Learning by teaching; knowledge level visual immediately updated and shown throughout; competition mode indicates agent skills and misconceptions; status reminder; guided discovery better than pure discovery learning; agent answers in contest mode prompt reflection
Author(s) and game purpose	Kickmeier-Rust and Albert (2010); Verpoorten et al. (2014); Teach optics to secondary school (grade eight) students
Back story and production	Players must save a girl and her uncle from kidnappers; experiment freely; game-world exploration; learning must be convincingly embedded in the game scenario; narrative must not have breaks; content is based on curriculum
Realism	Modeling and texturing is comparable to commercial entertainment games; some textual feedback
AI and adaptivity	Non-invasive assessment of knowledge; micro-adaptation; games should adapt to player prior knowledge, learning progress, motivational states and gaming preference; game updates competence states
Interaction	Point-and-click; mouse; players had to use what was learned at the experiment table later in the game; players were briefed about the game, confidence degrees and the slope device; 3D
Feedback and debriefing	NPC hints and feedback; textual pop-ups on task completion; HUD displayed throughout; feedback can decrease cognitive load; tailored feedback enhanced learning; short reflection episodes; confidence ratings as reflection amplifier
Author(s) and game purpose	Kiili and Perttula (2012); Improve logical and mathematical tasks among elementary school (grade three) students
Back story and production	Player fish eat fish with answers to gameplay questions; players progress to more difficult levels by eating a number of "right" fish; whole class cooperated against the game itself
Realism	Fish are drawn caricatures; environment resembles an ocean bed; low detail artwork
Interaction	Running and standing still; mobile phone; age-appropriate tasks; interface easily learned; motivation to perform boosted by class spectators; students debated answers; 2D; exergame; single-player
Feedback and debriefing	Peer mentoring appreciated; HUD with score, the question and number of lives shown throughout; the use of mobile phones as controllers can be extended to displaying personalized texts or using voice feedback
Author(s) and game purpose	Kiili (2005); Determine the usefulness of content creation in a game environment for university students
Back story and production	Players produce learning material about usability; three game phases; players like interesting stories; points are not enough to motivate gameplay (players value intrinsic motivation); game skill matches real-life skill
Realism	Text-based; menu-driven; no sound or visual stimuli; time pressure (deadlines); players did not require audio-visually rich games; if the game achieves flow, it will be an effective learning tool
Interaction	Laborious and difficult for some; content creation and market place induced flow; remove usability errors; intuitive controls; climate of collaboration should surround a collaborative game; discussion area for players; cooperative multi-player
Feedback and debriefing	Teacher breeds collaborative culture; game not stand-alone; constructivist and pragmatist; random boss messages; industry experts gave post-game feedback; players want to know game status; cut out slow feedback; player status reports
Author(s) and game purpose	Knight et al. (2010); Assist in the education of trainees in major incident management

Table 2 continued

Back story and production	Players must tag bomb casualties with appropriate priority; open-ended; experts and the users involved in play-testing; pilot testing revealed experts and users should have been involved sooner
Realism	Photo-realistic patient model; game is based on a system that emergency responders use in real-life; realistic looking injuries in high detail; target time per casualty
Interaction	Point-and-click; mouse only; 15 min tutorial on gameplay; gameplay assistance was available; single-player; 3D models in a 2D environment for patient interaction
Feedback and debriefing	Learn by playing; activity summary after patient; text-based feedback; visual reminder of the victim; feedback was too complex; post-game review screen enables reflection
Author(s) and game purpose	Kuk et al. (2012); Enhance the computer graphics course taught to first-year vocational studies students
Back story and production	Pedagogical agent decides (based on a pre-defined score) if player may progress to a new level
Realism	The camera is a photo of a real camera; color to indicate selections; visual effects; time pressure; surroundings conform to age and prior knowledge of end users; agents should poses voice, emotion and ability to learn
AI and adaptivity	Markov decision process for model tracing; reflex agent; user model reveals player state; slight agent intervention better than no intervention; correct answers increased after agent interventions; progress tracking updates user model
Interaction	Point-and-click; mouse; gaming interface should be familiar to players; 2D; single-player
Feedback and debriefing	Pre-game content lecture; agent decides when to show textual help window; HUD with score and time shown throughout; agent help when needed without irritating players; textual messages had the same effect as animated agents
Author(s) and game purpose	Papastergiou (2009a); Teach computer science content (other than programming) to high school students
Back story and production	Players navigate through mazes; answer questions to progress; linear progress; students suggested a more adventurous plot; game content matches curriculum
Realism	Realistic 3D graphics avoided; music; sound effects; learning material has text, images and animation; complexity and attractiveness may distract players from learning tasks; 3D graphics, more sounds and music requested
Interaction	Interaction intended to be simple; easy to learn interface; greater variety of events and more competition requested; game tips shared; no written direction or technical skill needed; brief oral instruction; 2D; single-player
Feedback and debriefing	Hypermedia learning material; instructors should be given appropriate training on game use and design aspects; immediate explanatory feedback upon answering questions; lives and score shown throughout
Author(s) and game purpose	Sadler et al. (2015); Develop interest in learning science and bring about understanding of core biology concepts to high school students
Back story and production	Players must identify cause of a viral outbreak; scaffolding is part of the narrative; four successive levels; conceptual complexity increases with each level; game could serve as anchor for a game-based curriculum
Realism	Game environment is modeled after a real-world laboratory facility; mid-polygon modeling; realistic people; players can interact with NPCs; real-time game activities
Interaction	Laboratory exercises outside gameplay; brief lectures; formative assessments; NPCs serve as guides; 3D
Feedback and debriefing	Teach teachers how to implement games; NPC laboratory assistants; short-content lectures prior to game; inventory list; facility map and NPC locations shown throughout; post-game classroom chat; cite that tracking student progress allows optimal timing of custom feedback
Author(s) and game purpose	Schmitz et al. (2014); To foster the ability for at-risk learners (some post-school) to utilize commonly used application software (i.e., MS Office)
Back story and production	Players help construction foreman with documents; option to answer SMS questions; SMS answers link to game; questions are in the context of the construction game; questions stem from European Computer Driving License test
Realism	Low-detail 3D modeling; sound and music; time pressure; players edit their own avatars; questions sent by recognized SMS format; target group would have preferred state-of-the-art mobile game with an appealing interface
Interaction	SMS question response; point-and-click; mobile phone; mouse; players used SMS questions as cooperative tasks; pervasive gameplay appreciated; clear SMSs with four answer options; 3D; single-player; asynchronous coupled game
Feedback and debriefing	Hints also via SMS; content database available from the browser part of the game; alienating the classroom; immediate correct answer sent once player responds; HUD shown throughout; rival scores shared; game-generated event logs
Author(s) and game purpose	Schmitz et al. (2015a, b); Give school children (ages 11–14) an understanding of cardio-pulmonary resuscitation (CPR) and giving them the confidence to act in an emergency
Back story and production	Two-person team must find and resuscitate a manikin; SMSs inform players of emergency and progress; synchronized SMSs support collaboration; surprise events; content tails European Resuscitation Council guidelines; experts validated content; play-testing with users for design tweaks

Table 2 continued

Realism	Real environment with real equipment and CPR manikins; time pressure; role-playing heightens immersion; inappropriate rich elements cause cognitive overload; players wanted audio to avoid switching between phone and real world; time-critical tasks is strong motivational factor to play
Interaction	Physically get to emergency; mobile phone; tasks overlooked through high workload; lengthier intervals between SMSs; video messages skipped due to long download times; verbal introduction and basic directions on using the device; collaborative two-person game; real-time game
Feedback and debriefing	Process via SMSs; player tracking and mobile device afforded support at all times; active learning approach; game does not replace CPR training; drill-and-practice; avoid redundant SMSs; special education needs requested a checklist for constant game status; progress tracking for debriefing
Author(s) and game purpose	Serrano-Laguna et al. (2014); Teach persons with psychical disabilities daily life skills and habits; due to limited details we did not analyze this study's other game that teaches XML
Back story and production	Players begin in their virtual bathrooms where they need to get ready for a work party where they will have to mingle with their co-workers; game analytics recorded to determine where gameplay experience could be improved
Realism	Scenes are actual photographs
Interaction	Type; point-and-click; mouse
Feedback and debriefing	Instructors provide scaffolding; game traces build the assessment system for automated timely feedback; cull irrelevant data before storing; mouse-click heat map gives visual of game actions; firewalls and proxy can hamper progress tracking;
Author(s) and game purpose	Soflano et al. (2015a, b); Teach the basics of the database programming language Structured Query Language (SQL) to undergraduate students who have no knowledge of SQL
Back story and production	Players gain warrants of arrest based on information from SQL queries; retry chance provided; players still receive warrant if SQL query remains incorrect; SQL query learning material blended into game story as challenge;
Realism	High-detail environment; realistic people characters; NPCs reply according to gameplay performance; parallels between gameplay and real-life investigations; textual NPC interaction; players create own avatars
AI and adaptivity	Content presentation style adapted to player liking; player preferred style built at every conversation; adaptivity can improve learning value; autonomous adaptivity cut gameplay times; interaction log files form basis of adaptive games
Interaction	Type SQL queries into a text box; point-and-click; keyboard shortcuts; mouse only for movement and fighting; keyboard for typing; in-game journal listing key locations and other details of the missions; 3D; single-player
Feedback and debriefing	Textual NPC feedback; map that shows mission locations and points out important characters and their locations shown throughout; game missions give players the opportunity to test their acquired knowledge
Author(s) and game purpose	Squire (2013); Three game types discussed; non-violent conflict for human rights; show high school students exciting accounting careers; teach vehicle options to sellers
Back story and production	Use cut scenes; context allows failure and recovery; open-ended; focus less on content and more on experience; episodic levels as refresher; invite learner to participate in design meetings
Realism	Use language players are familiar with; abstraction of reality must remain plausible; realistic parts; time pressure; artwork to elicit emotion
AI and adaptivity	End-user model based on data gathered in situ; gather user choices for custom content; intelligent tutors for guiding gameplay
Interaction	Create challenges one step ahead of player skill; facilitate player discussion; scaffolding; affinity groups for complex interfaces; 2D, 3D and 2.5D (respectively); single-player and collaborative multi-player
Feedback and debriefing	Knowledge comes from activity in relation to prior experience; entice failure tied to player misconceptions; negative game consequence; graphics convey a problem; explain choices in social setting as reflection
Author(s) and game purpose	Torrente et al. (2009); To show effectiveness of linking gameplay with learner management systems
Back story and production	Learning contents as self-contained distributable learning objects; <e-Adventure> editor allows instructors to focus on pedagogical aspects of the game
Interaction	Point-and-click; games can also be integrated with other learning object types (e.g., containing web-based content) to suit players who may not benefit from pure DGBL
Feedback and debriefing	Staff preparation is essential for implementing DGBL; player tracking usefulness is dependent on the communication protocol of the learner management system
Author(s) and game purpose	Torrente et al. (2014); Game modification according to the needs of players with physical disabilities (hearing, eyesight, mobility and cognitive); the main aim is to reduce the anxiety felt by people with disabilities when they enter a new environment

Table 2 continued

Back story and production	Players must perform several assignments on their first day at work; control narrative pace or alternative difficulty levels for cognitive disability; additional content to fully support the various disabilities; accessibility should be considered a priori when designing games
Realism	High-contrast, large text and luminosity (low vision or color blindness); sound-to-text and sound radar (hearing loss); speech recognition (blindness and limited mobility); audio and haptic feedback (blindness); text-to-speech voices criticized; intuitive speech recognition commands
AI and adaptivity	Game adaptivity for special needs is a serious challenge
Interaction	Games should remain keyboard-controlled for non-disability players; errors in accessibility options cause frustration; reduce stimuli for cognitive disability; interaction should be slowed for limited mobility; extra tutorials explaining accessibility interfaces a; 2D
Feedback and debriefing	Blind players often encounter feedback as a gameplay barrier; symbols instead of color for feedback; audio feedback can be replaced by subtitling or close captioning; sound radars to indicate direction and intensity of sound cues
Author(s) and game purpose	Van der Spek et al. (2013); Game to supplement traditional triage training
Backstory and production	Players categorize victim injuries; light narrative; surprising events before new concepts; linear progress; surprising events aids text comprehension; triage system abstracted to keep it learnable in a short space of time
Realism	High-detail environment and victims; sound; animation; textual communication; lighting effects; real-life limitations reflected by game; content to illicit emotion; timer
Interaction	Point-and-click; mouse; navigation and actions can make learning a challenge; gradual increase in difficulty; surprising events did not increase subjective difficulty, engagement or enjoyment; 3D; single-player
Feedback and debriefing	Experiential learning; triage buttons provide textual description and value for current victim; textual review of performance and score update after categorizing a victim; text messages inform players of game situational changes
Author(s) and game purpose	Van Eck (2006b); Improve the self-efficacy and attitude of middle school (grades seven and eight) students toward mathematics
Backstory and production	Players must calculate resources for remodeling job; players can choose to work on any wall or ceiling panel at any time (open-ended); support aids competition to make players function beyond their ability; content aligned with curriculum
Realism	NPCs are real people on video; NPCs are presented to scale; player-to-NPC communication by list selection; time pressure; players choose competitor traits; modeling human-like pedagogical agents may not be worth it; players want support that exhibits social cues
Interaction	Point-and-click for movement and tool use; keyboard for formula completion; tool icons did not hamper view; two minute interface introduction video by NPCs; five minute practice tutorial; 2D; single-player
Feedback and debriefing	NPC support not AI driven; in-game reference book of facts and formulas; in-game calculator; NPC opponent communicates his status; immediate feedback was available at the point when players required it; data stored for later retrieval
Author(s) and game purpose	Virvou and Katsionis (2008); Virvou et al. (2005); Teach geography to primary school children; a second version of the game includes a reasoning diagnostic and tutoring component
Backstory and production	Players navigate several virtual worlds; answer questions to progress levels; reasoning in the system's diagnostic process is part of the game plot; players wanted a game similar to commercial games they are used to; content matches curriculum
Realism	Low-detail surroundings; high-detail image of a dragon; sound; textual questions; speech or text windows for animated agents; players enjoyed engaging with voice-enabled tutor; character animations distracted players; more background sounds requested
AI and adaptivity	Negotiate if answer is unsure; points based on accuracy of player reasoning; answer list ensures students stay within the game's knowledge domain; no system can imitate diagnosing and explaining abilities of a real teacher
Interaction	Keyboard to navigate and respond; point-and-click; complex game worlds can hamper learning; novice players struggle with controls; practice level suggested; game errors decreased learning and likeability; novice players used interface elements less; 3D; single-player
Feedback and debriefing	Game objects provide hints; virtual companion; memorize facts for later use; games as classroom additions; selectable map shows game-world, player location, locked doors and hint sites; tailored feedback via virtual companion; computer logging for usability evaluation
Author(s) and game purpose	Zin and Yue (2013); Impart knowledge about the history of the development of Europe to secondary (form four) students
Backstory and production	Players travel to European epochs to solve problems; teleport to different eras; solve problems to return to the current world for next teleport; historical facts are all accurate; content matches syllabus; teachers and users in requirements phase

Table 2 continued

Realism	Animated cut scenes introduce epochs; static backgrounds; modeling is based on each epoch environment; NPCs communicate via textual speech bubbles; game helps to visualize historical events; audio preferred over reading; audio and illustration pique curiosity
Interaction	Players are not interested in games with complex controls; game rules are easy to understand; easy to learn interface; game is designed so that players don't bother each other; explanation and clear rules are important; 2D; single-player
Feedback and debriefing	In-game help and tips; immediate feedback after answering a question; some textual labeling about the environment; feedback must be at the correct time (when students need it); feedback for wrong answer can encourage continued gameplay

4 Findings and discussion

From the initial content breakdown, the 63 articles (comprising 55 unique games) under review discussed learning areas such as knowledge transfer, behavior change, affective impact and soft skills (e.g., communication, collaboration or managerial) acquisition; no motor skill acquisition games were encountered. Most of the attention was given to knowledge transfer (28 games), followed by soft skills acquisition (15 games) and behavior change (8 games). Very few studies were dedicated to affective impact (4 games). Admittedly, with serious games, it is possible to have primary and secondary learning areas within a single environment. For instance, it may occur that a game wishes to affect behavior change toward diet and physical activity, but to do so requires a knowledge transfer about healthy foods and exercise. We focused only on the primary aims of the reviewed games.

An explanation for the overwhelming majority of studies dealing with knowledge transfer may lie in the target audience and purpose of the serious games in the reviewed articles. The researchers have classified the target audience by their level of education at the time the games were researched. Only one game was aimed at a pre-primary audience, 18 games were implemented among primary (elementary and middle) school students, 17 games at high (secondary) schools, six games at under-graduate studies and the remaining 13 games were geared toward further professional development or training. The reason most often cited for the school games was to assist students in mastering subjects that have a history of poor achievement.

Content analysis also unexpectedly (given the relatively lower production cost of 2D games) revealed that 2D and 3D games are almost equally common (18 and 22 games, respectively) with five games making use of a pseudo-3D (2.5D) environment and six games combining 2D and 3D styles within a single game. Two games were physical games, which required no screen-time gameplay, but relied on communication through mobile technology instead. The last two games are not clearly defined and have no accompanying screen depictions.

The following section synthesizes the data from Table 2 into a comprehensive reporting of the most recurring points raised under each of the serious game themes. The limitations of the study, practical guidelines conclusion and suggestions for future research succeed these in-depth discussions on backstory and production; realism; AI and adaptivity; interaction; and feedback and debriefing.

4.1 Backstory and production

The backstory, or game narrative, refers to the storyline and game-world players encounter and expectantly immerse themselves in as they play the game. More than this, the narrative is what players attempt to uncover to progress in the game. Where audio-visual techniques seize the attention of players, it is the story or plot that keeps them engaged (Couceiro et al. 2013) and motivated (Hämäläinen 2008) to return to the game once the novelty of the captivating graphics and sound wears off. Ke (2008) observed that sensory stimuli become familiar and their attention-grabbing properties diminish. The importance of narrative with regard to learning can, therefore, not be overlooked—if the game is being played, it implies engagement with the learning material. A good story, however, does not imply credible learning. Learning must be stealthily integrated into the appealing storyline (Ke and Abras 2013) without disrupting the player's immersive experience. Players become frustrated, and as a result are reluctant to play the game, when confronted by distinct breaks between learning and playing activities (Brom et al. 2010; Hwang et al. 2013a). This dilemma can be resolved through ensuring that the intended learning material (real-life skill) is mirrored by the knowledge or skill required for progressing in the game narrative (Cheng and Annetta 2012; Couceiro et al. 2013; Hämäläinen 2008; Ke 2008). By illustration, if the game's intention is to teach safe laboratory practices, the game's narrative should only be allowed to progress if the player displays the correct behavior within the game. Linking the game's reward mechanic directly to the desired learning outcome further reinforces the intended impact (Kiili 2005).

Players enjoy crafting their own narrative. Not in the sense that they want to be the story writers, but rather that they prefer not to be led through the game in a linear fashion. Linear gameplay entails progressing from one game scenario to another in a fixed sequence, which remains unchanged with every restart of the game. Moreover, players are excited by the opportunity to explore and to mold their own narrative (Ke and Abras 2013; Kickmeier-Rust and Albert 2010; Verpoorten et al. 2014)—another motivating feature drawing players back to the game. However, one study showed that learning style might be a determining factor for the preferred type of progression. Hwang et al. (2012b) found significantly better learning results among students who played games personalized to their learning styles than those who learned from games not meeting their learning styles. This places serious games makers in a predicament. Creating an exclusively open-ended or linear game is bound to alienate a subset of the game's target audience, lowering the learning effectiveness of the game where serious games should pursue maximized learning effect. Having said this, and keeping the player desire for control in mind, serious game producers should give players the option to choose which progression version of the game they wish to play, or perhaps more elegantly, let the game adapt to the learning style of the player. True, it means that two alternate versions of the game are required, but through game design, costs can be restricted to possibly a matter of locking and unlocking scenarios with minimal game asset differentiation between the two versions. Torrente et al. (2014) expresses the value of this technique in the context of making a game playable by users with cognitive disabilities. We are inclined to believe that the perceived value of learning gain could outweigh this lock–unlock technique's development cost increment.

We have ascertained that narrative keeps players involved with the learning material (or content), but the storyline must be coupled more closely with the content as opposed to just being an attractive presentation thereof. The narrative must deliver a fitting context for the learning material (Bellotti et al. 2012; Cheng et al. 2014; Couceiro et al. 2013). It makes no sense to devise a story and to plot centering horse-riding when the learning content involves dental hygiene. These bi-lateral game personalities confuse players, add extra cognitive load, diminish immersion and curtail their enjoyment. Ke (2008) found such exogenous fantasy less effective in promoting learning than storylines engrained within the context of the learning material. In addition, a number of studies advocate uniting serious game content with a curriculum or professional training material (Hong et al. 2013a; Papastergiou 2009a; Van Eck 2006b; Virvou and Katsionis 2008). This is in contrast to research which shows that analogy facilitates learning (Donnelly and McDaniel 1993; Gentner and Holyoak 1997; Mayo 2001). This review did not encounter any evidence that could argue for or against analogy-driven serious games. We nevertheless posit that extrinsic motivation, apart from in-game rewards, progress metrics and status, drives the will to play serious games as much as intrinsic motivation (personal interest in playing a game). Players would more likely engage in serious gameplay if they could earn extra course credits. They could subsequently attribute improved formal assessment of their competencies to the skills and knowledge they have gained through gameplay.

Serious games, much more so than entertainment games, are aimed at very specific well-defined target playing groups, each with their own set of whims and requirements. The value of involving the end user in the design and playtesting production phases (Schmitz et al. 2015a) of serious games, both for physical attributes and storyline, is immeasurable and recommended (Hwang et al. 2013b). Studies implementing user-collaborative design strategies (Arnab et al. 2013; Buttussi et al. 2013; Knight et al. 2010; Squire 2013) not only evidenced success in transferring knowledge or abilities, but also received affirmative feedback regarding gameplay satisfaction. Knight et al. (2010) claimed that involving the user even earlier than the first pilot trial in the design process would have saved considerable time during subsequent development-evaluation-refinement iterations of game production. Several articles express subject matter experts as another valuable inclusion to the production side of serious games (Arnab et al. 2013; Cheng et al. 2014; González-González et al. 2014; Schmitz et al. 2015a). Serious games, or games in general for that matter, cannot render every aspect of gameplay exactly as it would be in real life (something simulators strive to achieve), hence requiring some in-game abstraction. Implementing abstraction without harming the learning effect of the game requires expert understanding of the content. Just from a time perspective, and given the wide range of disciplines and topics applicable to serious games, developers should turn to subject matter experts every time a game is made. Lastly, a variety of teaching and learning approaches and theories are broadcast, yet barring Hong et al. (2013b); little mention is made of pedagogical experts ensuring their unyielding integration into the game.

4.2 Realism

Realism stipulates how close a game under scrutiny replicates or resembles real life. Since an extensive discussion of fidelity is beyond the scope of this article, it suffices that we define realism as the *physical* (graphical and audial aspects), *functional* (simulation accuracy and non-player character (NPC) response) and *psychological* (noise/

interference, emotional content and time pressure) dimensions of fidelity. We established fidelity preferences from careful consideration of presented screens, qualitative (sometimes verbatim) reporting of player feedback and descriptions offered by the authors. Triangulating the data within and between groups of articles led us to conclude that from a pure gaming perspective, the higher the fidelity of the game (i.e., the more realistic the game), the higher the game appreciation. From a learning perspective, this statement becomes significantly less certain as other authors claim that overly rich presentation of the context distracts students from in-game learning tasks (Ke and Abras 2013; Papastergiou 2009a; Virvou and Katsionis 2008). Kiili (2005) declares that players do not require audio-visually rich games, and as long as the game achieves flow, it will be an effective learning tool. This is in direct contrast to multiple studies showing game screenshots with high-polygon modeling (Chittaro and Buttussi 2015; Verpoorten et al. 2014) and describing detailed game sounds (Chittaro and Sioni 2015; González-González et al. 2014; Van der Spek et al. 2013). Some insist that accurate 3D modeling and realistic sound help players understand and experience the physical space (Baranowski et al. 2011; Byun and Loh 2015; Dickey 2011). All-in-all, this presents serious games makers with another hard-to-solve puzzle. Keeping with the visuals, we encountered in the articles, yet another layer of fidelity complexity comes into play. It is evident that physical fidelity is dependent on the age (or possibly the learning level) of the target players. Games aimed at pre- and early-elementary school children clearly contained unsophisticated 2D graphics with distinctly more stylized artwork. Although we cannot provide an accurate portrayal of the evolution of the visuals (due to a limited number of articles), the physical fidelity of games at high school level and beyond was decidedly more complex and real-looking (most often in 3D). Therefore, we suggest that serious game designers take the age of their target audience into account, before deciding on a serious game's physical fidelity assets. More holistically, we advocate that serious game designers involve their playing audience from the outset when designing a game. With such narrow target audiences, serious game designers may find very specific cultural nuances and environmental conditions that influence fidelity preferences. Notwithstanding age, culture or environment, we did find that players demand more sounds (Papastergiou 2009a), better graphics (Couceiro et al. 2013) and more credible and varied NPC responses (Johnson and Mayer 2010). In such instances, we suggest creating games which are high in realism without overcluttering the game world with unnecessary objects. Annetta et al. (2009b) support this view when suggesting a realistic game-world presentation with less emphasis on animation, text and audio that does not aid learning. Bellotti et al. (2009) advocate a highly realistic game environment focusing solely on the learning aspects. In this way, both the learning and gaming camps of serious games can rest assured that players will be eager to play without the risk of detracting from learning efficacy.

Players enjoy fashioning their own narrative. This desire for control extends to the player character (PC)—frequently part of successful serious games (Alamri et al. 2014; Bellotti et al. 2009; González-González et al. 2014; Schmitz et al. 2014; Soflano et al. 2015a). Creating their own avatars excites players (Brom et al. 2010; Ke and Abras 2013). Avatar personalization provides an opportunity for players to create a unique reflection of themselves, their perceived selves or (most likely) desired selves within the game (Gee 2005). All of this stimulates a sense of player relevance and game immersion (González-González and Blanco-Izquierdo 2012), in turn promoting motivation to play and therefore increases engagement with the learning material. We are aware that the option of creating highly sculpted avatars is a tall order for serious game developers due to budgetary, resource and time constraints. With this in mind, we propose a three-tier hierarchy of avatar distinctiveness options; at the top is detailed avatar creation; second is avatar customization which enables the changing of ready-made characters in terms of clothing, hair color and ethnicity; and third is avatar selection where a player could choose an avatar from a prepared range of characters. That players want the option of a unique PC is undeniable, and it is furthermore imperative that both male and female avatars can be realized in order for both genders to have an enhanced PC experience during gameplay (Couceiro et al. 2013).

Engaging with non-player characters (NPC) is vital to serious games. NPCs are game companions and can be in the guise of peer players (in multi-player games) or game-controlled characters with roles varying between guiding gameplay, conveying/explaining learning material or humorous distractions. Given these NPC roles, communication between players and NPCs is a resounding functional fidelity focus. The primary modes of NPC-to-player communication are textual or vocal, while player-to-NPC remains textual. We did not encounter voice recognition for player-to-NPC communication during this review. Only Torrente et al. (2014) at length spoke about this technology in the context of assisting players with limited mobility to control the PC's movement. We therefore focus our discussion on the NPC-to-player direction of communication. Players prefer NPCs to interact with them through voice rather than text (Johnson and Mayer 2010). This is once more in line with the overarching sentiment of players wanting more realistic games. We safely reason that NPC voice communication is less flow-disruptive than text; predominantly owing to the time it takes to read the text and the additional cognitive load, this activity creates. From a learning perspective, players are accustomed to facial expression and intonation in their traditional education settings and know how to interpret these social cues. They, hence, enjoy engaging with support that offers information and encouragement through social cues (Van Eck 2006b). Byun and Loh (2015) point out that voice-overs positively affect play-learner engagement and that text is unable to replicate intonation, pauses and emotion of spoken words. For this reason, Kuk et al. (2012) and Bellotti et al. (2009) insist that particularly pedagogical NPCs should own voice and emotional characteristics. If voice-over recordings cannot be executed, serious games producers should keep the textual bursts to the point (Bellotti et al. 2012) with polite rather than direct (Johnson and Mayer 2010) natural language (González-González and Blanco-Izquierdo 2012). However, authors agree that players enjoy interacting with voice-enabled NPCs (Annetta et al. 2009a; Virvou and Katsionis 2008).

Serious games are well embedded in the constructivist learning theory (Cheng et al. 2014; Zin and Yue 2013), where thoughtful reflection and a non-competitive environment are part of the underlying assumptions (Jonassen 1994). That is, constructivist learning is about new environments, challenging the player's existing knowledge framework and allowing them the time to explore and test this conflict. In other words, we find it counter-intuitive to engage in explorative learning with time limits in place and as such were startled to uncover that 36 % of the studies utilized time pressure as a form of psychological fidelity. Stepping away from the learning aspect and focusing on gameplay, we believe that competition may hold the key. Serious games producers do not deny that competition is one of the primary drivers spurring gameplay (Arnab et al. 2013; Hong et al. 2013b; Hwang et al. 2012a; Zin and Yue 2013). We take the stance that serious games are successful if they get played (granted that the pedagogic infusion is decent)—fun games are played. Therefore, if competition supports this goal, it should be included. When focusing on learning aspects, competition among students is often discouraged. This leaves competing against the clock as an option to satisfy both learning and playing. Time is an adversary that cannot be physically singled out among a group of learners, yet it remains a worthy opponent drawing players to the game. Furthermore, time pressure can offer a furrow for collaborative learning—a learning approach many authors highlight (Admiraal et al. 2014; Hämäläinen 2011; Kiili 2005; Schmitz et al. 2015b). Serious games producers must be equally aware that using severe time pressures can be detrimental to cognitive learning (Hong et al. 2015).

4.3 AI and adaptivity

In our view, a disappointingly small proportion (21 %) of the reviewed articles employed what we broadly consider as AI—a seemingly intelligent or unscripted game response to player activity (i.e., by our definition, *Super Mario Bros*^{TM} has no AI). AI influences serious games on two fronts: (a) adjustment within the game through agents; and (b) adjustment of the game itself by means of adaptivity. Game agents operate either as reflex or goal-directed agents. Reflex agents are programmed to react to instantaneous player actions, while goal-directed agents continuously aim to manipulate the game toward their preset goal state (Russell and Norvig 2014) (no article was found that employed goal-directed agents). Adaptivity does not respond to a single action, but rather constructs user profiles for matching game presentation with player characteristics (Cheng et al. 2015; González-González et al. 2014).

Player progress-tracking takes place either through recording player activity in a database or activating programmatic flags and is the core of reflex agents and adaptivity (Soflano et al. 2015a). Such flags include: (a) taking too long to answer a question; (b) repeated mistakes; or (c) aimless roaming of the game world. Reflex agents respond to these triggers by informing the player, intervening when misconceptions occur, hinting or providing the player with appropriate feedback. Often agents act under the appearance of an NPC, making their intervention both unobtrusive and timely (Bellotti et al. 2009). The unobtrusive nature of the intervention sustains player immersion (Kickmeier-Rust and Albert 2010), while the timeliness (receiving help when requiring it) of the intervention has indisputable formative learning benefits. Kuk et al. (2012) observed students giving more correct answers after agent interventions. Natural NPC reactions (Barab et al. 2012) and tailored responses (Thompson et al. 2010) from reflex agents deliver a greater sense of enjoyment among players.

Adaptivity's role is principally to enhance the learning facet of serious games. Hwang et al. (2012b) and Soflano et al. (2015a) created games which adapted player learning styles, while (Bellotti et al. 2012) applied adaptivity to adjust the game's difficulty level according to player ability profiles. These approaches indicated significant learning gains over their respective control groups, leading us to conclude that adaptivity not just has the "potential to significantly shorten completion time" (Soflano et al. 2015a), but adaptivity also promotes individualized learning—something not easily achieved in traditional education.

In as much as AI boosts enjoyable learning, we must not lose sight of the computational costs involved with AI (Ketamo and Kiili 2010), especially when effecting machine learning and neural networks. This is further compounded with the increased popularity of web-based multi-player games requiring centralized processing (Ketamo and Kiili 2010). The simplest solution to this dilemma comes from Virvou et al. (2005) who generated a pre-defined knowledge domain. Players are kept from straying outside its boundaries by allowing only multiple-choice interactions with answers which do not extend beyond the existing domain. Brom et al. (2011) promote the selection of audience-appropriate machine learning algorithms and state that algorithms capable beyond the game's desired impact take longer (through unnecessary computation) to process seemingly simple computations and as a result, frustrate players. Ketamo and Kiili (2010) resolved their quandary by pruning the resultant neural network in order to remain within a pre-determined size.

4.4 Interaction

What sets serious games apart from other forms of edutainment is the element of interactivity. Games require user input and respond accordingly, in turn instigating the next player action and continuing in a repeated player-game feedback loop. Games present players with an interface comprising of the game world, where action-consequence is audio-visually experienced and a heads-up display (HUD) to communicate the current status of the game back to the user. Serious games producers should avoid complex interfaces as they take time and effort to become accustomed to (González-González and Blanco-Izquierdo 2012), frustrate novice players into possible quitting of the game (Kiili 2005; Van der Spek et al. 2013) and induce additional cognitive load (Hong et al. 2013b; Hwang et al. 2015). This implies that the game interface should be as straightforward as possible both in the way players provide input to the game and the way communication is returned to the player. Chittaro and Buttussi (2015), Knight et al. (2010) and Soflano et al. (2015a) make use of a minimalist control mechanic (point-and-click for movement and selection) replacing the entertainment game standard (simultaneous use of the mouse and keyboard for movement and other actions) because students are not be interested in a game with hard-to-use controls (Zin and Yue 2013).

Serious games producers should be cognizant that their intended playing audience is not necessarily familiar with games. Consequently, the HUD should transfer the game status and available gameplay tools in a clear and unsophisticated manner to the player. Virvou and Katsionis (2008) found that novice players did not use the available game-world map or inventory. As a result, players got lost in the game and did not access the learning material provided via the inventory. Therefore, a complex interface will turn players away, causing them to miss out on what could have been a fun-filled learning experience. Many successful entertainment games resolve this by allowing users to customize the controls, the HUD and/or level of gameplay complexity (e.g., crash damage in racing games). We promote the notion that games should *become* complex as players welcome gradual difficulty level increments of game tasks (Couceiro et al. 2013; Ke 2008). This is an integral part of flow theory dictating that challenge should constantly be on the fringes of player ability (Csikszentmihalyi 2008). This also relates to scaffolding as an approach to learning Vygotsky (1978). To commence the scaffolding process, several studies advocate introductory or practice levels allowing players to acclimatize to the game's interface (Hämäläinen 2011; Hwang et al. 2013b; Ke and Abras 2013; Van Eck 2006b). Hong et al. (2015) noted that increased practice times improved game-learning performance.

As collaborative learning is a dominant approach of successful serious games, it comes as no surprise that player-to-player interaction emerged as a leading serious game success factor. Even when play is not intended to be collaborative, players often share gameplay tactics and solutions with one another. Kiili and Perttula (2012) described an accelerated form of this behavior when players transformed (not programmatically, but through gameplay) a single-player game into a turn-based collaborative effort. Player-to-player interaction modes include chat interfaces (Dickey 2011), avatar communication through text (Bellotti et al. 2009) or integration with voice communication tools such as Skype™ (Hämäläinen 2011). Although in-game player-to-player communication proposes distinct solutions, we have not uncovered any forums outside of gameplay allowing players to share their game accomplishments. We postulate that incorporating opportunities to discuss game tactics and achievements in post-game debriefing sessions will provide less strong learners a different voice to speak with, which in turn, would facilitate increased participation during debriefing.

4.5 Feedback and debriefing

Serious games feedback presents the double-barrel option of: (a) in-game feedback experience through a variety of in-game reward mechanics or NPC interaction; and (b) post-game debriefing and reflection sessions which ultimately elucidate the learning material and place the game-learning experience into a greater context. In-game feedback affords players the opportunity to experience *immediate* cause-and-effect of their activities (Cheng and Annetta 2012; Johnson and Mayer 2010), while *instant* updates of the game's current status give players a sense of progress and competitive standing (Cheng et al. 2015; Kiili 2005; Kuk et al. 2012). The latter leads us to concur with a multitude of studies, which recommend showing the game's reward mechanics (e.g., points, leaderboard and level indicators), resource tools (e.g., inventory items and maps) and/or time-related elements *throughout* (Arnab et al. 2013; Chittaro and Sioni 2015; Verpoorten et al. 2014). Resource tools such as an integrated map indicating PC and other key locations best obliges vast game worlds (Hämäläinen 2011; Sadler et al. 2015) to prevent frustration and time wasting.

Serious games could provide a setting conducive to a high degree of formative learning through the exploration of possible cause-and-effect in a risk-free environment (Cheng et al. 2015) with the knowledge of likely safe recovery (Hwang et al. 2015; Ketamo and Kiili 2010; Squire 2013). To further enhance this setting, real-time teacher support should be the gold standard for serious game producers. Players appreciate unobtrusive support when necessary (Ke 2008; Kuk et al. 2012) and support through pedagogical intervention when asked for (Ke and Abras 2013; Serrano-Laguna et al. 2014; Van Eck 2006b). Several studies demote the lecturer to technical support, for the obvious purpose of otherwise risking the study's credibility. The reality, however, is that serious games should supplement the learning environment, not replace it (Sadler et al. 2015; Schmitz et al. 2015a; Virvou et al. 2005). It is impossible for teachers to be omnipresent during gameplay. We suggest dedicated gameplay times during which facilitators are part of the game play. In multi-player games, teachers' presence is appreciated as a game avatar who could provide support (Barab et al. 2012; González-González et al. 2014). Single-player serious games require a chat interface to a master computer or a communal learning space with the teacher physically present (Annetta et al. 2014; Brom et al. 2011); or the game could be played via a projector on a big screen either in a turned-based fashion (Kiili and Perttula 2012) augmented with teacher discussions (Arnab et al. 2013) or narration. The latter option diminishes the interactive advantage of serious games while reducing the players to spectators of the story where they were actors before.

Debriefing is the most important opportunity for players to process and consolidate their in-game learning events (Crookall 2014). Debriefing is not something that changes the game's appearance, but in-game learning activities certainly support its cause. Not just by means of a recollection of memorable gameplay moments, but by game-generated progress-tracking reports. Progress tracking has the advantage, especially in the case of health-related games (Alamri et al. 2014), of sending immediate player progress reports, which the facilitator can use as enablers for post-game debriefing (Baranowski et al. 2011; Hong et al. 2013b). Couceiro et al. (2013) envision a future version of their game with a progress-storing mechanism for remote inspection and delayed debriefing. Although some articles described the effective use of debriefing discussions during paused gameplay (Arnab et al. 2013; Brom et al. 2010), we are reluctant to recommend incorporating this into serious game designs. Only one study mentioned using chat logs as progress tracking specifically suited to post-game debriefing (González-González et al. 2014). Nevertheless, given our earlier finding that chat interfaces are a success factor for multi-player serious games and the relatively small programming step required for recording these logs, we foresee chat logging as a definite value-add for post-game debriefing. Even if conversations are not about the learning material, some valuable input about the fun, or not-so-fun, elements of the game may arise. Therefore, facilitators should make the effort to scrutinize the chat logs before making them public. The usefulness of progress tracking extends beyond current players as it could point out gameplay trends or game flaws to tweak scaffolding for future learners or to remove game errors. Games with errors are known to deter gameplay (Torrente et al. 2014; Virvou and Katsionis 2008). Lastly, the thought of cross-pollinating the functionality of backend databases for feedback and debriefing with AI or "micro-adaptivity" (Kickmeier-Rust and Albert 2010) should convince serious game producers of a positive cost-benefit ratio—both for fun and learning.

5 Limitations

We have only examined academic serious games, therefore limiting ourselves to games that have been designed and tested within academic contexts and which may not be representative of the best in the field. Limitations, common to reviews in general, include the use of search terms and delineation of time period. Additional limitations of this review, however, include: (a) picking salient work from the sheer volume of available articles within the review's scope; and (b) the effort of locating some journal articles that we would have liked to review for inclusion. The most overt limitation with regard to article inclusion for this study came about in the search phase. Although we had identified them initially, we did not search the IEEE and ACM databases because of the large number of articles (1 232) we had already amassed before delving into these databases. Admittedly, we may have missed some key research, but we remain confident that searching these databases would not have made a noteworthy impact on our findings. With regard to the field of application, only 20 % of the articles reported on post-study professional development and/or training. It seems that schools and higher education have replaced the military as the primary consumers of serious games. Multiple reviews (Akl et al.

2008; DeSmet et al. 2014; Papastergiou 2009b) evidence that the health sector readily embraces serious games, yet only 14 % of our inclusions represented this segment. The health sector (and others) employs games that are not just geared toward learning, but also have the aim to bring about behavior change or improve motor skills. We have limited our discussion to the learning construct of serious games and have therefore not included serious games that have other aims. Our view on this, however, is that each different purpose of a serious game will bring about a new set of requirements that is best reported in separate reviews. In spite of these obstacles, the authors concur that the list of common serious games success factors isolated from the articles is valid and representative for serious game across a broad spectrum of applications.

6 Conclusion

What practical guidelines can serious game producers incorporate to guarantee successful learning with games? From our analysis, it is the playing audience who hold the key to successful serious games. From the reviewed articles, we conclude that they want to have fun before they value the subsequent learning-benefit serious games can offer them. Serious games producers must not impede this hunger for fun, but rather use it to stealthily engage the player with the required learning material. This implies that the games need to have replay value rather than be a once-off learning endeavor. These single learning exercises often result in positive player feedback because they are fresh presentations of the learning material. We uncovered five themes (backstory and production; realism; AI and adaptivity; interaction; and feedback and debriefing), which provided containers for the various success factors, combating this novelty effect.

When players encounter a dull-looking game with little or no story, they will play it once or twice with great enthusiasm, maybe a third time after some persuasion and then turn their backs on it. Confront players with the high degree of realism and open-ended narrative they favor and admittedly learning will be minimal. That is, until the sensory stimuli become familiar and lose their attention-grabbing ability. The value lies in what remains—a game deemed worthy of repeated play. A narrative, which has no distinct breaks between learning and playing while providing a fitting context for the learning material must now take over gameplay motivation. This motivation drives players to become adept at the skills required to progress in the game. Hence, the game-task skills should mirror the intended learning impact.

No matter how captivating the game, learners will not step away from a game with the desire to learn more about the game's subject material. This would be akin to changing a player's sphere of personal interest; not many Rollercoaster Tycoon™ players build their own backyard loop-the-loop tracks or read up on the physics of a Ferris wheel. Serious games producers should rather maintain the situational interest (playing a good game) that has been cultivated thus far. This can be achieved through promoting a player's sensation of flow (immersion) and avoiding game elements that disrupt it. Flow theory suggests that as gameplay progresses, player abilities go up and that challenges should always be on the edge of player ability. This suggests that game tasks should become gradually more difficult in order for a player's cycle of mastery to be continuously challenged—as also prescribed by the constructivist learning theory. Immediate in-game feedback, an intuitive game interface with minimalist control mechanics and an uncomplicated heads-up display will prevent flow interference.

Thus far, the player has been captivated, motivated and immersed in going through a fun-learning process. AI can polish off the aesthetic by establishing an emotional connection with the player through personalized responses and gameplay modes maintained by progress-tracking mechanisms. These mechanisms for fun can be shared with the learning aspect of serious games by assisting post-game debriefing activities designed to place the in-game learning experience into a greater perspective. Some researchers herald debriefing as the most important learning mediator for the serious games experience. We recommend utilizing progress-tracking reports of in-game learning activities and possibly chat logging to further enhance the value of debriefing.

The production team of serious games involves a medley of proficiencies of artistic, programming, subject matter and pedagogical experts. The bona fide success component of the production team, however, is the end user. Involving a homogenous target player group from early in the design and play-testing phases will ensure that the game will be enjoyed. Enjoyable games are not just played when the intervention is due or when the curriculum demands it. Enjoyable games are played by choice. We reiterate that this is the true measure of successful serious games as players will be engaging with the learning material when they would otherwise have been doing something fun.

7 Future research

Our analysis revealed minimal theoretical underpinning as a design basis of serious games. The limited use of theoretical approaches is possibly explained by their diversity. We found an almost one-to-one ratio of theoretical approaches to game designs in the reviewed articles. This may partly be the cause of allegations that the field of serious games is scattered with inconsistent research. We suggest a consolidation of existing frameworks, theories and models drawing out the most significant aspects from each of them into an understandable and practically implementable approach concretizing the requirements for successful serious games.

Keeping in line with the pragmatic nature of this review, we would like to see a summary and application recommendation of the different authoring tools and techniques to speed up, without jeopardizing quality, the creation of serious games. (Petridis et al. 2010) have proposed similar ideas in their investigation on different game engines suitable for serious games production. Their work, however, is limited to game engines and is buttonholed with the idea of developing serious games from scratch. We suggest to extend their work to XML-driven platforms for serious game development such as <e-Adventure> (Torrente et al. 2014), or technologies such as Neverwinter Nights where game modding is the fundamental exploit to speed up serious game creation (Byun and Loh 2015; Soflano et al. 2015a), which can be further augmented with the use of ScriptEase (González-González and Blanco-Izquierdo 2012). This suggested work may even include additional specific lower-level techniques such as *enhanced billboard modeling* (Bellotti et al. 2012).

A further managerial tool more often associated with corporate climates, which could be equally useful to serious games makers, is a risk assessment model—not just an impact-likelihood presentation of the risks associated with building and implementing serious games, but also providing appropriate mitigation strategies for the related risks. Although serious game risk analysis was outside the scope of this review, we scrutinized a telling number of articles, without encountering pertinent work toward establishing a risk profile for serious games development.

Most of the serious game researches brought forward in this review, as well as many of the excluded studies, examines the impact of serious games on the end-consumer. Moreover, the studies are conducted under the guidance of researchers well versed in the environmental requirements of serious games implementation. We advise shifting some of the research emphasis to the supply side of serious games and suggest more attention be given to the professional development (PD) of serious games protagonists in their qualified capacities as trainers or educators. Although some studies (Papastergiou 2009a; Sadler et al. 2015; Torrente et al. 2009) refer to the importance of teaching-the-teachers to implement serious games, a formal theoretical framework (or set of guidelines) for the teaching of teachers would be a valuable addition to the field of serious games. A natural progression would be to refine the suggested framework by evaluating its training effectiveness through well-designed experiments comparing the impact and reception of games for those who have received PD versus those who have not.

Our research indicates that 2D and 3D games are almost equally popular with, respectively, 33 and 40 % of the 55 unique games encountered categorized into these two styles. Since cost and time are explicitly mentioned as recurring factors in the building of serious games, it would be valuable to determine practically useful time and cost structures to show the real implication of developing and maintaining 2D versus 3D games. Precluding this, however, we feel a comparative meta-analysis of the effectiveness of each these environments should be undertaken. In this way, a true reflection of the cost-benefit analysis for each style could be initiated. Furthermore, our analysis could not reveal whether specific playing audiences prefer either 2D or 3D games. We speculate a likely correlation between age and preferred game style. Further research will have to verify this and other explicit style preferences—combining it with clear cost- and time-structures, which provide a powerful guide to the commencement of any serious game production. Careful consideration should also be given to pseudo-3D (2.5D) or combinations of 2D and 3D environments—each of these made up 9 and 11 %, respectively, of the games investigated.

A last, but fundamental, aspect of games, which raises many questions, is that of competition. Some learning theories have shown that competition may raise anxiety levels causing players to either quit gameplay or avoid it altogether, both of which are detrimental to the desired learning aspects of serious games. From a gameplay perspective, however, competition is what drives the motivation to play games. Given the conclusion of this review; that a successful serious game is one that is played out of choice, we find ourselves hard-pressed to eliminate competition from serious games. Turning to one of the major findings of this review: players appreciate a sense of control regarding their gameplay environment, may reveal the answer. We suggest creating an environment where players have the option to switch off the competitive elements (player score, leaderboard or time pressure) of gameplay that monitors which players actually perform this action and attempt to correlate this to (among possible others) learning style, prior achievement in the learning subject and/or previous gameplay exposure. Carefully crafted experiments determining a game's learning impact with and without competition, taking player preference into account, will round this topic off neatly and maybe provide a clear-cut answer to the competition-in-serious-games debate.

Acknowledgments This work is based on research support, in part, by the National Research Foundation of South Africa. Any opinion, findings and conclusions or recommendations expressed in this material are those of the authors, and therefore, the NRF does accept any liability in regard thereto. We also wish to acknowledge the effort of the librarians of the North-West University.

Author contributions All authors contributed to this article, in content and in form. WSR and ASB wrote the manuscript. VL assisted the mechanics of the systematic literature review. AW assisted with inter-reliability and quality assurance. All authors contributed equally to the editing of the manuscript.

Compliance with ethical standards

Conflict of interest The authors declare no conflicts of interest with respect to the authorship and/or publication of this article.

References

Abt CC (1970) Serious games. Viking Press, New York

Admiraal W, Huizenga J, Heemskerk I, Kuiper E, Volman M, ten Dam G (2014) Gender-inclusive game-based learning in secondary education Int J Incl Educ 18:1208–1218. doi:10.1080/13603116.2014.885592

Akl EA, Sackett K, Pretorius R, Erdley S, Bhoopathi PS, Mustafa R, Schunemann HJ (2008) Educational games for health professionals Cochrane Database Syst Rev:20. doi:10.1002/14651858.CD006411.pub2

Alamri A, Hassan MM, Hossain MA, Al-Qurishi M, Aldukhayyil Y, Hossain MS (2014) Evaluating the impact of a cloud-based serious game on obese people. Comput Hum Behav 30:468–475. doi:10.1016/j.chb.2013.06.021

Annetta LA, Mangrum J, Holmes S, Collazo K, Cheng M-T (2009a) Bridging realty to virtual reality: investigating gender effect and student engagement on learning through video game play in an elementary school classroom Int J. Sci Educ 31:1091–1113

Annetta LA, Minogue J, Holmes SY, Cheng MT (2009b) Investigating the impact of video games on high school students' engagement and learning about genetics. Comput Educ 53:74–85. doi:10.1016/j.compedu.2008.12.020

Annetta L, Lamb R, Minogue J, Folta E, Holmes S, Vallett D, Cheng R (2014) Safe science classrooms: teacher training through serious educational games. Inf Sci 264:61–74. doi:10.1016/j.ins.2013.10.028

Arnab S et al (2013) The development approach of a pedagogically-driven serious game to support Relationship and Sex Education (RSE) within a classroom setting. Comput Educ 69:15–30. doi:10.1016/j.compedu.2013.06.013

Barab S, Pettyjohn P, Gresalfi M, Volk C, Solomou M (2012) Game-based curriculum and transformational play: designing to meaningfully positioning person, content, and context. Comput Educ 58:518–533. doi:10.1016/j.compedu.2011.08.001

Baranowski T et al (2011) Video game play, child diet, and physical activity behavior change: a randomized clinical trial. Am J Prev Med 40:33–38. doi:10.1016/j.amepre.2010.09.029

Bedwell WL, Pavlas D, Heyne K, Lazzara EH, Salas E (2012) Toward a Taxonomy Linking Game Attributes to Learning: An Empirical Study Simulation & Gaming 43:729–760

Bellotti F, Berta R, De Gloria A, Primavera L (2009) Enhancing the educational value of video games. Computers in Entertainment 7:1–18. doi:10.1145/1541895.1541903

Bellotti F, Berta R, De Gloria A, D'Ursi A, Fiore V (2012) A serious game model for cultural heritage Journal on Computing and Cultural. Heritage 5:1–27

Bhoopathi PS, Sheoran R, Adams CE (2007) Educational games for mental health professionals: a Cochrane review The International Journal Of Psychiatric. Nurs Res 12:1497–1502

Blakely G, Skirton H, Cooper S, Allum P, Nelmes P (2009) Educational gaming in the health sciences: systematic review. J Adv Nurs 65:259–269. doi:10.1111/j.1365-2648.2008.04843.x

Boeije H (2002) A purposeful approach to the constant comparative method in the analysis of qualitative interviews. Qual Quant 36:391–409. doi:10.1023/A:1020909529486

Boyle E, Connolly TM, Hainey T (2011) The role of psychology in understanding the impact of computer games. Entertainment Computing 2:69–74. doi:10.1016/j.entcom.2010.12.002

Breuer J, Bente G (2010) Why so serious? On the relation of serious games and learning Eludamos Journal for Computer Game Culture 4:7–24

Brom C, Sisler V, Slavik R (2010) Implementing digital game-based learning in schools: augmented learning environment of 'Europe 2045'. Multimedia Syst 16:23–41. doi:10.1007/s00530-009-0174-0

Brom C, Preuss M, Klement D (2011) Are educational computer micro-games engaging and effective for knowledge acquisition at high-schools? A quasi-experimental study Computers & Education 57:1971–1988. doi:10.1016/j.compedu.2011.04.007

Buttussi F, Pellis T, Vidani AC, Pausler D, Carchietti E, Chittaro L (2013) Evaluation of a 3D serious game for advanced life support retraining. Int J Med Inform 82:798–809. doi:10.1016/j.ijmedinf.2013.05.007

Byun J, Loh CS (2015) Audial engagement: effects of game sound on learner engagement in digital game-based learning environments. Comput Hum Behav 46:129–138. doi:10.1016/j.chb.2014.12.052

Cheng M-T, Annetta L (2012) Students' learning outcomes and learning experiences through playing a serious educational game J Biol Educ 46:203–213

Cheng M-T, Su T, Huang W-Y, Chen J-H (2014) An educational game for learning human immunology: what do students learn and how do they perceive? British Journal of Educational Technology 45:820–833

Cheng M-T, Lin Y-W, She H-C (2015) Learning through playing Virtual Age: exploring the interactions among student concept learning, gaming performance, in-game behaviors, and the use of in-game characters. Comput Educ 86:18–29. doi:10.1016/j.compedu.2015.03.007

Chittaro L, Buttussi F (2015) Assessing knowledge retention of an immersive serious game vs. a traditional education method in aviation safety. IEEE Trans Visual Comput Graphics 21:529–538. doi:10.1109/tvcg.2015.2391853

Chittaro L, Sioni R (2015) Serious games for emergency preparedness: evaluation of an interactive vs. a non-interactive simulation of a terror attack. Comput Hum Behav 50:508–519. doi:10.1016/j.chb.2015.03.074

Connolly TM, Stansfield M, Hainey T (2011) An alternate reality game for language learning: aRGuing for multilingual motivation. Comput Educ 57:1389–1415. doi:10.1016/j.compedu.2011.01.009

Connolly TM, Boyle EA, MacArthur E, Hainey T, Boyle JM (2012) A systematic literature review of empirical evidence on computer games and serious games. Comput Educ 2012:661–686. doi:10.1016/j.compedu.2012.03.004

Cook DA et al (2013) Comparative effectiveness of instructional design features in simulation-based education: systematic review and meta-analysis. Med Teach 35:e844–e875. doi:10.3109/0142159X.2012.714886

Couceiro RM, Papastergiou M, Kordaki M, Veloso AI (2013) Design and evaluation of a computer game for the learning of Information and Communication Technologies (ICT) concepts by physical education and sport science students. Education and Information Technologies 18:531–554. doi:10.1007/s10639-011-9179-3
Crookall D (2014) Engaging (in) gameplay and (in) debriefing Simulation & Gaming
Csikszentmihalyi M (2008) Flow: The psychology of optimal experience, 2nd edn. Harper Perennial, New York
De Freitas S, Ketelhut DJ (2014) Introduction for the Journal of Information Sciences special issue on serious games. Inf Sci 264:1–3. doi:10.1016/j.ins.2014.01.036
DeSmet A et al (2014) A meta-analysis of serious digital games for healthy lifestyle promotion. Prev Med 69:95–107. doi:10.1016/j.ypmed.2014.08.026
Dickey MD (2011) Murder on Grimm Isle: the impact of game narrative design in an educational game-based learning environment. British Journal of Educational Technology 42:456–469. doi:10.1111/j.1467-8535.2009.01032.x
Dondlinger MJ (2007) Educational video game design: A review of the literature Journal of applied educational technology 4:21–31
Donnelly CM, McDaniel MA (1993) Use of analogy in learning scientific concepts Journal of Experimental Psychology: learning. Memory, and Cognition 19:975–987. doi:10.1037/0278-7393.19.4.975
Echeverría A, García-Campo C, Nussbaum M, Gil F, Villalta M, Améstica M, Echeverría S (2011) A framework for the design and integration of collaborative classroom games. Comput Educ 57:1127–1136. doi:10.1016/j.compedu.2010.12.010
Feinstein AH, Cannon HM (2002) Constructs of simulation evaluation Simulation and Gaming 33:425–440. doi:10.1177/1046878102238606
Garris R, Ahlers R, Driskell JE (2002) Games, motivation, and learning: A research and practice model Simulation and Gaming 33:441–467 doi:10.1177/1046878102238607
Gee JP (2005) Good video games and good learning Phi Kappa Phi Forum:33
Gentner D, Holyoak KJ (1997) Reasoning and learning by analogy: introduction. Am Psychol 52:32–34. doi:10.1037/0003-066X.52.1.32
Giessen HW (2015) Serious Games Effects: an Overview. Procedia - Social and Behavioral Sciences 2015:2240–2244. doi:10.1016/j.sbspro.2015.01.881
González-González C, Blanco-Izquierdo F (2012) Designing social videogames for educational uses. Comput Educ 58:250–262. doi:10.1016/j.compedu.2011.08.014
González-González C, Toledo-Delgado P, Collazos-Ordoñez C, González-Sánchez J (2014) Design and analysis of collaborative interactions in social educational videogames. Comput Hum Behav 31:602–611. doi:10.1016/j.chb.2013.06.039
Hainey T (2007) Reviews: games and Simulations in Online Learning: Research and Development Frameworks Int J. Inf Manage 27:438. doi:10.1016/j.ijinfomgt.2007.08.008
Hämäläinen R (2008) Designing and evaluating collaboration in a virtual game environment for vocational learning. Comput Educ 50:98–109. doi:10.1016/j.compedu.2006.04.001
Hämäläinen R (2011) Using a game environment to foster collaborative learning: a design-based study Technology. Pedagogy and Education 20:61–78. doi:10.1080/1475939X.2011.554010
Hong J-C, Hwang M-Y, Chen Y-J, Lin P-H, Huang Y-T, Cheng H-Y, Lee C-C (2013a) Using the saliency-based model to design a digital archaeological game to motivate players' intention to visit the digital archives of Taiwan's natural science museum. Comput Educ 66:74–82. doi:10.1016/j.compedu.2013.02.007
Hong JC, Tsai CM, Ho YJ, Hwang MY, Wu CJ (2013b) A comparative study of the learning effectiveness of a blended and embodied interactive video game for kindergarten students Interact Learn Environ 21:39–53. doi:10.1080/10494820.2010.542760
Hong J-C, Lin M-P, Hwang M-Y, Tai K-H, Kuo Y-C (2015) Comparing animated and static modes in educational gameplay on user interest, performance and gameplay anxiety. Comput Educ 88:109–118. doi:10.1016/j.compedu.2015.04.018
Huizenga J, Admiraal W, Akkerman S, ten Dam G (2009) Mobile game-based learning in secondary education: engagement, motivation and learning in a mobile city game. J Comput Assist Learn 25:332–344. doi:10.1111/j.1365-2729.2009.00316.x
Hunicke R, LeBlanc M, Zubek R (2004) MDA: A formal approach to game design and game research. Paper presented at the AAAI Workshop on Challenges in Game AI, San Jose
Hwang G-J, Wu P-H, Chen C-C (2012a) An online game approach for improving students' learning performance in web-based problem-solving activities. Comput Educ 59:1246–1256. doi:10.1016/j.compedu.2012.05.009
Hwang GJ, Sung HY, Hung CM, Huang I, Tsai CC (2012b) Development of a personalized educational computer game based on students' learning styles. Education Tech Research Dev 60:623–638. doi:10.1007/s11423-012-9241-x
Hwang G-J, Yang L-H, Wang S-Y (2013a) A concept map-embedded educational computer game for improving students' learning performance in natural science courses. Comput Educ 69:121–130. doi:10.1016/j.compedu.2013.07.008
Hwang GJ, Sung HY, Hung CM, Yang LH, Huang I (2013b) A knowledge engineering approach to developing educational computer games for improving students' differentiating knowledge. British Journal of Educational Technology 44:183–196. doi:10.1111/j.1467-8535.2012.01285.x
Hwang GJ, Chiu LY, Chen CH (2015) A contextual game-based learning approach to improving students' inquiry-based learning performance in social studies courses. Comput Educ 81:13–25. doi:10.1016/j.compedu.2014.09.006
Hyungsup Y (2014) A study on an analysis of success factors of a serious game: in case of "Anti-Aging Village" International Journal of Multimedia and Ubiquitious Engineering 9:205–214 doi:http://dx.doi.org/10.14257/ijmue.2014.9.7.17
Johnson CI, Mayer RE (2010) Applying the self-explanation principle to multimedia learning in a computer-based game-like environment. Comput Hum Behav 26:1246–1252. doi:10.1016/j.chb.2010.03.025
Jonassen DH (1994) Thinking technology: toward a constructivist design model. Educational Technology 34:34–37
Ke F (2008) A case study of computer gaming for math: engaged learning from gameplay? Comput Educ 51:1609–1620. doi:10.1016/j.compedu.2008.03.003
Ke F, Abras T (2013) Games for engaged learning of middle school children with special learning needs. British Journal of Educational Technology 44:225–242
Ke F, Grabowski B (2007) Gameplaying for maths learning: cooperative or not? British Journal of Educational Technology 38:249–259. doi:10.1111/j.1467-8535.2006.00593.x
Ketamo H, Kiili K (2010) Conceptual change takes time: Game based learning cannot be only supplementary amusement Journal of Educational Multimedia and Hypermedia 19:399–419
Kickmeier-Rust MD, Albert D (2010) Micro-adaptivity: protecting immersion in didactically adaptive digital educational games. J Comput Assist Learn 26:95–105
Kiili K (2005) Content creation challenges and flow experience in educational games: the IT-Emperor case. The Internet and Higher Education 8:183–198. doi:10.1016/j.iheduc.2005.06.001

Kiili K, Perttula PTA (2012) Exerbraining for schools: combining body and brain training. Procedia Computer Science 15:163–173. doi:10.1016/j.procs.2012.10.068
Kitchenham B (2007) Guidelines for performing systematic literature reviews in software engineering. Technical report, EBSE Technical Report EBSE-2007-01
Knight JF et al (2010) Serious gaming technology in major incident triage training: a pragmatic controlled trial. Resuscitation 81:1175–1179. doi:10.1016/j.resuscitation.2010.03.042
Kriz CW, Hense JU (2006) Theory-oriented evaluation for the design of and research in gaming and simulation Simulation and Gaming 37:268–283. doi:10.1177/1046878106287950
Kuk K, Milentijević I, Rančić D, Spalević P (2012) Pedagogical agent in Multimedia Interactive Modules for Learning – MIMLE Expert Syst Appl 39:8051–8058 doi:10.1016/j.eswa.2012.01.138
Mayo JA (2001) Using analogies to teach conceptual applications of developmental theories. Journal of Constructivist Psychology 14:187–213. doi:10.1080/10720530126292
McHugh ML (2012) Interrater reliability: The kappa statistic Biochemia Medica 22:276–282
Mcmahon M, Henderson S (2011) Enhancing nutritional learning outcomes using within a simulation and pervasive game-based strategy. Paper presented at the AACE Edmedia Conference 2011
Michael DR, Chen SL (2006) Serious games: Games that educate, train, and inform. Thomson, Boston
Minovic M, Milovanovic M, Starcevic D (2011) Modelling Knowledge and Game Based Learning: Model Driven Approach J Univers Comput Sci 17:1241–1260
Mortara M, Catalano CE, Bellotti F, Fiucci G, Houry-Panchetti M, Petridis P (2014) Learning cultural heritage by serious games. Journal of Cultural Heritage 15:318–325
Moseley A, Whitton N, Iacovides I, McAndrew P, Scanlon E, Aczel J (2014) The Gaming Involvement and Informal Learning Framework Simulation & Gaming 45:611–626
Niedenthal S (2009) What we talk about when we talk about game aesthetics. EBSCOhost. http://hdl.handle.net/2043/13326 Accessed June 2, 2015
Norman G, Dore K, Grierson L (2012) The minimal relationship between simulation fidelity and transfer of learning. Med Educ 46:636–647. doi:10.1111/j.1365-2923.2012.04243.x
Osterman KF (1998) Using Constructivism and Reflective Practice To Bridge the Theory/Practice Gap. American Educational Research Association, San Diego
Papastergiou M (2009a) Digital game-based learning in high school computer science education: impact on educational effectiveness and student motivation. Comput Educ 52:1–12. doi:10.1016/j.compedu.2008.06.004
Papastergiou M (2009b) Exploring the potential of computer and video games for health and physical education: a literature review. Comput Educ 53:603–622. doi:10.1016/j.compedu.2009.04.001
Peters VAM, Vissers GAN (2004) A Simple Classification Model for Debriefing Simulation Games Simulation & Gaming 35:70–84
Petridis P, Dunwell I, De Freitas S, Panzoli D (2010) An engine selection methodology for high fidelity serious games, pp 27–34. doi:10.1109/VS-GAMES.2010.26
Prensky M (2001) Fun, play and games: what makes games engaging. In: Digital game-based learning. McGraw-Hill, pp 1–31
Riffe D, Lacy S, Fico FG (1998) Analyzing media messages: Using quantitative content analysis in research. LEA's communications series (general theory). Lawrence Erlbaum Associates Publishers, Mahwah, NJ, US
Rodriguez DM, Teesson M, Newton NC (2014) A systematic review of computerised serious educational games about alcohol and other drugs for adolescents. Drug Alcohol Rev 33:129–135. doi:10.1111/dar.12102
Russell SJ, Norvig P (2014) Artificial intelligence: a modern approach. Pearson Education Limited, Pearson custom library. Harlow **(Third edition, Pearson new international edition)**
Sacfung A, Sookhanaphibarn K, Choensawat W (2014) Serious game for fire safety evacuation plan. Adv Mater Res 931–932:583–587.10.4028/http://www.scientific.net/AMR.931-932.583 doi:
Sadler TD, Romine WL, Menon D, Ferdig RE, Annetta L (2015) Learning biology through innovative curricula: a comparison of game- and nongame-based approaches. Sci Educ 99:696. doi:10.1002/sce.21171
Schmitz B, Klemke R, Specht M (2014) The impact of coupled games on the learning experience of learners at-risk: An empirical study Pervasive Mob Comput 14:57–65. doi:10.1016/j.pmcj.2013.09.002
Schmitz B, Klemke R, Walhout J, Specht M (2015a) Attuning a mobile simulation game for school children using a design-based research approach. Comput Educ 81:35–48. doi:10.1016/j.compedu.2014.09.001
Schmitz B, Schuffelen P, Kreijns K, Klemke R, Specht M (2015b) Putting yourself in someone else's shoes: the impact of a location-based, collaborative role-playing game on behaviour. Comput Educ 85:160–169. doi:10.1016/j.compedu.2015.02.012
Serrano-Laguna Á, Torrente J, Moreno-Ger P, Fernández-Manjón B (2014) Application of learning analytics in educational videogames. Entertainment Computing 5:313–322. doi:10.1016/j.entcom.2014.02.003
Sherry JL (2013) The Challenge of Audience Reception: A Developmental Model for Educational Game Engagement Digital Games: A Context for Cognitive Developments 139:11–20. doi:10.1002/cad.20027
Sitzmann T (2011) A meta-analytic examination of the instructional effectiveness of computer-based simulation games Pers Psychol 64:489–528
Soflano M, Connolly T, Hainey T (2015a) An application of adaptive games-based learning based on learning style to teach SQL. Comput Educ 86:192–211. doi:10.1016/j.compedu.2015.03.015
Soflano M, Connolly T, Hainey T (2015b) Learning style analysis in adaptive GBL application to teach SQL. Comput Educ 86:105–119. doi:10.1016/j.compedu.2015.02.009
Squire KD (2013) Video game-based learning: an emerging paradigm for instruction. Performance Improvement Quarterly 26:101–130
Susi T, Johannesson M, Backlund P (2007) Serious games—An overview. Technical Report No. HS-IKI-TR-07-001, University of Skövde, Skövde
Thompson D, Baranowski T, Buday R, Baranowski J, Thompson V, Jago R, Griffith M (2010) Serious video games for health: How behavioral science guided the development of a serious video game Simulation & Gaming 41:587–606
Torrente J, Moreno-Ger P, Martinez-Ortiz I, Fernandez-Manjon B (2009) Integration and deployment of educational games in e-learning environments: The learning object model meets educational gaming Educ Technol Soc 12:359–371
Torrente J, Del Blanco A, Serrano-Laguna A, Vallejo-Pinto JA, Moreno-Ger P, Fernandez-Manjon B (2014) Towards a low cost adaptation of educational games for people with disabilities Comput Sci. Inf Syst 11:369–391. doi:10.2298/csis121209013t
Van der Spek ED, Van Oostendorp H, Meyer JJC (2013) Introducing surprising events can stimulate deep learning in a serious game. British Journal of Educational Technology 44:156–169. doi:10.1111/j.1467-8535.2011.01282.x
Van Eck R (2006a) Digital Game-Based Learning: It's Not Just the Digital Natives Who Are Restless EDUCAUSE Review 41:16–18
Van Eck R (2006b) The effect of contextual pedagogical advisement and competition on middle-school students' attitude toward

mathematics and mathematics instruction using a computer-based simulation game. Journal of Computers in Mathematics and Science Teaching 25:165–195
Vandercruysse S, Vandewaetere M, Clarebout G (2012) Game-based learning: a review on the effectiveness of educational games. In: Handbook of Research on Serious Games as Educational, Business and Research Tools. pp 628–647. doi:10.4018/978-1-4666-0149-9.ch032
Verpoorten D, Castaigne J-L, Westera W, Specht M (2014) A quest for meta-learning gains in a physics serious game. Education and Information Technologies 19:361–374
Virvou M, Katsionis G (2008) On the usability and likeability of virtual reality games for education: the case of VR-ENGAGE. Comput Educ 50:154–178. doi:10.1016/j.compedu.2006.04.004
Virvou M, Katsionis G, Manos K (2005) Combining software games with education: Evaluation of its educational effectiveness Educ Technol Soc 8:54–65
Visschedijk GC, Van der Hulst AH (2012) Hoe realistisch moet een serious game zijn? Op zoek naar de optimale fidelity. Homo Ludens Magazine:96–111
Vygotsky LS (1978) Mind in society: the development of higher psychological processes
Webster D, Celik O (2014) Systematic review of Kinect applications in elderly care and stroke rehabilitation Journal Of Neuroengineering And. Rehabilitation 11:108. doi:10.1186/1743-0003-11-108
Westera W, Nadolski RJ, Hummel HGK, Wopereis IGJH (2008) Serious Games for Higher Education: a Framework for Reducing Design Complexity. J Comput Assist Learn 24:420–432
Whitton N (2011) Encouraging Engagement in Game-Based Learning International Journal of Game-Based Learning (IJGBL) 1:75–84
Whitton N (2013) Games for Learning International Review of Qualitative Research 6:424–439 doi:10.1525/irqr.2013.6.3.424
Wiemeyer J (2010) Serious Games—The challenges for computer science in sport International Journal of Computer Science in Sport 9:65–74
Wouters P, van Nimwegen C, van Oostendorp H, van der Spek ED (2013) A meta-analysis of the cognitive and motivational effects of serious games. J Educ Psychol 105:249–265. doi:10.1037/a0031311
Zin NAM, Yue WS (2013) Design and evaluation of history Digital Game Based Learning (DGBL) software. J Next Gen Inf Technol 4:9–24 doi:10.4156/jnit.vol4.issue4.2
Zyda M (2005) From visual simulation to virtual reality to games. Computer 38:25–32