Investigating the success factors of

serious games

a systematic review

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Investigating the success factors of serious games: a systematic review

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Dissertation submitted in fulfilment of the requirements for the degree Magister Scientiae in Computer Science at the Vaal Triangle Campus of the North-West University

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Dedication

This dissertation is dedicated to YHVH:
For many times, there was only one set of footprints.

AND

To my dear wife and two young sons, who have endured my dedication to this task with endless patience and understanding.

Acknowledgements

I would like to express my sincere gratitude to the following persons and institutions for their valuable contribution to this study:

- Prof A Seugnet Blignaut for all her dedication and unwavering support in leading me to the conclusion of this journey. Her astute knowledge of the field and effective transferring thereof is insurmountable—thank you.
- Dr Verona Leendertz for the many days spent under her tutelage of the systematic review process, and the countless words of encouragement.
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- The four BSc Honours in IT students for volunteering to be part of the pilot-testing of the serious games gauge.
- Mr Malan den Heijer who graciously elevated my pen-sketched understanding of serious games factors to digital glory.

Preamble

My work as head of the Serious Games Institute of South Africa (SGI-SA) has absorbed me into a three-year serious games journey of commercial establishment, international collaborations, curriculum development and event coordination. Although these experiences had an academic mantle, I had yet to produce subject matter that announced my entry to the world of serious games scholarship. I immersed myself into journal articles, conference proceedings and books that investigate the field of serious games. Through this exploration, I discovered that the field's research is somewhat inconsistent regarding serious games requirements and decided to conduct a systematic literature review about serious game success factors. In consultation with my study leaders, we coordinated a strategy that would combine my desire to: (a) become a serious games scholar; (b) concretise my standing as a serious games practitioner; and (c) meet the expectations of obtaining an MSc. The proposal to initiate such a study in Computer Science, that orbits an academic journal article, was presented to the Faculty of Economic Sciences and IT Research Leaders Committee. Once approved, I commenced with an article-based MSc dissertation.

On completion of the proposed article, I submitted an abstract of the article based on a comprehensive qualitative systematic literature review to the journal Simulation and Gaming. After scrutinising the abstract for approval, the editor of Simulation and Gaming responded with, "the topic is marvellous and your subtract is fascinating." The editor welcomed the submission of the full text for peer review and eventual possible publication. As excited as I was about this development, I reserved some concern. In spite of the proposal for my MSc being approved, I knew that my study format would now deviate from my faculty's traditional MSc dissertations. The reading of this dissertation therefore, requires different interaction.

This dissertation comprises four sections with somewhat independent reading spheres. Section 1 completely describes the context, all constituent objectives and the research process; Section 2 is the systematic literature review article that, at the time of submitting the MSc study, is under formal peer review; Section 3 details the testing of the theory by means of a practical tool, as well as the actual development and formative pilot-testing thereof; and Section 4 provides a conclusive reflection of the research journey. A visible indicator of the stylistic differences amongst the four sections, is the different citation styles required by the journal and the North-West University in terms of the use of page numbers. Even though each section should be viewed on its own merit, the study as a whole contributes towards the theory building of serious games.

Abstract

Investigating the success factors of serious games: a systematic review

Serious games are a vehicle for enhanced learning experiences and are delivered across a multitude of sectors and disciplines on a variety of platforms—some more successfully than others. This study addressed *what makes serious games successful* through the voices of significant authors in the field of serious games by means of a systematic literature review (SLR). An additional aim of the study was to determine whether the theoretical understanding of the empirical answer could contribute to a practical *prototype tool for rating serious game designs*. The varied levels of serious games success could be attributed to disputes about pedagogy over enjoyment (or *vice versa*), how much realism is enough or whether artificial intelligence is worth the cost. Furthermore, the contested debating gives rise to a perceived disconnection amid serious games protagonists. An initial investigation amongst individual articles to uncover specific serious games success factors was unsatisfying. Serious games articles predominantly report on the criteria that serious games are measured against (e.g. the ability to capture and maintain player interest). Researchers, *inter alia*, tend to repeatedly measure whether or not their games meet the criteria instead of seeking the success factors leading to these standards. Through this, the field of serious games appears to be in a perpetual spiral of *does-my-game-work* research while *why-does-my-game-not-work* research would be more worthwhile. Notwithstanding unconnected and somewhat led-astray studies that have little value, the field of serious games does seem to be built around immeasurable contributions and the selected SLR studies certainly contain nuggets of wisdom relating to the success factors of serious games. This success-factor wisdom was mined from 63 papers, obtained from a variety of electronic libraries and databases, for the time period 2000 to 2015. A constant comparison method for qualitative analysis unearthed five themes (backstory and production; realism; artificial intelligence and adaptivity; interaction; and feedback and debriefing) which became containers for the multiple success factors that were also brought to light. Three dimensions (learning, fun and dynamics) and their interplay with the five theoretical themes emerged from the SLR. This interpretation provided the backdrop for pilot-testing the practically oriented serious games gauge (SGG) prototype developed in Excel™ with an underlying weighted grid structure. Four BSc Honours in IT students formatively pilot-tested the SGG against four serious games. Observation, interviews, perceived usefulness questionnaires and comparing the SGG ratings with existing remarks about the test games supplied a basis for determining that the SGG prototype has taken the first strides towards further development. A three-dimensional model describing the inter-relationships between the themes and dimensions concluded the theory-building exercise towards better understanding of the heart of serious games. The SLR indicated that the

face value of significant individual studies should not be used to judge the unity of serious games research, but that the consolidated embedded details impart an essential structure of cohesiveness to the field of serious games. Future research with the SGG prototype has the potential to contribute a practical set of standards for quality serious games—games that will no longer be imposed, but rather *played out of choice*.

Keywords

dynamics; fun; learning; pilot test; prototype; serious games; serious games gauge (SGG); success factors; systematic literature review (SLR); theory building

Opsomming

Die ondersoek van elektroniese leerspelsuksesfaktore: 'n sistematiese literatuuroorsig

Elektroniese leerspele is 'n middel tot bevordering van positiewe leerervarings, en word deur middel van 'n verskeidenheid platforms aan verskeie sektore en vakgebiede verskaf. Sommige elektroniese spele is meer suksesvol as ander. Hierdie studie, deur middel van 'n sistematiese literatuuroorsig (SLO), fokus op die kwessie van *Wat maak leerspele geslaagd?* soos in ooreenstemming met die gepubliseerde opinies van gevierde outeurs in die leerspelstudieveld. 'n Verdere doel van hierdie studie was om te bepaal of die teoretiese insette afkomstig van die empiriese ondersoek kon bydra tot 'n doelmatige *prototipe vir leerspelbeoordeling*. Die verskillende leerspelsuksesvlakke wat so 'n stelsel kon uitwys, sou kon bydra tot die debat met betrekking tot die kwessie van *leer* met elektroniese spele teenoor die sensasie van *genot* wat spelers ervaar; die mate van realisme in leerspele, en, of die koste verbonde aan die gebruik van kunsmatige intelligensie die moeite werd is vir die produksie van elektroniese leerspele. Hierdie reeds bespreekte akademiese betoog spreek die debat tussen gebruikers van elektroniese leerspele aan. 'n Aanvanklike ondersoek na gepaste elektroniese leerspelfaktore vanuit lukraak gekose artikels het geblyk onbevredigend te wees. Artikels met betrekking tot elektroniese leerspele lewer meestal verslag oor die kriteria waarteen leerspele gemeet word (bv. die vermoë om die belangstelling van speler te wen en te behou). Navorsers neig om, onder andere, herhaaldelik elektroniese leerspele teen sulke kriteria te meet in plaas daarvan om die suksesfaktore wat tot sekere standaarde lei, na te vors. Dit blyk dat die gebied van elektroniese leerspele eindeloos wentel rondom *werk-my-speletjie*-navorsing terwyl *hoekom-werk-my-speletjie-nie*-navorsing meer waardevol kon wees. Nieteenstaande onsamehangende of misleidende studies met min akademiese waarde, blyk dit dat die studieveld van elektroniese leerspele op aspekte gebou is wat nie gemeet kan word nie/moeilik gemeet kan word, en die sistematies-uitgesoekte studies slegs brokkies inligting met betrekking tot suksesfaktore van elektroniese leerspele uitwys. Die aspekte met betrekking tot suksesfaktore is uit 63 navorsingsartikels vanuit 'n verskeidenheid elektroniese biblioteke en -databasisse ontgin ten aansien van die periode 2000 tot 2015. 'n Konstante vergelykingsmetode vir die analise van kwalitatiewe data het vyf teoretiese temas aan die lig gebring (storielyn en spelvervaardiging; realisme; kunsmatige intelligensie en aanpasbaarheid; interaksie; en terugvoer en ontlonting) wat ankers geword het vir die groepering van meervoudige suksesfaktore. Die SLO het drie dimensies (leer, pret en dinamika) en hul gepaardgaande koppelvlakke van vyf teoretiese susksesfaktore opgelewer. Die interpretasie van die analise het gelei tot die ontwikkeling van 'n voortoets van 'n praktiese leerspelmeter (LSM) in Excel™. 'n Geweegde matriksstruktuur vorm die basis van die LSM. Vier BSc Honneurs in IT studente het

deelgeneem aan die formatiewe voortoetsing van die LSM. Waarneming, onderhoude, ‘n inisiële bruikbaarheidsvraelys en vergelykings van die LSM-metings teen deelnemeruitsprake oor vier lukrake toets-leerspeletjies het as basis gedien vir die bepaling van die waarde van die LSM vir verdere ontwikkeling. ‘n Drie-dimensionele model wat die verhoudings tussen die temas en dimensies beskryf, het die poging met betrekking tot teoriebou van ‘n konkrete verstaan van die kernbeginsels van elektroniese leerspele vervat. Die SLO het aangedui dat die sigwaarde van individuele artikels nie gebruik kan word om die konsep van elektroniese leerspelnavorsing te beoordeel nie, maar dat die versameling van belangrike artikels die onderliggende aspekte as ‘n samehangende struktuur van die elektroniese leerspelstudieveld uitbeeld. Toekomstige navorsing met die LSM-prototipe hou die moontlikheid in om ‘n stel pragmatiese standaarde daar te stel vir die beoordeling van die kwaliteit van elektroniese leerspele. Die uiteindelike maatstaf is egter dat elektroniese spele nie aan leerders opgedring word nie, maar dat hulle uit eie keuse sal speel en leer.

Sleutelterme

aanvoertoets; dinamika; elektroniese leerspele; genot; leer; leerspelmeter (LSM); prototipe; sistematiese literatuur oorsig (SLO); suksesfaktore; teoriebou

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I declare herewith that the thesis / dissertations / mini-dissertation entitled:

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which I herewith submit to the North-West University as completion / partial completion of the requirements set for the **MSc in Computer Science** degree, is my own work and has not already been submitted to any other university.

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In terms of the provisions of paragraph 80 of the Statutes of the North-West University, the undersigned declares that the cadidate attended an approved course of study for the relevant qualification and that the work for the course has been completed or that work approved by the Senate has been done.

He is hereby granted permission to hand in his dissertation.

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To whom it may concern,

Confirmation of language edit for MSc Dissertation

This letter serves to confirm that I, Natasha Ravyse (8712260045085), a registered language practitioner with the Professional Editors' Guild, have language edited the MSc Dissertation written by Werner Ravyse entitled *Investigating the success factors of serious games: a systematic review.*

Natasha Ravyse
Registered independently contracted editor

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16 October 2015.

TO WHOM IT MAY CONCERN

This letter serves to confirm that Natasha Ravyse ID No. 8712260045085 is a fully paid up member of the Professional Editors' Guild. Her membership is valid until 29 February 2016.

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Applying the success factors of serious games as a Serious Games Gauge

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List of Acronyms

AED	automated external defibrillator
AI	artificial intelligence
ALS	advanced life support
BSc	*Baccalaureus Scientiae*
CCM	constant comparison method
COTS	commercial off-the-shelf
CPR	cardio-pulmonary resuscitation
CRD	Centre for Reviews and Dissemination
DGBL	digital games-based learning
DTD	document type definition
EA	Electronic Arts
ERIC	Education Resources Information System
ESA	Entertainment Software Association
EU	European Union
GPS	global positioning system
HUD	heads-up display
ICT	information and communication technology
IMF	International Monetary Fund
IP	Internet protocol
IT	information technology
MDA	mechanics, dynamics and aesthetics
MDP	Markov decision process
MMOG	massively multi-player online game
MMORPG	massively multi-player online role-playing game
MOG	massive online game
MSc	*Magister Scientiae*
MSDS	material safety data sheet
NGO	non-government organisation
NPC	non-player character
NRF	National Research Foundation
NSTA	National Science Teachers Association
NWU	North-West University
OS	operating system
PC	player character
PCD	portable computing device
PD	personal development
SG	serious game
SGG	serious games gauge
SGI-SA	Serious Games institute of South Africa
SLR	systematic literature review

SMS	short message service
SQL	structured query language
TELIT-SA	Technology Enhanced Learning for Innovative Education and Training in South Africa
US	United States
VR	virtual reality
XML	extensible markup language

Setting the scene for investigating the success factors of serious games

1. Introduction

"The scientific method of separating, explaining, and arranging becomes conscious of its limits, set by the fact that the employment of this procedure changes and transforms its object; the procedure can no longer keep its distance from the object" (Heisenberg, 1958:107). What Heisenberg (1958) implied was that in order to understand a particular object, a thorough comprehension of that which imposes itself on the object under scrutiny is needed. In the same way, the mode of delivery imposes itself on learning and in order to achieve more effective learning, understanding the mode of delivery better is necessary. One of these modes of delivery that this study sets out to understand is serious games in which a specific form of learning manifests itself through the amalgamation of fun and pedagogical foundation. In the 1970s, Clark Abt spoke of serious games as games that have deliberate educational intent without the goal of engaging with them for entertainment only (Abt, 1970:9). Admittedly, Abt (1970) was referring to analogue board and card games and in the advent of technological advancement, the term *serious game* rather found a new digital context than undergoing a definition change. This is evident from the myriad of academic authors (Marsh, 2011; Mitgutsch & Alvarado, 2012) researching digital serious games who still turn to Abt's original definition of serious games. The researcher intends to investigate the collection of serious games literature under the framework of reflective practice to obtain a clearer understanding of the field and transpose this newfound knowledge into a practical solution.

Serious games are not only about activities that educate, instruct or train, but rather that the addition of pedagogy is what sets them apart from entertainment games (Zyda, 2005:26). Moreover, serious games are challenged to find a balance between the ludic and pedagogical goals so that neither a dominant game mode (taking away from the learning outcomes) nor learning mode (removing the fun element) is present (Giessen, 2015:2241).

From the 2015 Horizon Report "*The Hechinger Report* points to games and videos as two of the primary ways that students learn outside of their schooling" (Johnson *et al.*, 2015:22). The use of computer games to foster learning has steadily been finding favour amongst government policy makers, health professionals, advertisers, training practitioners and educators alike (Connolly *et al.*, 2012:662). Also, many researchers (Hyungsup, 2014:205; Mortara *et al.*, 2014:318; Sacfung *et al.*, 2014:583; Wiemeyer, 2010:65) keenly report on various games to teach a diverse suite of fields and

subjects including sports, resilience amongst the elderly, fire evacuation and cultural heritage to name a few.

This study focuses on *digital* serious games and is approached with a positive lens on the potential learning value such games have. The digital arena does however, open a source of confusion with digital games based learning (DGBL), e-learning, edutainment, gamification and gameful design all inhabiting this space and claiming some title in education through electronic games. Given some overlap, serious games are none of these. In scouring existing literature on DGBL it soon becomes apparent that the primary aim of such products is increased cognitive success (Chen & Lin, 2015; Hussain *et al.*, 2014; Ronimus *et al.*, 2014) while serious games extend beyond this into the realms of healthcare (recovery and therapy), advertising, training (e.g. how to use specialised equipment) and research/data collection. Table 1 gives a detailed two-dimensional (content and sector) serious game taxonomy to illustrate the wider application field of serious games.

Table 1: Serious games taxonomy (Sawyer & Smith, 2008)

		GENRE						
		Games for health	**Advergames**	**Games for training**	**Games for education**	**Games for science and research**	**Production**	**Games as work**
SECTOR	**Government and NGO**	Public health education and mass causality response	Political games	Employee training	Inform public	Data collection or planning	Strategic and policy planning	Public diplomacy and opinion research
	Defence	Rehab and wellness	Recruitment and propaganda	Soldier support training	School house education	War games and planning	War planning and weapons research	Command and control
	Healthcare	Cybertherapy or exergaming	Public health policy and social awareness	Training games for health professionals	Games for patients	Visualisation or epidemiology	Biotech manufacturing and design	Public health response planning and logistics
	Marketing and communication	Advertising treatment	Advertising, marketing with games and product placement	Product use	Product information	Opinion research	Machinima	Opinion research
	Education	Inform about disease and risks	Social issue games	Train teachers or workforce skills	Learning	Corporate science and recruitment	Documentary?	Teaching and distance learning
	Corporate	Employee health information and wellness	Customer education and awareness	Employee training	Continued education and certification	Advertising or visualisation	Strategic planning	Command and control
	Industry	Occupational safety	Sales and recruitment	Employee training	Workforce education	Process optimisation and simulation	Nano- or biotech design	Command control

e-Learning, although ranging through the same sectors, extends to the use of *any* digital media for the purpose of learning (Keller, 2012:4). Although serious games are most certainly an e-learning

branch, e-learning does not exclusively combine gameplay and education. The next games and learning family member is the somewhat pioneering edutainment. Edutainment is a term that was first used in the late 1980s (and still) refers to gameful education aimed at conveying factual knowledge to young children (Ito, 2006:142). Okan (2003:256) states that edutainment software claims to benefit a child's skill development in a variety of subjects. Further scrutiny of existing literature titles and popular media quickly reveals that edutainment is indeed education by means of gameplay primarily aimed at children (CHALK Preschool Online, 2015; Seongwon & Duk-Shin, 2014), while the taxonomy presented above clearly shows that serious games have a more far-reaching potential for adult education and training than just for children, making edutainment a subset of serious games. Figure 1 shows a Venn diagram of where serious games find themselves in the digital and non-digital (not discussed here) gaming educational concepts.

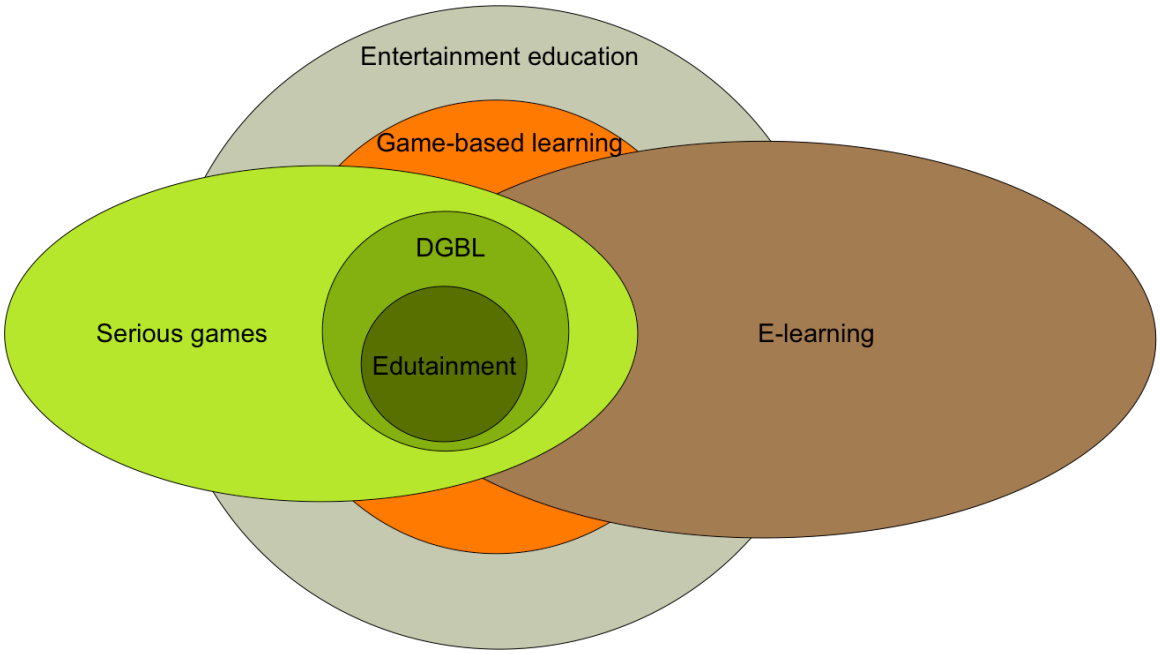

Figure 1: **Serious games within the educational gaming context (**adapted from Breuer and Bente (2010:11))

From an intent-of-design perspective, gameful design and gamification (used interchangeably and mostly regarded as synonymous) are closely associated with serious games. This approach targets the aesthetic appeal (by means of graphics, animated characters and/or other) of learning and introduces game mechanics (such as a leader board, progress bars, points and even quests) to stimulate participation in activities that are not games (O'Donnell, 2014:349) or could otherwise be

deemed boring. In short, gamification does not include actual gameplay whereas serious games do combine gaming and learning (Kim, 2015:21).

The global games market totals approximately $90 to $100 billion (Digi-Capital, 2015; Newzoo, 2015) and has been steadily growing at an annual rate of between seven and ten per cent since 2012. This trend is set to accelerate with a 2017 market forecast by Newzoo (2014) of about $103 billion while the more recent report (Digi-Capital, 2015) predicts a 2017 market nearing $120 billion. The continuous development and release of new game titles (particularly for mobile platforms), gaming consoles and technologies (oculus rift, augmented reality games and others) also indicate that this is not about to slow down (Gartner, 2013). Figure 2 gives an overview of the game genres and where they present themselves on a level of complexity and extent of social interaction required matrix.

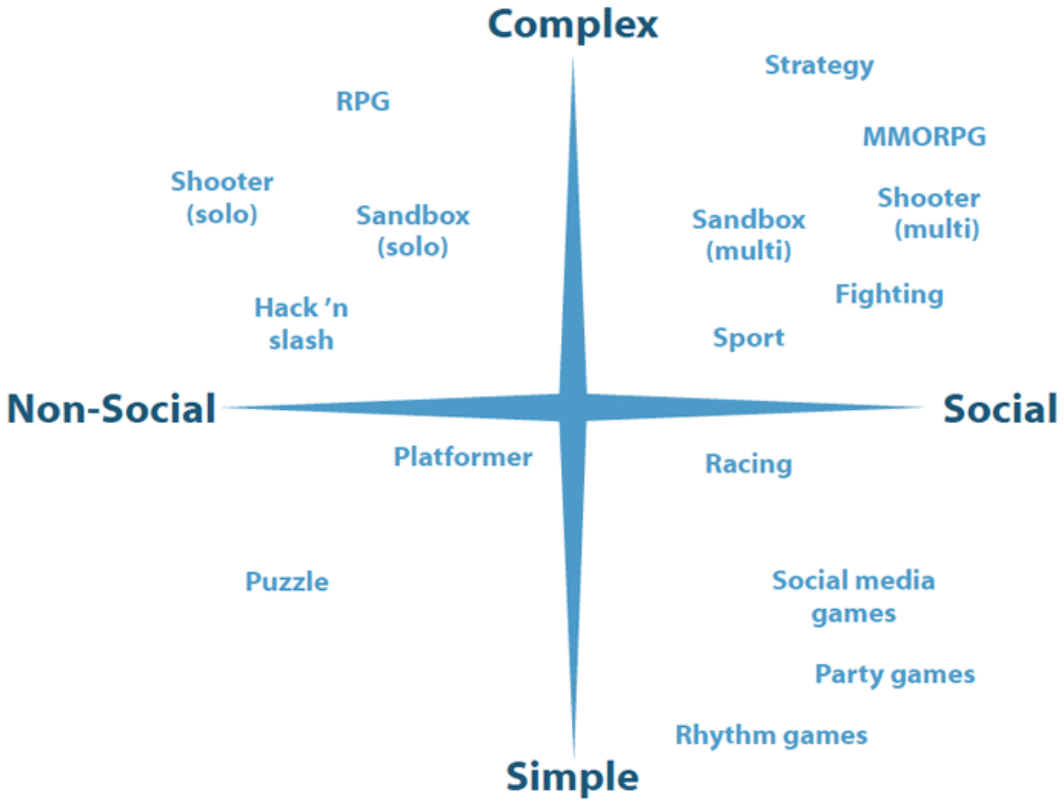

Figure 2: **Game genre matrix (**adapted from Granic *et al.* (2014:70))

What then makes this sector so successful that it is able to outgrow the global economic growth of 3,6% and 3,8% for 2015 and 2016 respectively (IMF, 2015) by such a significant margin? Such growth can only take place through a sustained demand and increasing popularity amongst consumers. Gaming achieves this through providing an entertaining virtual environment that

captures a player's imagination, sense of adventure, pursuit of challenge and/or any combination of these and more that awakens a sense of intrinsic reward—games are fun (Oswald *et al.*, 2014:119).

To understand what makes games fun, a suitable decomposition of games is first required. Games are best grasped through a formal approach to understanding their design. One such framework is afforded by Hunicke *et al.* (2004) who raise the acceptance that mechanics, dynamics and aesthetics (MDA) hold the key to decomposing game designs and artefacts. The fun, or entertainment, feature of the game is encapsulated within the aesthetic design component as a set of "desirable emotional responses (sensation, fantasy, narrative, challenge, fellowship, discovery, expression and submission) evoked within the player" (Hunicke *et al.*, 2004:2) when engaged with the game. Niedenthal (2009:2) adds that aesthetics, in the context of a game, is also sometimes intended to convey the visual phenomena encountered by players or the aspects of game art that are shared with other art forms. Both of which, in the view of the researcher, lead to an emotional expression of the gaming encounter. Game mechanics refer to the rules of the game, or rather what players can do in a game, how they go about doing this and in what way feedback of their actions takes place via the user interface and/or haptic controls (Elson *et al.*, 2014:526). Game developers directly control this aspect at algorithm level as "methods invoked by agents, designed for interaction with the game state" (Sicart, 2008). This definition of mechanics by Sicart (2008) touches on the role dynamics has in game design. Game dynamic is the run-time result of interaction between the mechanics and user inputs to create aesthetic experience (Hunicke *et al.*, 2004:3). In other words, game dynamic is the game's behaviour that is exhibited during gameplay (LeBlanc, 2006:440). Using the classic game Pac-Man, Gallant (2009) provides a clear illustration of the interplay between video game mechanics, dynamics and aesthetics: "The pathfinding logic of the enemies is defined by a formal set of rules. Each ghost has a unique seeking mechanic: Blinky targets the tile that the player currently occupies, while Pinky targets four tiles ahead. Together, these rules create a dynamic wherein the player becomes boxed in by Pinky in the front and Blinky from behind. This dynamic presents a challenge to the player, creating an aesthetic of fun and excitement."

A less formal, yet compelling and practically oriented explanation of what makes a good game is provided by Marsden (2013). Two distinct components of game design (gameplay and presentation) with their respective considerations are presented. On the gameplay side, controls refer to the mechanisms the game revolves around and must be perfectly planned; the concept, which should be strong enough to provide an immersive environment, imparts the virtual area (or

context) where the player interacts with the game; and the learning curve drives the player's excitement by a mix of challenge and achievement and should ideally hover around the edge of the player's ability (Csikszentmihalyi, 2008). The presentation side focuses on the user interface that communicates the game state to the player and must never break the player's sense of control; the audio and visual elements are synonymous for the art style of the game and must suit the theme of the game; feedback is the direct result of the player's interaction and can be positive or negative as long as it amplifies the experience. The researcher summarises this reflection in Figure 3 and relates it to the MDA framework explaining the structure of games that make players keep coming back to play more.

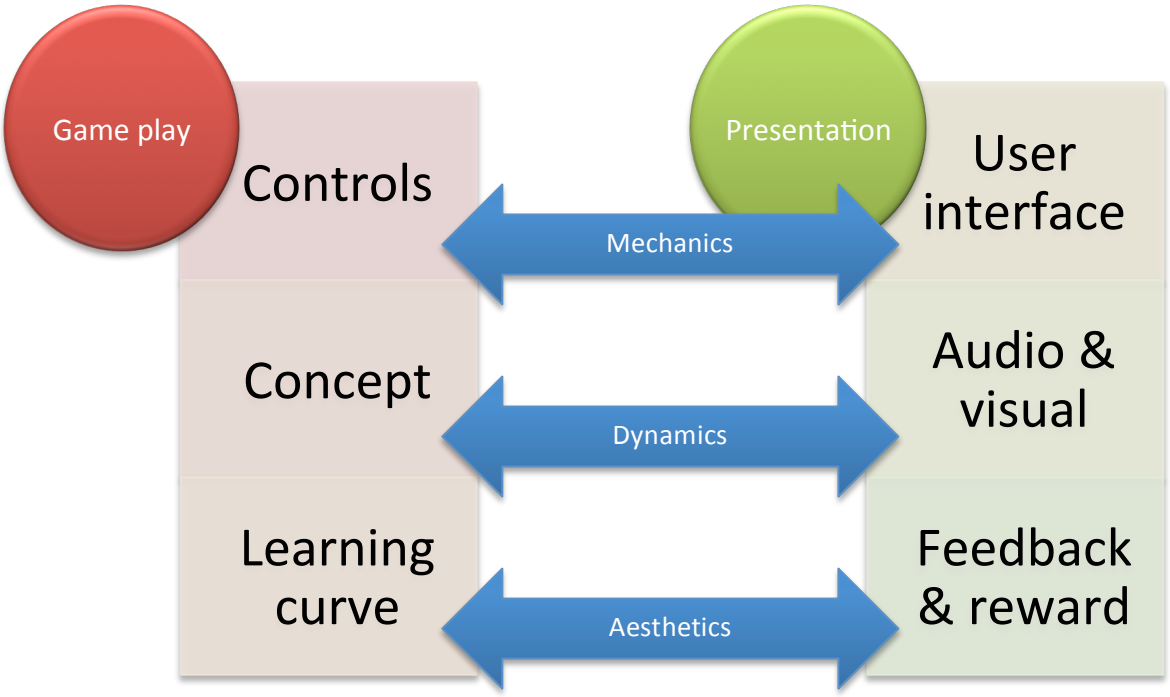

Figure 3: Practical game design discourse related to the MDA framework

When something is repeated often enough, it sticks; this is considered learning (from an experiential (Kolb, 1984) viewpoint), which by definition of serious games, is key to the field's existence. Serious games by intent, delineated earlier, allow learners to apply their current knowledge in a digital environment with the aim of acquiring a new skillset by their own volition to overcome contextual challenges (Boyle *et al.*, 2011:72). With the added possibility of multi-player games, players can achieve this on a social platform. There are several learning paradigms, or rules of the *game* as Barr and Tagg (1995:15) put it, defining learning's playing field and can be compared to one another to determine which one best suits our *game*—serious games. Ireland (2007) crafted a

table of different learning paradigms (Table 2) which are differentiated through five definitive questions. The researcher supplemented Table 2 with a *heat map* to indicate the paradigm best suited for learning by serious games. The shaded cells in Table 2 show the applicable thoughts that relate directly to the intention of serious games.

Table 2: Comparing different learning paradigms and how they relate to serious games (adapted from Ireland (2007))

Questions	Behaviourism	Cognitivism	Constructivism	Connectivism
How does learning occur?	Black box—observable behaviour is main focus	Structured and computational	Socially, where personal meaning is created by each learner	Distributed within a network, technology enhanced and recognising-interpreting patterns
What factors influence learning?	Nature of reward, punishment and stimuli	Existing schema and previous experience	Engagement, participation and social/cultural	Diversity of network
What is the role of memory?	Memory is the hardwiring of repeated experiences	Encoding, storage and retrieval	Prior knowledge remixed to current context	Adaptive patterns representative of current state existing in networks
How does transfer occur?	Stimulus-response	Duplicating knowledge constructs of the 'knower'	Socialisation	Connecting and/or adding nodes
What are the types of learning best explained by this theory?	Task-based learning	Reasoning, clear objectives and problem solving	Social or vague (ill-defined)	Complex learning, rapid changing core and diverse knowledge sources

Granted that there is some learning activity overlap with behaviourism and connectivism, it is fair to suggest constructivism as the most suitable rule-set for serious games (Boyle *et al.*, 2011:72). Osterman (1998:8) confirms this reasoning with a list of constructivist pedagogical strategies that the researcher aligns with serious game properties taken from Gee (2005). Table 3 illustrates this notion and also makes it evident that the learners, as active discoverers and constructors of their own knowledge, are the central constructivist theory cogs (Barr & Tagg, 1995:21).

Table 3: Comparison of constructivist pedagogical activities and serious game properties (adapted from Osterman (1998:8))

Pedagogical activities	Serious game properties
Engage the learner. Enable learner to play active role in the learning process	Nothing happens until a player acts and makes decisions
Provide opportunities to explore, articulate and represent knowledge	In good video games, the problems players face are ordered so that the earlier ones are well built to lead players to form hypotheses that work well for later, harder problems
Challenge existing views; build conceptual; heighten awareness of problems	They encourage players to explore thoroughly before moving on; to think laterally, not just linearly; and to use such exploration and lateral thinking to reconceive one's goals from time to time
Provide opportunities for students to reconceptualise and test the efficacy of new ideas	Then the game throws a new class of problems at the players, requiring them to rethink their now taken-for-granted mastery

Not all learners have the same partiality towards the various ways knowledge construction can be administered or processed (Felder & Spurlin, 2005:103) and many models describing these learning styles exist; Kolb (Kolb, 1984), Modality Strengths (Barbe & Milone, 1981) and 4MAT (McCarthy, 1997). The model proposed by Felder and Silverman (1988:675) and adapted by Felder in 2002 classifies learners into four dimensions with preference for one of two categories in each of the dimensions:

- Sensing (concrete thinker, practical, oriented towards facts and procedures) or intuitive (abstract thinker, innovative, oriented toward theories and underlying meanings);
- Visual (prefer visual representations of presented material, such as pictures, diagrams and flowcharts) or verbal (prefer written and spoken explanations);
- Active (learn by trying things out, enjoy working in groups) or reflective (learn by thinking things through, prefer working alone or with a single familiar partner); and
- Sequential (linear thinking process, learn in small incremental steps) or global (holistic thinking process, learn in large leaps).

The significance of learning styles in relation to serious games (the researcher has evidenced into the constructivist paradigm) is that when the learning and teaching styles do not support each other, the students are bound to dismiss the learning experience as a negative one (Felder & Silverman, 1988:671).

Lastly, learning essentially invokes altered behaviour or advances knowledge acquisition (Louw & Edwards, 1997:225). Such learning outcomes can be arranged along skill-based (including dexterity and technical), cognitive (including declarative, procedural and strategic) and affective

(including emotional or attitude) dimensions (Garris *et al.*, 2002:456-457). Learning with serious games similarly impacts a player's behavioural practices and/or cognitive processes (De Freitas & Ketelhut, 2014:1).

All by all, the researcher is firmly convinced that serious games can have a pleasurable and beneficial influence on acquiring new-found knowledge, ability or emotional intelligence. Serious games have the inherent potential to be fun and given the right injection of pedagogy, be educationally valuable.

2. Problem statement

Serious games are expensive and time-consuming to produce, therefore much care needs to be taken to ensure that they will be successful. Ambient Insight's (Greer, 2014:6) latest annual study reports a combined simulation- and game-based market of $4.7 billion for 2013 and growing to $9.6 billion in 2018. This data brings up two salient points: (a) there is a sizeable serious games market; but (b) it currently comprises only about five per cent of the total games market.

The Serious Games Institute of South Africa (SGI-SA) is in the serious games market and has been actively designing and developing serious games since May 2012 with limited success. Successful games, for the purpose of this study, are understood as *games that are enjoyed while offering an enhanced learning experience*. To understand the serious games commercial market would only result in dividing the five per cent total gaming market amongst another player. Rather, an understanding of serious games themselves and what could make them sellable should be gained. In this way, either the five per cent stake on the electronic games market increases or the entire games market grows, providing a larger income pool for commercial serious games practitioners.

The question now remains, what must serious games professionals do to improve their learning tools? 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 & Bente, 2010:7; Susi *et al.*, 2007:2).

Reviews on the empirical evidence or effectiveness (Bellotti *et al.*, 2013; Connolly *et al.*, 2012; Girard *et al.*, 2013; Wouters *et al.*, 2013) of serious games and what considerations (user, expert

content, aesthetics and mechanics) intended serious game developers should keep in mind (Kickmeier-Rust & Albert, 2012:17; Mitgutsch & Alvarado, 2012:123) are well documented. The evidence for defining serious games and gauging their raison d'être, however, is far more scattered amongst individual studies (Müller-Lietzkow & Jacobs, 2012:42). A further search of the literature reveals 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. Marsh (2011:62) also argues the point that academics labelling and outlining serious games, approach it from a familiar corner. The researcher however, believes that existing reviews and individual studies hold the key to producing more desirable, effective and ultimately more sellable serious games. In searching for such a combined work, the researcher has not been able to find any literature that explores and summarises key serious game success factors that need to be considered from the outset when creating a serious game. This is echoed by De Freitas and Ketelhut (2014:1) who assert that the field of serious games is accused of being disorganised, fragmented across disciplines and geographies. This might provide a clue why quality games for learning are hard to come by (Mcmahon & Henderson, 2011:3599).

In supporting the notion that learning games need to improve their playability, Zyda (2005:26) argues that pedagogy should be subordinate to story and entertainment, while researchers such as Michael and Chen (2006:17) argue that educating the player should be the primary goal of serious games—further adding to the confusion of understanding serious games. A review study on the pedagogical foundations of educational computer games shows that many educational games lack a sound pedagogical foundation (Kebritchi & Hirumi, 2008:1729). From the 55 games investigated during this study, pedagogical foundations supported only 24 games and 18 were based on recognised instructional strategies (Kebritchi & Hirumi, 2008:1739). The review does not answer whether the serious games with pedagogical foundations were more successful than those without.

Further confusion stems from the question of realism (fidelity). Research has shown that fidelity levels and knowledge transfer are not necessarily positively correlated (Feinstein & Cannon, 2002:426) and that lowered levels of fidelity may even have a value-added effect on knowledge transfer (Mania *et al.*, 2006:402). Often enough though, when customers ask for a game, the request to "make it as realistic as possible" is expressed. This typically stems from their exposure to high fidelity entertainment games (Visschedijk & Van der Hulst, 2012:104). If this expectation of fidelity is not met, it could interfere with a player's motivation to play the game (Alexander *et*

al., 2005:8). No literature could be found that unravels the instilled sentiment of uncertainty about the right level of fidelity required in serious games.

One must also not lose sight of a deeper level of complexity prevailing in the world of serious games, that is the close-knit dynamic existing between the game developers, design artists (graphics and sound) and content experts (Barbosa *et al.*, 2014:1). The serious game design assessment framework proposed by Mitgutsch and Alvarado (2012:123) suggests pedagogical overseers and consumers are likewise integral role players. This web of inter-relationships leads to one of the major quandaries that serious games must overcome; players experiencing a disjointed gaming and learning activity (Kickmeier-Rust & Albert, 2012:16) taking away from the flow state (Csikszentmihalyi, 2008) that keeps players engaged and intrinsically motivated to play (Gee, 2005:36)—for which nobody seems to have a clear answer.

The evidence from above leaves much room for debate and unanswered questions. Are serious games meant to be more fun than educational? Do they need to replicate/simulate the environment accurately? Should they be written with a specific target audience in mind? Is an underlying pedagogical approach key to their success? In addition to answering these questions and providing the key ingredients for a successful serious game, this study will present serious game producers with a pilot-tested evaluation tool to estimate the potential of an intended serious game. The researcher envisages that this tool, when applied at the start of a serious game project, will reciprocate considerable time and money in developing the game or a playable demo thereof.

3. Objectives of the study

The following objectives were formulated for the study.

3.1 Primary objective

To conduct a systematic review of credible sources in order to compile a single body of evidence that advocates the key success factors of serious games.

3.2 Secondary objective

To suggest a guidelines review tool called the serious game gauge (SGG) that applies weighted key serious games success factors in the form of a usability evaluation instrument for serious games.

3.3 Theoretical objectives

The theoretical objective for this study was: (a) to understand the field of serious games; and (b) to be able to synthesise the criteria through theory building (Merriam & Tisdell, 2016:13) for evaluating serious games into a practical tool.

3.4 Empirical objectives

Pilot-test against four serious games to verify if the SGG is able to rate the games' success accurately.

4. Research design and methodology

To overcome the disorderly affair of building and dispersing serious games without much telling impact, the researcher elected to evaluate the aims, activities and results of serious games through systematically reviewing the field's existing literature. The salience of this review lies in attaining a greater understanding of the field which will alter the researcher's serious game development practices and ultimately lead to producing high-quality serious games. This kind of behaviour change in the dimensions of professional habit is the primary agenda of reflective practice (Schön, 1987). Reflective practice is best described as a learning cycle (illustrated in Figure 4) consisting of four stages: experience, assessment, re-conceptualisation and experimentation (Osterman & Kottkamp, 1993:20). Figure 4 also super imposes the researcher's problem identification and solution-driven strategies towards a *new* experience—refreshing the reflective practice cycle.

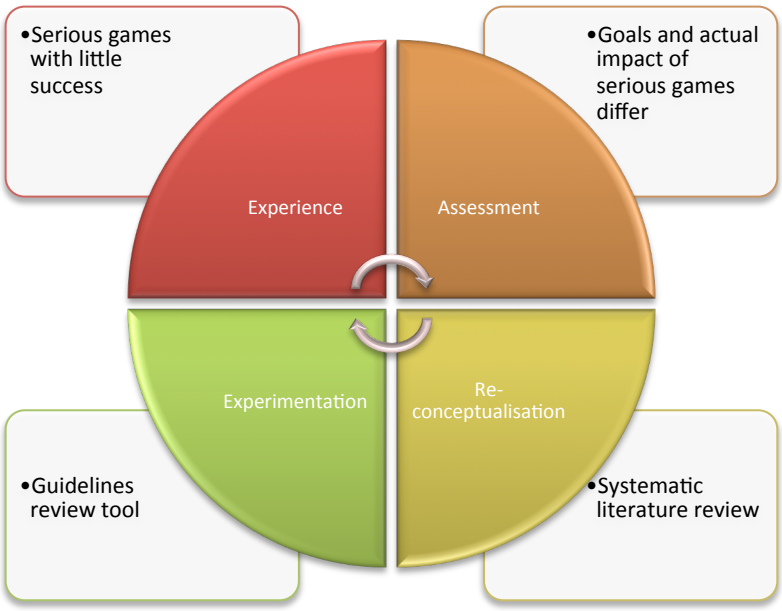

Figure 4: The researcher's reflective practice cycle (adapted from Osterman and Kottkamp (1993:20))

From this, it is clear that the researcher intended to put the emerging aspects (Perkins, 1992) from the systematic review into operation to develop a new set of ideas in the form of a practical tool as a basis for enhanced performance and continued research (Osterman, 1998:3).

This study primarily aimed to collect reliable voices from scholarly literature in order to identify and describe the key success factors for serious games. Serious games fall within the field of learning and instruction (Wouters *et al.*, 2013:249) and have become accepted educational tools (Kickmeier-Rust & Albert, 2012:15) geared towards changing the way in which players/learners interact with their immediate environment (Johnson *et al.*, 2015:29; Mayer *et al.*, 2014:504)—all of which indicates that serious games are a social scientific discipline. Therefore, in understanding that this study fell within a social context, the researcher adopted the approach taken by Burrell and Morgan (1979) who prescribe that both the nature of society as well as the nature of social science must be taken into consideration when conducting social research.

The nature of society attempts to explain the fundamental interrelationships and unity within social constructs. Burrell and Morgan (1979) suggest moving away from the "order-conflict" debate. Instead, they propose the use of a continuum that ranges between regulation and radical change. Table 4 shows what each extreme belief of this regulation-radical change spectrum is concerned with.

Table 4: The regulation-radical change dimension (Burrell & Morgan, 1979:18)

Regulation	**Radical change**
Status quo	Radical change
Social order	Structural conflict
Consensus	Modes of domination
Social integration and cohesion	Contradiction
Solidarity	Emancipation
Need satisfaction	Deprivation
Actuality	Potentiality

This study intended to understand and describe the current serious game success factors. Therefore, in order to suggest the SGG that could elicit a change in the way serious games are approached, the researcher attempted to answer questions that the sociology of regulation is concerned with.

The nature of social science gives sets of philosophical assumptions (ontology, epistemology, human nature and methodology) that govern the approaches to social science. Burrell and Morgan

(1979) propose a continuous subjective-objective dimension that can be used to determine the philosophical standpoints of social researchers. Remaining within the sociology of regulation, the two divergent views along the subjective-objective continuum can be summarised as interpretivistic and functionalist respectively (Burrell & Morgan, 1979:22).

This study explored the current practices and results (sociology of regulation) of serious game application in order to understand and describe (theory of subjectivity) the factors that contribute to successful serious games. In the second phase of this research, the study sought to create and pilot a pragmatic guidelines review tool based on the primary report. The tool however, was not stringently tested by means of structured positivist or post-positivist constructs and procedures. This implies that while the second phase of the study had practical application value and therefore, plotted as a functionalist approach, it was not coordinated enough to take on the radical structuralist guise. In short, and illustrated in Figure 5, this study started by interpreting the field of serious games so that a practical and functional tool could be proposed.

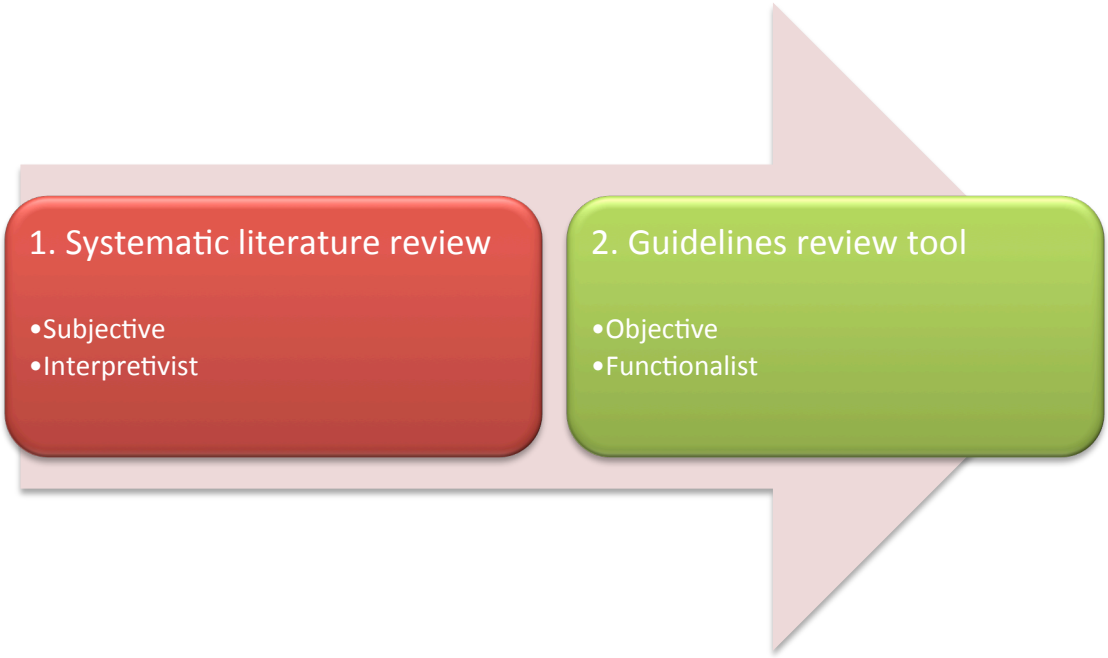

Figure 5: The two phases of this research study and their respective approaches

4.1 Systematic literature review

Scientific research produces an abundance of evidence reporting on similar topics, disciplines and fields. Although the results of a literature search do not directly relate to one another, except in cases where one study follows up on another, they do provide the sum of parts for a larger integrated whole (Mulrow, 1994:598). A systematic review is a formally structured and stringent

search of existing literature with a traceable set of steps which other scholars are able to replicate or contribute to (Tranfield *et al.*, 2003:209). To complete the systematic review audit trail, researchers must explicitly present their search and study selection criteria and show how the data was extracted and synthesised, before providing a definitive report of the findings and how these relate to the matter being investigated (Briner & Walshe, 2015:65). Systematic reviews comprise of documents relating to quantitative or qualitative (or a combination) evidence (Hemingway & Brereton, 2009:1) and collating these scattered parts to address research questions that random studies of the literature cannot achieve (Kitchenham, 2004:1).

This study aimed to provide validity, reliability and repeatability to researching the success factors of serious games. Figure 6 illustrates the systematic review process adhered to in this study, and is followed by a more detailed discussion.

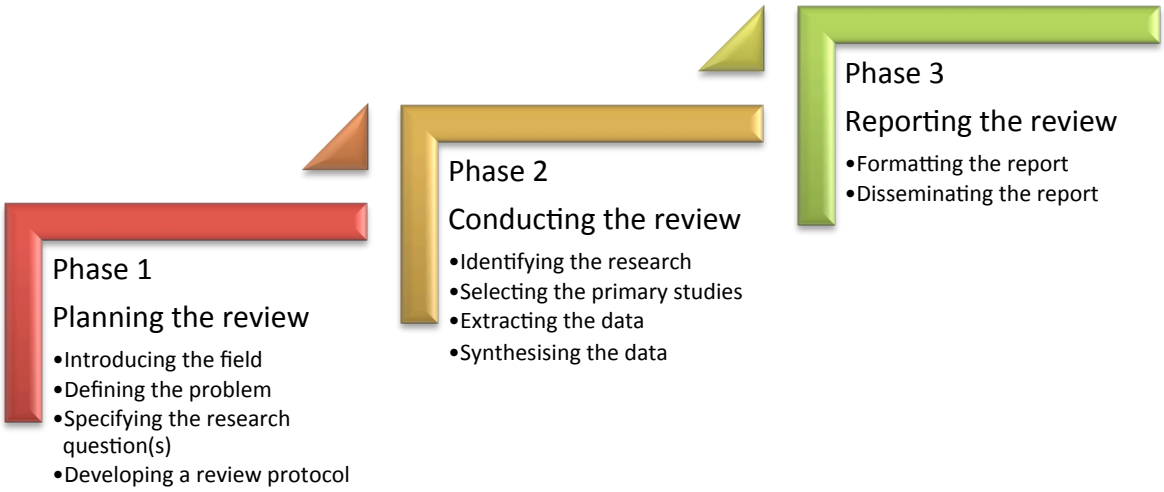

Figure 6: Systematic review steps (adapted from Kitchenham (2007:6))

4.1.1 Identifying the research

To identify the primary studies for this review, the researcher applied a series of search terms to a host of electronic databases and digital libraries. A basic Internet search was not required since the digital libraries provided a sufficient number of hits to draw data from. The researcher has been in contact with a number of serious games experts and researchers over the past eight months to garner knowledge about other sources of information pertaining to serious games. These people include, Dr Ernest W. Adams (consulting professor at Uppsala University and former lead game designer at Bullfrog and EA Games), Mr T. Lanning (owner and founder of Grendel Games), Mr A. Sikkema (manager of Game Academy Leeuwarden), Dr A. Woolner (specialist researcher in serious games

at Coventry University), Prof. P. Kato (head of The Serious Games Institute Coventry), Dr H. van Dijk (head of serious gaming Nederlandse Hoogeschool Leeuwaden) and several other influential players in the serious games arena. Once the primary studies were finalised, a second filter of inclusion/exclusion criteria was administered on their abstracts and full texts (where necessary) to ensure only studies relevant to the research question were included (CRD, 2009:13).

Digital databases that are applicable to computer science, information science and technology, health sciences (the most prominent sector for serious games) education and social sciences were explored. The following databases were searched: Web of Science core collection, Science Direct, EBSCO (comprising of ERIC (Education Resources Information Centre), 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 head librarian at NWU: Vaal Triangle Campus (Ms M. Esterhuizen) dissuaded the use of Google Scholar as a formally searched database since many articles uncovered by Google Scholar are inaccessible from the NWU library system.

The researcher, after consultation with a librarian at NWU: Potchefstroom Campus (Ms L. Snyman), chose to employ broad terms for searching the digital libraries. The reason for this was that after several test searches with secondary terms included, the researcher was of the opinion that there were too few hits for the time period and number of databases in question—concern was raised over the possible omission of pertinent work. Search terms for this study included *serious games* and synonymous terminology for serious games observed in studies encountered when the scope of this review was established. The following search terms were used: *("serious games"; "games-based learning"; "simulation games"; "gamification"; "edutainment"; "educational games"; "games for learning").* Advergames create awareness and were not included in the search because this review examined studies that bring about knowledge transfer, behaviour change and motor skill acquisition. Each search term was used in a singular fashion on each of the databases mentioned earlier and depending on the search capabilities of the respective databases, different reference fields (e.g. title, abstract, keywords and others) and search strings were used. In short, each of the seventeen databases were searched seven times resulting in 119 searches totalling 30 070 hits. All hits were exported to EndNote™ X7 (an electronic reference manager) where they

were stored in 119 distinct sub-groups on a per-search-term-per-database basis. A series of strategies to reduce the number of hits was engaged (Addendum I).

The first of these strategies was a two-step removal of duplicates where the first step was to let EndNote™ find duplicates and the researcher deleted all duplicate references. Step two required the researcher to list all the searches alphabetically and manually peruse and delete the remaining duplicates. The reasons why EndNote™ did not uncover these duplicates, in all cases in this auto search function, were the discrepancy in publication dates (some databases record the journal publication date while others report the e-publication date of the reference), author and journal naming conventions and misspelled titles. Hits that had no title and non-English references were also removed at this stage. This first round of removals reduced the number of hits to 13697. Subsequent removal strategies are shown in Table 5.

Table 5: Removal strategies to reduce the number of hits for SLR process

References removed	Method	Reason	Hits remaining
Generic literature	Sort by *journal*, identify and remove references of known newspaper and magazine titles	These references are not peer-reviewed and are most likely a summary of select studies	12 255
Conference proceedings	Sort by *ref type* and remove all references labelled as *conference proceedings*; search titles for exact matches of *conference proceeding* or *conference* and remove the hits	Conference proceedings are very concise and omit much of the detail required for this study	9 589
Conference papers	Sort by *ref type*, manually examine all references labelled as *serial* and remove those that were clearly indicated as conference papers	Conference papers may present work that is later published as journal articles that would be identified and scrutinised later in the study (i.e. double counting is eliminated)	9 002
Theses	Sort by *ref type* and remove all references labelled as *thesis*	Theses are difficult to obtain	8 867
Books and book reviews	Sort by *ref type* and remove all references labelled as *book*; search titles for exact matches of *book review* or *book*, manually examine the search results and remove references that are clearly indicated as book reviews or books	Some books are anthologies of existing articles; books tend to be summaries of existing academic literature; books can be problematic to obtain	8 767
Reviews	Search titles for exact matches of these terms and remove the appropriate references	These studies are author-produced summaries and may omit some salient points for this study; these studies most likely included articles that were identified later in this study	8 651

At this point, the researcher started to evaluate the titles of each of the studies and removed the irrelevant studies from the list. This was done in a per-search-per-database fashion and followed the steps: (a) searching for terms in the titles that would identify obviously irrelevant articles; (b) manually examining these obvious exclusions to ensure that they were truly irrelevant before removing them; (c) searching for terms in the keywords that would identify obviously applicable titles; (d) manually examining these obvious inclusions to ensure that they were truly relevant before moving them to a temporary sub-group for storage; (e) manually inspecting each of the remaining titles for relevance and removing all irrelevant studies; and (f) returning the temporarily stored references back to their original sub-group. During this lengthy phase of the study rejection process, more examples of previously removed study types (e.g. generic literature, conference proceedings, books, etc.) were encountered and subsequently removed. This round of elimination brought the number of hits down to 1799. The researcher then set about removing all references that could not be accessed via the NWU library system. Table 6 shows a summary of the 1231 hits that remained across the different databases.

Table 6: Number of hits per data source

Date of search	Data source	Initial number of hits	Remaining number of hits
10 June 2015	Web of Science	3 212	283
14 June 2015	Science Direct	4 283	290
14 June 2015	ERIC (Education Resources Information Centre)	1 272	124
15 June 2015	Applied Science and Technology Source	1 602	118
15 June 2015	MasterFILE Premier	881	13
15 June 2015	PsycINFO	1 670	49
15 June 2015	SocINDEX	223	8
15 June 2015	Academic Search Premier	2 483	41
15 June 2015	Business Source Premier	1 311	20
16 June 2015	Electronic Journal Services	684	11
16 June 2015	CINAHL	264	8
16 June 2015	E-Journals	3 281	134
16 June 2015	MEDLINE	630	19
16 June 2015	JSTOR	355	7
16 June 2015	PsycARTICLES	29	2
16 June 2015	Teacher Reference Centre	350	11
18 June 2015	Scopus	7 540	93
	TOTAL	**30 070**	**1231**

Addendum II shows a detailed record of all search terms employed per database, the resultant number of hits and the number of remaining hits after each of the elimination procedures.

The researcher realised that applying inclusion/exclusion criteria at this stage could possibly leave 400 to 500 studies for analysis—a number that is both impractical and unnecessarily large as a representative sample. Therefore, a strategy was employed to draw out the literature by the most prominent authors in the field still remaining in the researcher's database. Confirmation that this study's database contained the foremost serious games authors was essential. This was executed by searching Google Scholar with the *allintitle: "serious games"* and *allintitle: "game based learning"* search strings. Further criteria included the time frame 2000 to 2015, only English and only articles (and by default in Google Scholar) including books—the researcher chose not to eliminate citations because some prominent experts (e.g. Ben Sawyer) are reported via citations. These searches resulted in 1960 (serious games) and 1751 (game(s) based learning) results. Each search result reports, apart from the expected reference detail, the number of citations for that result. The researcher recorded all search results that have been cited more than 45 times and listed the 34 authors that were both highly cited in Google Scholar and present at least eight times (as first author) in the remaining 1231 references of this study (Addendum III). This served as confirmation that the researcher's database contained the field's leading authors, encouraging the researcher to continue extracting the literature by author prominence.

The researcher sorted the EndNote™ references by author and all authors occurring three or more times (*as first author*) were listed separately in an Excel™ file. These authors were then searched in Scopus and their respective publication counts were incorporated into the list. In searching Scopus for these authors, some additional prominent authors were encountered and appended to the list. The entire list was sorted according to the number of first-author publications based on the Scopus searches. All authors that had at least one first-author publication AND occurred in the researcher's EndNote™ database were retained. This left 397 articles for inclusion/exclusion. Addendum IV shows the author (number of publications) comparison between Scopus and the researcher's database as well as the number of articles from each author included for analysis.

4.1.2 Selecting the primary studies

Three researchers scrutinized each article's title, abstract and conclusion to determine which articles could 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. Serious games gained traction in 2002 with the release of America's Army and the founding of the Serious Games Initiative (Susi *et al.*, 2007:2). The researcher therefore, opted for a timeframe from January 2000 to May 2015 to include a period of research running up to these events. From these inclusion/exclusion criteria, 72 articles were found relevant for this review. The researcher assembled an *author map* based on these studies. Since the field's foremost authors correspond to those from the researcher's database, Figure 7 visually communicates who the prominent authors are (Tranfield *et al.*, 2003:218) for both this study and the serious games arena. Additionally, as the selected documents can be trailed through the author map, it highlights the reliability of the documents included for analysis.

Figure 7: Author map of prominent authors for this study and the field of serious games

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 (Addendum V provides more detail about the exclusion of these articles as well as notes on some included articles). That is, 63 articles underwent in-depth analysis. Addendum VI lists the studies (alphabetically by author) that were included in this systematic review.

4.1.3 Extracting the data

Serious games differ from entertainment games in that they not only aim to engage or entertain the player, but also offer a learning experience in a specified area. In light of this, it would be unfair to assume that all serious games are created with equal parts. That is, the success factors of a serious game with marketing aspirations will differ from games that set out to train corporate governance. In the same vein, serious games can be played by diverse, yet very distinct, sets of players varying from primary school girls with cerebral palsy to mine workers or highly qualified researchers. Van Eck (2006:18) points out, "the impression that all games are good for all learners and for all learning outcomes is not the case." One can therefore, expect the playing audience to have a decisive impact on the desired serious game elements. The serious game success factors themselves lie, by definition of serious games, in a carefully considered melange of entertainment and education (Giessen, 2015:2241; Kickmeier-Rust & Albert, 2012:16). This review embarks on dissimilating each of the included studies according to the elements that promote learning and/or those that elicit enjoyment. Serious games have been shown to have an impact on learning and behaviour (De Freitas & Ketelhut, 2014:1; Mitgutsch & Alvarado, 2012:121) and the review attempted to unearth these different effects that serious games may have. The researcher designed a data extraction form to capture each study's salient data (as expressed above) pertaining to the research question.

The data extraction form for this study initially set out to collect information over four broad categories, each with their own sub-set of questions. The four broad groups of questions adapted from Connolly *et al.* (2012:663-664) aimed to typecast each study against a categorisation of serious games, a profile of intended users/players, a collection of possible success factors and a set of impacts or effects. Moreover, each extraction form captured standard information such as reviewer name, date of extraction, study reference details, source of the answer options, and additional notes (Kitchenham, 2007:30-31). The initial extraction form is shown in Table 7.

Table 7: Initial data extraction form for collecting data from primary studies

Data item	Value	Source	Notes
Reviewer name			
Date of extraction			
Study identifier			
Categorisation of serious games			
Serious game genre		Taxonomy of Sawyer and Smith (2008)	
Intended sector		Taxonomy of Sawyer and Smith (2008)	
Discipline covered			
Gameplay platform		PC, mobile, console, VR mask or other	
Game style		Classification of Herz (1997)	
Player/user profile			
Age		Numerical range or category	
Gender			
Socio-economic status		Kuppuswamy socio-economic status scale	
Geographic region		Country where study is conducted	
Player language proficiency			
Player technology exposure		How much time is spent using technology	
Player disabilities (if any)			
Possible success factors			
Which game mechanic(s) were discussed			
How was game mechanic(s) evaluated			
Which game aesthetic(s) were discussed			
How was game aesthetics evaluated			
What game narrative was presented			
How was narrative evaluated			
What AI (if any) was used			
How was the AI (if used) evaluated			
How was feedback integrated into the playing experience			
How did learning assessment take place			
How were the outcomes (if any) presented			
Impacts and effects of the game			
Behavioural impact discussed			
Learning effect discussed			
Intentional or unintentional impact			

Two peer researchers and a serious games expert inspected the data extraction form. The extraction form was amended according to their comments and other inputs. Once the form was finalised and additional instructions were added (Addendum VII), it was sent with seven randomly selected studies to Dr Woolner for implementing the extraction—Addendum VIII contains Dr Woolner's completed extraction forms. Unique identifiers for each study were placed in a concealed container and the seven studies were randomly drawn. It was intended that the researcher would also perform data extraction on the same studies with the same extraction form for the purpose of an inter-rater

reliability check. However, the unsatisfactory usefulness of the extraction form and additional observations (shared via e-mail and Skype discussions) by Dr Woolner, discouraging further use of the extraction forms, prompted the researcher to change strategy.

The researcher bypassed the data extraction form and opted to commence coding directly in Atlas.ti™. Atlas.ti™ is a computer aided qualitative data analysis system used to amalgamate the natural language (qualitative) data from the pool of collected literature. The coding process was inductive and formative. Themes and categories were identified *a priori* during the review's scope determination phase and based on Dr Woolner's comments. The categories were used as codes in Atlas.ti™. This early code classification provided a basis for the coding process and as the analysis progressed, codes were added, updated or deleted. The identified themes (categorisation of serious games; player/user profile; design aspects of the game; implementation and environment; impacts and effects of the study; and game as assessment tool) remained unchanged during the coding procedure. Addendum IX gives the set of the six themes and 95 codes that were in place at the conclusion of the coding phase; a total of 4352 quotations were extracted.

Several measures to ensure validity, reliability and avoiding bias of the data extraction method were put into place. The classification themes and codes were derived from literature and corroborated by serious game experts. As a measure of intra-rater reliability, the researcher coded two different articles with the same set of codes a week apart (Cohen's kappa = 0.78). For inter-rater reliability, two researchers independently coded the same randomly selected studies with the same set of codes (Cohen's kappa = 0.83). Table 8 presents an interpretation of Cohen's kappa (McHugh, 2012:279) indicating that the codes exhibit moderate intra-reliability and strong inter-reliability. That is, the researcher is confident that the codes and (by extension) the extraction method are reliable.

Table 8: Interpretation of Cohen's kappa (McHugh, 2012:279)

Value of kappa	Level of agreement	% of data that are reliable
0.00-0.20	None	0-4 %
0.21-0.39	Minimal	4-15%
0.40-0.59	Weak	15-35%
0.60-0.79	Moderate	35-63%
0.80-0.90	Strong	64-81%
Above 0.90	Almost perfect	82-100%

Furthermore, Riffe *et al.* (1998:104) suggests that research with a rich analytical value of the concepts it discusses and a reliability level within or somewhat below the 0.8 to 0.9 range can go

ahead. To avoid bias, duplicate publications of the same data were not included in the review and the most complete of these articles was selected for the review (Kitchenham, 2007:33).

4.1.4 Synthesising the data

The enduring set of themes and codes (Addendum IX) was obtained by way of a qualitative synthesis. Noblit and Hare (cited by Kitchenham, 2007:37) advise three possible qualitative synthesis strategies—these include: (a) reciprocal translation where each study is paraphrased in order to compare it with other studies reporting on similar topics; (b) refutational synthesis that involves translating both the original study and the refutation allowing a detailed analysis of the rejection; and (c) line of argument synthesis where researchers wish to infer about a subject as a whole from a set of individual research literature by first documenting and analysing the approach to issues of importance within individual studies and then doing the same for the entire set. In order to encompass reciprocal translation, refutational synthesis and line of argument synthesis tactics, the researcher decided to adopt a pseudo (due to pre-classification of themes and codes) grounded-theory approach and apply the constant comparison method (CCM) (Boeije, 2002).

The CCM facilitated the inductive development of a theory (Merriam & Tisdell, 2016:13) by categorising, coding, delineating categories and connecting them (Boeije, 2002:393). In developing a methodology for constant comparison, Boeije (2002:396) proposes several steps that systematise qualitative analysis. Table 9 gives a brief overview of the CCM steps this review undertook.

Table 9: Steps of the constant comparative analysis process used this review followed (adapted from Boeije (2002:396))

Step and type of comparison	**Analysis activities**	**Aim**	**Results**
1. Comparison within single study	Open coding; summarise core of the study; find consensus on interpreted fragments	Further develop an understanding of the pre-determined codes	Provisional codes (code tree); conceptual profile of serious game success factors
2. Comparison between studies within the same group	Axial coding; formulate criteria for comparing studies; hypothesise about patterns and types	Conceptualisation of the subject; produce a typology	Expansion of code words until all relevant themes were confirmed and description of concepts
3. Comparison of studies from groups with different perspectives	Triangulate data sources	Complete the picture; enrich the information	Verification of provisional knowledge from step one with additional information and memos

4.1.5 Reporting the review

This SLR was intended to be of theoretical and empirical benefit and was appropriately (i.e. without copyright infringement) circulated amongst academics and practitioners alike. The first phase of dissemination took the form of a section in an MSc thesis and as an article submitted to a peer-reviewed journal (Simulation and Gaming: An interdisciplinary journal of theory, practice and research). Simulation and Gaming requires authors to first submit an abstract to the editor for prior evaluation of the intended article in order to establish the journal's interest in the work. The abstract has been accepted and the editor of Simulation and Gaming provided instructions for submitting the article—the article was submitted on 3 November 2015 (Addendum X). Table 10 confirms the structure of the SLR submitted to Simulation and Gaming and provides the scope of each subsection discussed in the article.

Table 10: **Structure and scope of the SLR** (submitted to Simulation and Gaming journal) (adapted from Kitchenham (2007:42-43) and CRD (2009:78))

Section	**Subsection**	**Scope**
Title		
Authorship		Authors and their affiliations
Executive summary or Structured abstract		
Context		The data under scrutiny and why
Methods		Data sources, study selection and data extraction
Results		Headline outcomes
Conclusions		Implications for practitioners and researchers
Keywords		List of important concepts and synonyms
Main text		
Background (introduction)		Explanation of learning and fun as primary constituents of serious games; problem statement
Purpose of the paper		The aim of the review and research question being answered
Method	Databases searched and search terms	Strategies for removing these secondary references
	Selection of papers for inclusion	Application of inclusion/exclusion criteria
	Coding and synthesis procedure	Data extraction and analysis

Section	Subsection	Scope
Findings and discussion		Brief overview of key synthesis results on the periphery of the research question; in-depth discussion of findings directly pertaining to the research question (e.g. cause-and-effect, benefits, adverse effects, risks and the variation in the success factors)
Limitations		General SLR limitations and those specific to this study
Conclusion		Consequence and recommendation for practitioners
Future research		Consequence and suggested further work for researchers
Back matter		
Acknowledgements		All those who contributed, but did not meet criteria for authorship
References		All references used in the article
Appendix		Table of included studies and their respective key data

Once the article became accessible, a link to the article was made available on the SGI-SA website (www.sgisa.co.za). Lastly, an executive summary of the report was sent to the serious games specialists who contributed to this study.

4.2 The serious games gauge (SGG)

The researcher would like to mention from the outset that the development of a guidelines review tool (referred to as the serious games gauge (SGG) from here on) was based on initial thoughts flowing from the SLR. The SGG should be regarded under the auspices of a pilot study culminating in a preliminary reflection of its potential to predict the success rate of envisioned serious games.

The aim of the SGG is to be able to evaluate digital serious games for any sector, genre, discipline and electronic platform. The SGG's conceptual design was grounded in the findings of the SLR and translated into an Excel™-based spreadsheet model. The model implements a weighted grid structure for determining a rating, or measure of potential success, for the serious game under consideration. The SGG was also designed to rate the themes and dimensions to show the influence (positive and negative) each of these have on the overall rating. All ratings are communicated in the form of a graphical dashboard, giving users the opportunity to swiftly ascertain which themes require attention. The model's programming comprised primarily of in-sheet formulas and

conditional statements with some underlying Visual Basic coding. The SGG was then pilot-tested with four BSc Honours in IT students. These students were all completing (at the time of testing) their own serious games projects and were thus familiar with the field of serious games. In addition, this was intended as an opportunity to advance their personal development and exposure to serious games research.

Using non-probability judgment sampling, four web and commercially available serious games (Table 11) were selected for the initial formative evaluation of the tool. Each student was asked to play one of the randomly allocated serious games, and afterwards use the SGG to rate it. Each game was awarded, amongst other ratings, an overall percentage rating (100% indicates the highest possible success) that was compared against existing respective user remarks about the game and/or accolades bestowed on the game. The students were also asked to provide very brief qualitative feedback about the games they played and the future usefulness of the SGG was tested with a perceived usefulness questionnaire (Davis, 1989). These, together with impromptu question-and-answer sessions between the students and researcher yielded an interpretivistic discourse about the SGG.

Table 11: Serious games included for the informal evaluation of the SGG

Game	Rationale for inclusion
Mandela 27	Much hype was generated around its release and the SGG was made to point out if the topical excitement has been underpinned by its serious game qualities
DragonBox Elements™	Winner of the *best education and learning serious game of 2014* at the Fun and Serious Game Festival 2014. The SGG was intended to verify its quality with an indicative rating
FinMan	This is a low-key serious game being used to enhance a university financial management module, but with moderated impressions about its popularity. The SGG was made to indicate the success factors responsible for this under-confidence
Darfur is Dying	Regarded by many as one of the most influential serious games made. The SGG was created to highlight the building blocks of its success

5. Ethical considerations

This study comprised a systematic review of existing literature, followed by an informal desktop evaluation of a proposed instrument for rating serious games. No people were involved and no experimentation has taken place. A request for human subject ethics clearance however, was submitted to the NWU: Vaal Triangle Campus ethics committee. Ethical clearance was granted—clearance number ECONIT-2015-045. Addendum XI contains the ethics clearance certificate.

6. Contribution of the study

This study: (a) delivered a practical prototype tool that aids serious game creators in realising and harnessing the full potential of serious games; (b) made a theoretical contribution by providing understanding about the components that make up serious games; and (c) filled an empirical gap in literature by summarising the pitfalls and success factors to be considered when creating serious games. No other study of its kind was encountered throughout the researcher's extensive literature searches. The resultant SGG will provide other researchers with a starting point for further discovery related to using such tools in other games and various IT applications.

The research output of this dissertation, as well as the proposed article, contributed towards the scholarly work of the research niche entity at the NWU: Vaal Triangle Campus, Technology Enhanced Learning for Innovative Education and Training in South Africa (TELIT-SA).

7. Presentation of the study

This dissertation encompassed four sections that largely: (a) introduced the field of serious games and sets the scene for the research; (b) provided a clear understanding of the success factors of serious games; (c) introduced the initial thoughts of a serious games review tool by means of a desktop pilot study; and (d) concluded the study by means of a reflective synthesis paving the way for further research.

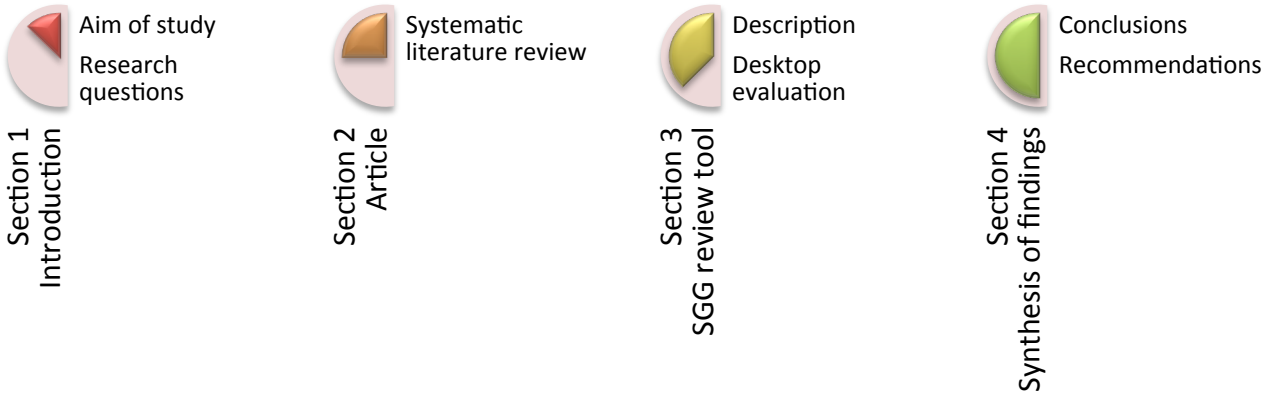

Figure 8: Schematic representation for the presentation of the study

Section 1: Introduction and background to the study

This section provided a background of serious games and explained the requisite integration of fun and learning. It further presented the problem statement, described the aim of the study and

introduced the research question. An explanation on how the following chapters link to form an integrated whole was given.

Section 2: Article

This section was in article format for the *Simulation and Gaming: An interdisciplinary journal of theory, practice and research* journal and adhered to its stylistic demands. It described, in detail, how literature for the period 2000 to present, that reports on serious games was exhaustively identified, acknowledged and investigated in order to summarise the factors serious games should adhere to for a most effective outcome. It also offered the review's findings in a structured and organised fashion.

Section 3: The Serious Game Gauge review tool

The findings from section two gave rise to the development of a guidelines review tool, called the serious games gauge (SGG), which developers of serious games can employ in creating valuable learning environments for their respective users/players. This section depicted the SGG and its underlying code, and communicated the results of a pilot desktop testing of the SGG against four serious games.

Section 4: Synthesis of findings

The conclusion of the study allowed the researcher to reflect on the process that was undertaken to state what factors in their respective contexts should be considered when setting out to develop a successful serious game. The researcher also concluded with the next steps for further design, development, evaluation and rigorous validation of the SGG.

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

Background. A conglomerate for game success factors exists. However, articles do not combine all salient factors for successful serious games—a trend that needs to be rectified for serious games to be successful. This may alleviate debates over pedagogy over enjoyment, how much realism is enough and whether artificial intelligence is worth the cost.

Aim. This article examines existing academic literature from 2000 to 2015, extracting shared factors of serious games that have had an encouraging impact on gameful learning experiences with the aim of withdrawing the field from a perpetual spiral of does-my-game-work research while why-does-my-game-not-work research would be more worthwhile.

Method. Qualitative content analysis, through the constant comparison method (CCM) analyzed a total of 63 articles from a variety of recognized electronic libraries and databases.

Results. The analysis revealed five central serious game themes: backstory and production; realism; artificial intelligence and adaptivity; interaction; and feedback and debriefing that require deliberate intertwining with pedagogical content.

Conclusions. This review provides practical guidelines serious games producers should strive to include for each of the five themes.

Recommendation. Applying these recommendations whenever serious games are considered will provide a foundation for effective gameful learning experiences.

KEYWORDS: adaptivity; artificial intelligence (AI); debriefing; feedback; fidelity; fun; interaction; learning; narrative; realism; serious games; success factors; systematic literature review (SLR).

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 & 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 that can 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 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 skillset by their own volition to overcome contextual challenges (Boyle et al., 2011).

This does not mean that 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, p. 2) when engaging with the game. Aesthetics, in a game context, is also sometimes intended to convey the audio-visual (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 & Cannon, 2002), yet exposure to high-fidelity entertainment games leads target players to ask for serious games to be as audio-visually realistic as possible (Visschedijk & Van der Hulst, 2012). No literature unraveling the mystery of the right amount of fidelity for a serious game could be found. Moreover, further search of the literature reveals 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 & Ketelhut, 2014). This may explain why quality serious games are hard to come by (Mcmahon & Henderson, 2011).

Yet, the use of computer games to foster learning has steadily found favor amongst 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 amongst the elderly, fire evacuation and cultural heritage to name a few. The rising popularity and number of

application fields makes discovering practical success factors for serious games a worthwhile endeavor.

Purpose of the article

This article aims to uncover the success factors of serious games by performing a systematic review of prior quality studies. Producing serious games are 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 should a serious game comprise of in order to guarantee its success?* Consolidating the serious games success factors from the wide distribution of literature and conflicting opinions to bring a much-needed veneer of consistency to the field.

Method

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 Centre), 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 there were too few hits for the time period and number of databases in question—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 was excluded as this review does not aim to create awareness, but examines studies that bring about (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 sub-groups 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, 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. 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 inclusion/exclusion process that followed—397 articles remained.

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.

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 9 gives a brief overview of the coding and synthesis steps following the initial theme and category identification.

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

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 that 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 to 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 was selected for the review (Kitchenham, 2007). Table 2 presents the 63 articles that underwent analysis. 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.

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 towards 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 amongst 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 towards 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 that 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.

A comprehensive discussion of the findings takes place according to the five serious games success factor themes of backstory and production; realism; AI and adaptivity; interaction; and feedback and debriefing.

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 (H**ä**m**ä**l**ä**inen, 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 means that there is engagement with the learning material. A good story however, does not imply credible learning. Learning must be stealthily integrated into the appealing storyline (Ke & 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 & Annetta, 2012; Couceiro et al., 2013; H**ä**m**ä**l**ä**inen, 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 that remains unchanged with every restart of the game. Moreover, players are excited by the opportunity to explore and mold their own narrative (Ke & Abras, 2013; Kickmeier-Rust & Albert, 2010; Verpoorten et al., 2014)—another motivating feature that draws 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 amongst 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 convinced that the perceived value of learning gain is bound to outweigh this 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 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, 2006; Virvou & Katsionis, 2008). From this, we 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). That is, if players can connect serious gameplay with possibly earning extra course credits, or more subtly perceive that the skills or knowledge being learnt will improve quality of life or formal assessments of their ability, they will be more likely to engage with the game.

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 play-testing 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; Gonz**á**lez-Gonz**á**lez 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.

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 & Abras, 2013; Papastergiou, 2009a; Virvou & 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 & Buttussi, 2015; Verpoorten et al., 2014) and describing detailed game sounds (Chittaro & Sioni, 2015; Gonz**á**lez-Gonz**á**lez 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 & Loh, 2015; Dickey, 2011). All-in-all, this presents serious games makers with another hard-to-solve conundrum. Players demand more sounds (Papastergiou, 2009a), better graphics (Couceiro et al., 2013) and more credible and varied NPC responses (Johnson & Mayer, 2010). We suggest creating games which are high in realism without over-cluttering 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; Gonz**á**lez-Gonz**á**lez et al., 2014; Schmitz et al., 2014; Soflano et al., 2015a). Creating their own avatars excites players (Brom et al., 2010; Ke & 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 (Gonz**á**lez-Gonz**á**lez & 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).

Non-player character (NPC) interaction is a 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 & Mayer, 2010). This is once more in line with the over-arching 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, 2006). 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 & Mayer, 2010) natural language (Gonz**á**lez-Gonz**á**lez & Blanco-Izquierdo, 2012). However, authors agree that players enjoy interacting with voice-enabled NPCs (Annetta et al., 2009a; Virvou & Katsionis, 2008).

Serious games are well embedded in the constructivist learning theory (Cheng et al., 2014; Zin & Yue, 2013). It was startling to uncover that 36% of the studies utilized time pressure as a form of psychological fidelity. Constructivist learning is about new environments, challenging the player's existing knowledge framework and allowing them to explore and test this conflict. We find it counter-intuitive to engage in explorative learning with time limits in place. Focusing on gameplay, we believe competition holds 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 & 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 amongst 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 amongst a group of learners, yet it remains a worthy opponent drawing players to the game. Furthermore, time can offer a furrow for collaborative learning—a learning approach many authors highlight (Admiraal et al., 2014; H**ä**m**ä**l**ä**inen, 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).

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 ™* 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 towards their pre-set goal state (Russell & 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; Gonz**á**lez-Gonz**á**lez 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 & 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 amongst 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, p. 204), 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 & 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 & 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.

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 (Gonz**á**lez-Gonz**á**lez & 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 & 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 (H**ä**m**äl**ä**i**nen, 2011; Hwang et al., 2013b; Ke & Abras, 2013; Van Eck, 2006). 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™ (H**ä**m**äl**ä**i**nen, 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.

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 & Annetta, 2012; Johnson & Mayer, 2010) while *instant* updates of the game's current status gives 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 that 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 & Sioni, 2015; Verpoorten et al., 2014). Resource tools such as an integrated map indicating PC and other key locations best obliges vast game-worlds (H**ä**m**ä**l**ä**inen, 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 & Kiili, 2010; Squire, 2013). To further enhance this setting, real-time teacher support should be the gold standard that serious game producers aim for. Players appreciate unobtrusive support when necessary (Ke, 2008; Kuk et al., 2012) and support through pedagogical intervention when asked for (Ke & Abras, 2013; Serrano-Laguna et al., 2014; Van Eck, 2006). 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; Gonz**á**lez-Gonz**á**lez 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 & 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 that 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 (Gonz**á**lez-Gonz**á**lez 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 & Katsionis, 2008). Lastly, the thought of cross-pollinating the functionality of backend databases for feedback and debriefing with AI or "micro-adaptivity" (Kickmeier-Rust & Albert, 2010) should convince serious game producers of a positive cost-benefit ratio—both for fun and learning.

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. Also, 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. 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 applications.

Conclusion

What should a serious game comprise of in order to guarantee its success? We believe that the playing audience holds 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) that 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 that 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, we believe 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 challenge should always be on the edge of player ability and that as gameplay progresses, player ability goes up. This proposes that game tasks should become gradually more difficult in order for a player's cycle of mastery to be continuously challenged—as 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.

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 & Loh, 2015; Soflano et al., 2015a) that can be further augmented with the use of ScriptEase (Gonz**á**lez-Gonz**á**lez & 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 that would 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 towards establishing a risk profile for serious games development.

Most of the serious game research 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 there are specific playing audiences preferring either 2D or 3D games. We speculate that there may be a 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 that 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; that 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 (amongst 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.

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Table 2. Serious games success factors.

Author(s) and game purpose	Back story and production	Realism	AI and adaptivity	Interaction	Feedback and debriefing
Admiraal et al. (2014); Huizenga et al. (2009); Impart knowledge about medieval Amsterdam (tested by secondary school students)	Players physically traverse Amsterdam; open-ended progress; learner-centered production suggested for future game development	Telephone messages with medieval background sounds; real people (no NPCs); act out actual medieval actions; game activities within context		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	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"
Alamri et al. (2014); Encourage healthy behavior amongst obese people	Find clues to progress; gradual advance; elements relate to game and impact	Day, night and rain themes; low polygon visuals; animated avatar; no time limit; player is avatar		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	Self-awareness through immediate bio-metric data; heads-up display (HUD) shown throughout; trend reports; therapists informed of player progress and suggest actions
Annetta et al. (2009a); Teach simple machines to elementary school (fifth grade) students	Retrieve stolen computer parts; solve riddles to progress	Low-polygon artwork; NPCs have audio voice; textual player-to-NPC communication; players liked hearing NPCs speak		Keyboard to move PC; further investigation with Lego® kits; player-to-player text chat; collaborative multi-player; 3D	Select in-game computer agent when needed
Annetta et al. (2009b); Impart knowledge on key genetic concepts to high school students	Find out who stole the inheritance based on genetic evidence; gameplay and game goals well-aligned with learning concepts; teleport to different scenes	Authentic scenarios; low-polygon modeling; NPCs present; less emphasis on animation, text and audio that does not aid learning		3D; multi-player (collaborative pairs)	NPCs give content specific help and information; let students question previous knowledge
Annetta et al. (2014); Educate pre-service science teachers about laboratory safety	School lab must become safe environment; linear progress; additional scenarios can be added; MSDS sheets from NSTA website; users provided content material; user-centered design; play-testing with users	Scenario mirrors real world; mid-polygon modeling; realistic NPC interaction; time element		Point-and-click selection; mouse; 3D; single-player	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
Arnab et al. (2013); Delivery of relationship and sex education (focus on sexual coercion) to secondary school students	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	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;		Point-and-click; type in textboxes; smart board (classroom purpose); appealing game show format; effective pause mechanism; dialogue amongst class members and teachers about scenarios; 2D and 3D; single-player; played as collaborative pseudo multi-player	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;
Barab et al. (2012); Teach persuasive writing to seventh grade students	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	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	NPCs treat players according to their game decisions (i.e. indirectly responding to player personal agendas)	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)	Teacher-led class discussion; teacher is mother character in game; immediate textual NPC feedback; opportunity to recant previous decisions before final quest (writing a persuasive essay)

Author(s) and game purpose	Back story and production	Realism	AI and adaptivity	Interaction	Feedback and debriefing
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	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	High-resolution cut scenes; low-polygon interactive scenes; animated sequences; sound and speech; accurate impact of fruit and veg 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;	Algorithm converts player information into personalized responses	Levels of gameplay and challenge are desirable; identify activities for at home; 3D; single-player	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
Bellotti et al. (2009); Promote best practices in sea-related behaviors (targeted at, but not limited to, high school students)	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	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	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	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)	NPCs provide knowledge; score updates throughout; all communication via NPCs or fellow players; continuous monitoring to check compliance and update score
Bellotti et al. (2012); Promote and develop European cultural heritage (tested by MSc and PhD students)	Complete missions in European cities; context and narrative are aligned; mini-games enhance exploration; sandbox-style progress; if tasks are meaningful there is no user-perceived disruption; short manuscript texts; top-down approach for determining content	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	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	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	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
Brom et al. (2010); Familiarize secondary school players with political, economical and social issues in united Europe	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	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		Hyper-text 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;	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
Brom et al. (2011); Teach high school students the basics of ethology, behaviorism and animal learning	Students teach virtual dog to wave its leg on verbal command; two more animals as new levels; context is familiar to students	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	*Q-learning* algorithm for animal behavior; simple state space causes learning to appear imitated; complex simulations more suited to advanced courses	Point-and-click; micro-games must not require special skills to play; expository lecture; interface and control briefly explained; single-player; 2D	Teacher guidance; game as lecture supplement; immediate animal response to button selection; post-game debriefing
Buttussi et al. (2013); Bolster advanced life support (ALS) knowledge through retraining with a serious game	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	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 was appreciated		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	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	Back story and production	Realism	AI and adaptivity	Interaction	Feedback and debriefing
Byun and Loh (2015) Modify a COTS game tutorial designed to acquaint players with the Neverwinter Nights environment (tested by college students)	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	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		Point-and-click for PC movement; mouse; tutorial prior to game; 3D	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
Cheng and Annetta (2012); Make elementary school (grade six to eight) students aware of the negative consequences of taking methamphetamine and learn basic neuroscience	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	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		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	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
Cheng et al. (2014); Impart knowledge to middle school (grades seven and nine) students about the workings of the body's defense system	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	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		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;	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
Cheng et al. (2015); Assist junior high school (grade seven) students comprehension of biological evolution	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	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	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)	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	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
Chittaro and Buttussi (2015); Educate passengers on aviation safety and how to survive aircraft emergencies	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	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		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	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
Chittaro and Sioni (2015); Provide recommendations about emergency evacuation of a train station after a terror (bomb) attack	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	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		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	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
Connolly et al. (2011)	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	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	Process learner speech; interpret and evaluate player actions to determine appropriate NPC reactions; AI can assist to provide timely hints and support	Interactive narrative amongst participants is valuable; skill-builder module as part of the game lessens later frustration	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

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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	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	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		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	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
Dickey (2011); Foster argumentation and persuasion writing for high school (grades 9 to 14) students	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	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		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	
González-González and Blanco-Izquierdo (2012); Teach physics and chemistry to secondary school students	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	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		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)	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
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 to 16 years old) with their classmates	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	Animation; sound; high-polygon modeling; realistic people; chat is enriched with animations and sound; players create their own avatars		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	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
Hämäläinen (2008); Teach vocational education students the design process of surface treatment	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	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		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	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
Hämäläinen (2011); Enhance understanding of electrical installation in a house and to support collaborative learning processes in a high school vocational context	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	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		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	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

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Hong et al. (2013b); Enhance cultural cognition amongst pre-primary school children	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	Sound, basic x-y movement animation, 2D pictures not high detail; mid-polygon 3D environment; some lighting effects; timer		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;	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
Hong et al. (2013a); Advance secondary school students' abilities to recognize archeological objects and motivate them to visit museum digital archives	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	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		*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	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)
Hong et al. (2015); Teach and explain Chinese idioms to elementary (grades five and six) school children	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	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		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	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
Hwang et al. (2012a); Promote learning performance of elementary school (grades five and six) students in butterfly ecology	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	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		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	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
Hwang et al. (2012b); Hwang et al. (2013b); Foster elementary school (grade five) student's competence in identifying plants	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	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	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)	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	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
Hwang et al. (2013a); Impart knowledge about the butterfly life cycle to elementary school (grade six) students	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	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		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	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

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Hwang et al. (2015); Instill financial management principles amongst elementary school (grade six) students	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	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		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	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
Johnson and Mayer (2010) Help college students learn how electrical circuits work	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	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		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	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
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)*	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	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		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; there must be enough help on game navigation; 2D (KS); 2.5D single-player (LS); 2D single-player (LL); turn-based (KS)	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
Ke and Grabowski (2007); Support primary school (grade five) students in learning basic arithmetic and problem solving	Fantasy is contextually relevant			Cooperative gameplay favored over competitive gameplay; orientation session for reading guidelines and trying the games; single-player	Peer cooperation made the mathematics appropriately difficult; cooperative learning approach (Team-games Tournament)
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	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	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	Scaffolding and debriefing to encourage reflection can be attained by informative feedback adapted to individual performances	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	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
Ketamo and Kiili (2010); Teach mathematics concepts to elementary school children	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	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	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	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	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

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Kickmeier-Rust and Albert (2010); Verpoorten et al. (2014); Teach optics to secondary school (grade eight) students	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	Modeling and texturing is comparable to commercial entertainment games; some textual feedback	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	Point-and-click; mouse; players had to use what was learnt at the experiment table later in the game; players were briefed about the game, confidence degrees and the slope device; 3D	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
Kiili and Perttula (2012); Improve logical and mathematical tasks amongst elementary school (grade three) students	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	Fish are drawn caricatures; environment resembles an ocean bed; low detail artwork		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	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
Kiili (2005); Determine the usefulness of content creation in a game environment for university students	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	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		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	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
Knight et al. (2010); Assist in the education of trainees in major incident management	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	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		Point-and-click; mouse only; 15 minute tutorial on gameplay; gameplay assistance was available; single-player; 3D models in a 2D environment for patient interaction	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
Kuk et al. (2012); Enhance the computer graphics course taught to first-year vocational studies students	Pedagogical agent decides (based on a pre-defined score) if player may progress to a new level	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	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	Point-and-click; mouse; gaming interface should be familiar to players; 2D; single-player	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
Papastergiou (2009a); Teach computer science content (other than programming) to high school students	Players navigate through mazes; answer questions to progress; linear progress; students suggested a more adventurous plot; game content matches curriculum	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 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	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
Sadler et al. (2015); Develop interest in learning science and bring about understanding of core biology concepts to high school students	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	Game environment is modeled after a real-world laboratory facility; mid-polygon modeling; realistic people; players can interact with NPCs; real-time game activities		Laboratory exercises outside gameplay; brief lectures; formative assessments; NPCs serve as guides; 3D	Teach teachers how to implement games; NPC lab 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

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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)	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	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		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	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
Schmitz et al. (2015a); Schmitz et al. (2015b); Give school children (ages 11 to 14) an understanding of cardio-pulmonary resuscitation (CPR) and giving them the confidence to act in an emergency	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	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		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	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
Serrano-Laguna et al. (2014); Teach persons with psychical disabilities daily life skills and habits; due to limited details we chose not to analyze this study's other game that teaches XML	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	Scenes are actual photographs		Type; point-and-click; mouse	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;
Soflano et al. (2015a); Soflano et al. (2015b); Teach the basics of the database programming language Structured Query Language (SQL) to undergraduate students who have no knowledge of SQL	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;	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	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	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	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
Squire (2013); Three game types discussed; non-violent conflict for human rights; show high school students exciting accounting careers; teach vehicle options to sellers	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	Use language players are familiar with; abstraction of reality must remain plausible; realistic parts; time pressure; artwork to elicit emotion	End-user model based on data gathered in situ; gather user choices for custom content; intelligent tutors for guiding gameplay	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	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
Torrente et al. (2009); To show effectiveness of linking gameplay with learner management systems	Learning contents as self-contained distributable learning objects; <e-Adventure> editor allows instructors to focus on pedagogical aspects of the game			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	Staff preparation is essential for implementing DGBL; player tracking usefulness is dependent on the communication protocol of the learner management system;
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	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	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	Game adaptivity for special needs is a serious challenge	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	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	Back story and production	Realism	AI and adaptivity	Interaction	Feedback and debriefing
Van der Spek et al. (2013); Game to supplement traditional triage training	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	High-detail environment and victims; sound; animation; textual communication; lighting effects; real-life limitations reflected by game; content to illicit emotion; timer		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	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
Van Eck (2006); Improve the self-efficacy and attitude of middle school (grades seven and eight) students toward mathematics	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	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		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	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
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	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	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	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	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	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
Zin and Yue (2013) Impart knowledge about the history of the development of Europe to secondary (form four) students	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	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		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	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

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Applying the success factors of serious games as a Serious Games Gauge

1. The Serious Games Gauge concept

The serious games gauge (SGG) is the functionalist transformation of the interpretivistic work undertaken during the SLR. The researcher set out to conceptualise the most salient findings of the SLR into a prototype instrument (later pilot-tested) that endows serious games producers with a means to save time, money and other resources. For this reason, the SGG was envisioned as a supplement for the conceptualisation (design) phase of the serious games production cycle and facilitates the transition to the initial prototyping phase. It is at this point that serious games producers stand to profit the most from the tool. Design changes later in the production cycle require a greater revisit of the work and as such, place a weightier demand on resources. "Spending enough time upfront in understanding requirements and in design to get it at least mostly right the first time can save a lot later on" (Bird, 2013).

The SGG poses questions pertaining to specific factors that have a direct impact on the success of serious games. Answering these Likert-style questions yields comparative percentage ratings for: (a) each of the game's five themes (backstory and production; feedback and debriefing; realism; interaction; and AI and adaptivity); (b) the game's dimensions (learning, fun and dynamics); as well as (c) the overall expected success of the game. Furthermore, the questions were envisioned to instil insight and a period of reflection about the game's design.

Five distinct themes emerged as important facets of serious game success during the qualitative synthesis phase of the SLR. The researcher postulated that it is not sufficient to consider the themes in isolation or without their accompanying factors since they all interweave to produce a web of serious games success. In short, the researcher intended to use Likert-style questions to reflect each of the themes as factors. These factors, which emerged from the SLR, may have a direct influence on the learning, fun and dynamics dimensions of serious games, making them, albeit in the form of questions, an essential SGG constituent as evident from the article forth-flowing from the SLR. Giessen (2015:2241) indicates that the foremost challenge for serious games producers is striking a balance between learning and fun. Hence, these two dimensions are common topics of debate in literature and it went without saying that the SGG must address them. Dynamics, an underlying conductor that distributes the game's learning and fun aspects (a more in-depth discussion is provided in this study's introduction) to the player, is also affected by the success factors. The researcher established that its covert nature also seems to exempt it from scrutiny amongst much of the serious games scholarly literature. For this reason, game dynamics was not included as an

ardent topic within the SLR. The researcher however, posits that the significance of dynamics cannot be overlooked and included it in the SGG as a rated dimension that serious games producers must pay heed to. Also, it is the only element of the MDA framework (Hunicke *et al.*, 2004) that is not, understandably so, thematically addressed. The other two elements (aesthetics and mechanics) are visually and tactilely experienced by the players and were therefore appropriately included amongst the five themes. The theme, overall dimension and overall game ratings were conceptualised as a dashboard-style representation of the game's anticipated success, enabling serious games producers to, at a single-glance, assess their proposed games.

2. Developing the Serious Games Gauge prototype

The researcher developed the SGG prototype in an Excel™ spreadsheet, as it comprises conditional statements and in-sheet formulas that compute the user inputs to produce the game's ratings. The researcher made use of the graphing capability in Excel™ to transform the ratings into bar charts. It is pertinent to remember that the development of the SGG was an *exploratory* practical interpretation of the SLR analysis result. The SGG should be regarded under the auspices of a *pilot study* culminating in a *preliminary* reflection of its potential to predict the success rate of envisioned serious games. That is, the researcher has by no means tested any part of the SGG for reliability.

A two-dimensional, three (game dimensions) by five (themes), matrix stipulates one of the starting points for the calculations that follow. The matrix (Table 1) comprises a set of weights that were assigned on the basis of the researcher's interpretation of the SLR's qualitative analysis. That is, the weights are not supported by any verifiable mathematical or statistical computation.

Table 1: Weights matrix for SGG calculations

		Dimension		
		Learning	**Fun**	**Dynamics**
Theme	**Backstory and production**	0.7	0.9	0.8
	Feedback and debriefing	1	0.2	0.6
	Realism	0.2	1	0.3
	Interaction	0.4	0.6	1
	AI and adaptivity	0.3	0.4	0.5

Table 1 can be read from top to bottom or left to right. In consideration of learning as an example, feedback and debriefing has the strongest influence on it, followed by backstory and production, while realism has the lowest impact on learning. From left to right, backstory and production influences fun more than it influences dynamics and learning. Table 1, presented in this study, is only the basis for checking whether such a weighted grid approach could work for the SGG. The

researcher compiled this table by establishing a ground rule (purely for the sake of having uncomplicated numbers to work with) that all weights would be from 0.1 to 1 in increments of 0.1. The researcher assigned weights to the matrix by drawing on knowledge gained from the data synthesis of the SLR and the SLR itself. The steps (each row was a step of the process) taken to progress towards the weights matrix were:

Table 2: Steps taken to determine the weights matrix

Rationale	Dimension × Theme	Weight
Feedback and debriefing factors act almost exclusively on the learning dimension.	Learning × Feedback and debriefing	1
Excitement over creating avatars, interacting with voice-enabled NPCs and competing in timed tasks.	Fun × Realism	1
Interaction theme is the custodian of control mechanics	Dynamics × Interaction	1
Motivating (for a brief period) players to play the game; high fidelity distracts learners.	Learning × Realism	0.2
Feedback and debriefing has very little impact (unless it is audio-visual response to user actions) on fun dimension.	Fun × Feedback and debriefing	0.2
Cosmetic nature of realism does not penetrate deeply enough into the coding that governs a game's dynamics.	Dynamics × Realism	0.3
Contains and reproduces all the learning content and provides the context for the game's learning delivery.	Learning × Backstory and production	0.7
More important role for narrative is to keep players entertained for the duration of their gameful connection with the game.	Fun × Backstory and production	0.9
Guides the user's input, with the game's dynamics providing the reaction to this input.	Dynamics × Backstory and production	0.8
Provides chat communication in multi-player games; surprising events and maintain player immersion by game; tasks becoming increasingly more complex; interaction theme does not approach the same weights backstory and realism do.	Fun × Interaction	0.6
Delivers the interaction channels for collaborative learning and provides scaffolding through increasingly complex tasks; interaction higher than realism in terms of impact on learning, but not as high as backstory and production.	Learning × Interaction	0.4
Immediate feedback sprouting into a sustained user-game feedback loop; dynamics could utilise progress-tracking for future responses to the player; feedback has more impact than realism on dynamics; the feedback theme was nudging towards the backstory and production theme's level of impact on dynamics.	Dynamics × Feedback and debriefing	0.6
A handful of the SLR's studies contained AI and did not want to give the AI and adaptivity theme too much impact on the dimensions.	Learning × AI and adaptivity	0.3
All-rounder nature of AI had to be reflected in the impacts carried over the three dimensions.	Fun × AI and adaptivity	0.4
AI algorithms and dynamics respond to player actions; The researcher felt that AI certainly has more impact on dynamics than realism does, but not as much as feedback.	Dynamics × AI and adaptivity	0.5

After the weights matrix was developed, the researcher conceptualised and built the SGG's answer grid that would harness the weights matrix for further calculations towards a success rating for serious games. The weights assigned to the responses of the Likert-style questions are the second starting point for the calculations. Although the user responses are on a visible scale from 1 to 5, the underlying (not visible to the user) weights for each of the responses adhere to a scale from -4 to 5. The reasons behind this scale disparity are: (a) some adjacent answers warrant a greater differentiation because the relative impact of that answer on the theme, is greater; (b) some answers will have a negative impact on the success of the game; (c) negative weights also make provision for the claimed negative correlation that realism has with learning (Feinstein & Cannon, 2002:426); and (d) keeping a visible scale of 1 to 5 will prevent confusion amongst the users. The weights assigned to the answers, communicate the researcher's interpretation of the SLR's qualitative data. Consequently, the weights are to some extent arbitrary, but remain substantiated by the SLR's findings. The shaded cells of Table 3 provide the prototype SGG's questions, answers and weights (in parentheses); each question is supplemented with a rationale for the weighting that accompanies each of the answers.

Table 3: Rationale behind each of the SGG's question weighting

Questions and themes	**Rationale for weighting, answers and weights**				
Backstory and production	*Option 1*	*Option 2*	*Option 3*	*Option 4*	*Option 5*
The story provides a fitting context for the learning material	Since the cognitive load increases and immersion decreases as the game's story and learning context become further removed, the weights were evenly distributed; once the story exhibits exogenous fantasy with regard to the learning material (Options 1 and 2), both learning and fun diminish and the game is negatively affected				
	Strongly disagree (-2)	Disagree (-1)	Partly agree and disagree (1)	Agree (3)	Strongly agree (5)
The skills for progressing in the game match the real-life skills to be learned	Players are confused and frustrated by game tasks that do not match the skills to be learned (hence the relatively strong negative impact when this occurs); this frustration becomes increasingly alleviated the closer the game and real-life skills are matched				
	Strongly disagree (-3)	Disagree (-2)	Partly agree and disagree (1)	Agree (3)	Strongly agree (5)
NO distinct breaks between play and learning are experienced	Sometimes breaks in gameplay can be put to good effect (hence option 3 remains positive); there is a significant jump from option 3 to 2 because distinct breaks cause players to be reluctant to play the game				
	Strongly disagree (-3)	Disagree (-2)	Partly agree and disagree (2)	Agree (4)	Strongly agree (5)
The end-user is involved in the game's production	The sooner the end-user is involved in the design, the more likely it is that the game will be enjoyed by them; options 4 and 5 are early in the game development cycle and are therefore given higher weights; involving end-users to evaluate the final product is high-risk and could result in the game getting a negative reception (hence the negative weight)				
	Not at all (-2)	Evaluate final version (-1)	Play-test beta version (2)	Play-test prototype (4)	Collaborative design (5)
Feedback and debriefing	*Option 1*	*Option 2*	*Option 3*	*Option 4*	*Option 5*
The cause-and-effect of game actions is conveyed	Immediate feedback gives the player instant learning experiences that aid game progress (hence the positive weights with small differences for options 3, 4 and 5); delayed				

Questions and themes	Rationale for weighting, answers and weights				
immediately	feedback can, on rare occasions, be used to good effect (hence the positive weight for option 2); continually delaying feedback hampers learning				
	Strongly disagree (-2)	Disagree (1)	Partly agree and disagree (3)	Agree (4)	Strongly agree (5)
Game progress is communicated throughout	Players are frustrated when their game progress or rating against others is not constantly visible (hence the positive weights with small differences for options 3, 4 and 5); sometimes showing too many progress indicators is overwhelming (hence option 2 still has a positive impact and option 1 only a small negative impact)				
	Strongly disagree (-1)	Disagree (1)	Partly agree and disagree (3)	Agree (4)	Strongly agree (5)
The opportunity to recover from in-game mistakes is present within the game	Any degree of safe recovery from mistakes is conducive to formative learning (hence options 3, 4 and 5 are given positive weights); when mistakes start to penalise (options 1 and 2) players, learning is jeopardised and the game's rating is negatively impacted				
	Strongly disagree (-3)	Disagree (-1)	Partly agree and disagree (3)	Agree (4)	Strongly agree (5)
Learning support is provided when demanded and when required	Players appreciate unobtrusive support that is on time (i.e. when they need it without asking for it), and expect it in full (i.e. when they demand it); the closer the game comes to providing this, the higher the weight; games that require outside resources break player flow; serious games should never be stand-alone learning environments without support				
	No support available (-4)	Ex-game resources (-1)	Selectable content file (1)	In-game helper NPC (3)	Real-time teacher (5)
The game tracks player progress to provide	Debriefing is touted by some as the most important learning construct of serious games; more detailed progress-tracking reports (options 4 and 5) provide more grounds for discussion and are given higher weights; option 2 has no real benefit or detriment for the game while option 1 most likely eliminates the prospect of debriefing				
	No progress tracking (-1)	Last game status (0)	Assessment metrics (2)	Learning evaluation (4)	Debriefing reports (5)
Realism (fidelity)	*Option 1*	*Option 2*	*Option 3*	*Option 4*	*Option 5*
The game's graphics, animation and sound are	Options 1 and 2 turn players away, while option5 distracts players from learning (hence their negative ratings); players request high quality (option4) graphics, but are also satisfied with mid-polygon modelling (option 3)				
	Poor (-3)	Low quality (-1)	Average (3)	High quality (5)	Highly realistic (-2)
The game's environment and objects are closely tied to the learning material	An over-cluttered game-world, especially when the objects are not related to the learning material, inhibits learning (hence the negative impacts for options 1 and 2); strong connections between objects and learning material are likely to promote both fun and learning (hence the relatively high weights for options 4 and 5)				
	Strongly disagree (-2)	Disagree (-1)	Partly agree and disagree (2)	Agree (4)	Strongly agree (5)
The opportunity for a personalised game presence is presented	Creating avatars excites players and instils gameplay enjoyment; high customisation options lead to a more personalised game presence (hence options 2, 3, 4 and 5 are rated according to the degree of avatar customisation); never seeing their PC (option 1) disappoints players and detracts from their fun				
	No avatar (-2)	No avatar options (0)	Select avatar (3)	Customise avatar (4)	Create avatar (5)
NPC-to-player interaction is by means of	NPCs with voice and emotion positively affects play-learner engagement (hence the relatively high weights for options 4 and 5); texts are informative, but are most effective as short bursts (hence option 3 is weighted higher then option 2); players enjoy interacting with NPCs and foregoing this (option 1), brings about reluctance to play the game				
	There is no interaction (-1)	Explanatory text (1)	Short textual bursts (2)	Voice (4)	Voice and social cues (5)

Questions and themes	Rationale for weighting, answers and weights				
The game's competitiveness element can be described as	Option 5 is negatively rated because competition raises player anxiety that leads to a diminished learning in games; competition (in the right dosage) does motivate players to play a game (options 1, 2 and 3 are weighted accordingly); although option 1 is very effective for learning, it does not draw players to a game as much as options 2 and 3 do				
	Non-competitive (2)	Time as only competitor (5)	Boss fights only (3)	Regularly competitive (1)	Highly competitive (-2)
Interaction	*Option 1*	*Option 2*	*Option 3*	*Option 4*	*Option 5*
The control mechanics are easily mastered	Players are not interested in games with complex controls and novice players may walk away from games with such controls (hence the strong negative weights for options 1 and 2); simplistic point-and-click controls are likely to keep players engaged for longer (options 3, 4 and 5 are weighted according to the simplicity of the controls)				
	Strongly disagree (-3)	Disagree (-2)	Partly agree and disagree (2)	Agree (4)	Strongly agree (5)
A high number of preference settings are available to the user	Preference settings allow novice and experienced players alike to set the game according to their respective wishes; there is no real detriment if setting preferences is not available (option 1) and any control over game settings imparted to the player will be positively received (hence the steady increase in weights for options 2, 3, 4 and 5)				
	Strongly disagree (0)	Disagree (1)	Partly agree and disagree (3)	Agree (4)	Strongly agree (5)
Players acclimatise to the game's interface and environment by	Increased practice times improve game understanding (this leads to more focussed learning); practicing within the game environment is ideal (hence the higher weights for options 4 and 5); the reference nature of option 3 makes it somewhat stronger than option 2; without game guidance (option 1), novice players will abandon gameplay				
	No gameplay guidance (-2)	Brief oral explanation (1)	Gameplay instructions (2)	Initial basic gameplay (4)	Practice level (5)
The game resources are clearly shown and easily accessible throughout	Players become frustrated and waste time if they cannot find or access game resources easily; options 4 and 5 refer to persistent (but discreet) resources that are no effort to engage; options 1 and 2 suggest that the game resources are too deeply embedded; option 3 indicates that the resources are available, but some menu traversing is required				
	Strongly disagree (-1)	Disagree (0)	Partly agree and disagree (2)	Agree (4)	Strongly agree (5)
The game tasks become gradually more complex	Options 1 and 2 are weighted negatively because they imply either the game's difficulty does not go up (equals boredom) or it goes up too quickly (game is beyond player ability); option 3 is weighted lower than options 4 and 5 because option 3 should imply that the game does its complexity increase in a clipped fashion				
	Strongly disagree (-2)	Disagree (-1)	Partly agree and disagree (2)	Agree (4)	Strongly agree (5)
AI and adaptivity	*Option 1*	*Option 2*	*Option 3*	*Option 4*	*Option 5*
There is a perceived high degree of AI in the game	Some games are perceived to have AI nuances while they contain no underlying AI programming; the cost of pseudo AI will be significantly lower than integrating complex AI algorithms, while still enjoying boosted enjoyable learning benefits; it would be unfair to penalise games if they do not manage this deception (hence option1 has zero weight); if games do manage this, their rating should be elevated (hence the further positive weights)				
	Strongly disagree (0)	Disagree (1)	Partly agree and disagree (3)	Agree (4)	Strongly agree (5)
Automatic and unobtrusive hinting is provided when players get stuck	Formative learning more likely when intelligent agents stealthily guide players; option 1 is the only negative rating because interfering agents will compromise flow; hinting in an intelligent way (options 4 and 5) not just promotes formative learning, but sustains player immersion (hence the slightly elevated weighting)				
	Strongly disagree (-1)	Disagree (1)	Partly agree and disagree (2)	Agree (4)	Strongly agree (5)

Questions and themes	Rationale for weighting, answers and weights				
Game responses are natural by means of tailored reactions/replies	Players enjoy tailored responses; achieving this means more valuable than the penalty incurred for not doing so (hence there is an enlarged weight difference between option 3 and options 4 and 5				
	Strongly disagree (0)	Disagree (1)	Partly agree and disagree (2)	Agree (4)	Strongly agree (5)
The game adapts to player habits/preferences	Adaptivity in any form harbours significant learning gains, but promotes individualised learning when suitably applied; this is why options 4 and 5 again have an enlarged weight difference with option 3; the same as before, a game should not be penalised if adaptivity is not incorporated (hence no negative weighting for this question)				
	Strongly disagree (0)	Disagree (1)	Partly agree and disagree (2)	Agree (4)	Strongly agree (5)

The researcher commenced the calculation travail towards an overall game rating through determining each theme's individual dimension contributions to the game's overall dimension ratings. The researcher rationalised that providing each theme's dimension contributions adds unnecessary complexity with little value to the SGG's purpose—to provide a dashboard representation of the game's anticipated success. Hence, the theme contributions are not presented to the user. This is something that may be altered in future renditions of the SGG. Instead, a much more useful metric (theme ratings) is delivered. To arrive at the intended game rating, the following major calculation steps were conceived:

1. When the user makes an answer selection, the weight of the chosen answer is multiplied by each of that theme's dimension weights to give the *dimension answer scores* for that specific question.
2. The weights matrix (Table 1) was transformed into a matrix of *maximum dimension scores* for every theme—since the scale extends to five, each weight was multiplied by five. For example, the maximum scores for AI and adaptivity are 1.5; 2.0 and 2.5 for learning, fun and dynamics respectively.
3. The sum of the maximum scores was calculated per dimension to give each dimension a *dimension maximum score*. That is, the dimension maximum scores are 13.0; 15.5 and 16.0 for learning, fun and dynamics respectively.
4. Returning to the user inputs, the sum of each dimension's answers for that specific theme is calculated and divided by the number of questions to give the *theme average score per dimension.*
5. The theme average score per dimension was divided into the maximum score of each respective dimension to give the *theme contribution* to the overall dimension ratings.

Table 4 summarises the scenario that unfolds if the user should answer 2, 1, 4 and 2 for the four AI and adaptivity questions. Steps four and five are repeated for every theme.

Table 4: Calculation example of theme contributions to the overall dimension ratings

AI and adaptivity questions	Selections	Learning dimension	Fun dimension	Mechanics dimension
There is a perceived high degree of AI in the game	2	0.3	0.4	0.5
Automatic and unobtrusive hinting is provided when players get stuck	1	-0.3	-0.4	-0.5
Game responses are natural by means of tailored reactions/replies	4	1.2	1.6	2
The game adapts to player habits/preferences	2	0.3	0.4	0.5
AI and adaptivity theme average score per dimension		0.375	0.5	0.625
Theme contribution to overall dimension ratings		**0.029**	**0.032**	**0.039**

6. The sum of theme average scores is divided into the sum of that theme's maximum scores to give a *theme overall rating*. For instance, the AI and adaptivity rating, for the given example, would be 0.3 or 30%.

Step six is repeated for every theme and all the resultant theme ratings are presented side-by-side in a bar chart as the first part of the SGG dashboard. This bar chart allows users to assess which of the themes have been suitably addressed by the game and which themes necessitate further work. The researcher suggests that themes scoring over 75% do not require urgent attention, while any theme with a rating of 50% or lower should be re-assessed and attended to further. It is also important to note that a perfect game will score 100% for every theme (i.e. the total for the themes of a perfect game is 500).

7. The sum of the theme contributions per respective dimension is calculated to give the game's *overall dimension ratings*.

The overall dimension ratings are placed on a second bar chart as part of the SGG dashboard. Once again, the user is able to perform a single-glance visual assessment. This time, the chart highlights how strongly or weakly each of the dimensions is imparted to the players. For instance, if a game is low on the fun dimension, the user can refer back to the initial weights matrix to determine which of the themes have the highest impact on the fun dimension (in this case, backstory and production and realism) and weigh up how the game adheres to the success factors of these themes. As with the themes, a perfect game will score 100% for every dimension (i.e. the total for the dimensions of a perfect game is 300).

8. The average of the three overall dimension ratings gives the *game rating*.

The game rating is shown on the same chart (in a distinct colour) as the overall dimension ratings offering a graphical forecast of the game's success. The researcher has further envisaged using the game rating as a means to compare different game designs with one another. This implies that individual SGG scrutiny for each design will be required. The researcher is *not* prescribing that the design with the highest rating *must* be developed further. It could occur that two design ratings are closely matched. In this case, the rest of the ratings (theme and dimension) should be considered as the user may find that some minor changes to the lower rated design will boost it's rating beyond the previously higher rated design. In summary, the design comparison will allow serious game producers to commence prototyping the design most likely to lead to a successful serious game measured in terms of the SGG's mentioned criteria.

3. Pilot-testing the Serious Games Gauge

3.1 Study design and sample

The SGG was pilot-tested in order to establish its further development value. A prototype of the SGG (Addendum XII) was used to rate four serious games and the ratings were compared to: (a) existing remarks about the game; (b) past comments regarding gameplay; or (c) accolade bestowed on the game. Furthermore, the ratings and content of the SGG were compared to initial instinctive ratings and comments (respectively) the various testers gave the games. This was done to ascertain preliminary construct, content validity and criterion validity of the SGG. Non-probability judgment sampling was used to select three publicly available (free) games and one commercially available mobile game. The games for testing included:

(a) Mandela27, designed to create awareness and understanding about the conditions of Robben Island Prison during the years of Nelson Mandela's incarceration there (Serious Games Institute SA, 2014);
(b) Darfur is Dying, designed to provide a window into the experience of refugees in the Darfur region of Sudan (mtvU, 2008);
(c) FinMan, designed to enhance the first-year Financial Management module at NWU (Serious Games Institute SA, 2014); and
(d) DragonBox Elements, designed to deliver a deeper understanding of the logic of geometry (WeWantToKnow, 2012).

The games were selected based on their reception by the respective playing audiences and their game-style and platform variety (Table 5). Game-style and platform variety were included to assess the SGG's versatility.

Table 5: Games used for SGG pilot testing

Game and release date	Platform	Game style	Existing remark, past comment or accolade
Mandela27 2014	Offline PC	Interactive graphic novel	Much hype in the press around the project's serious game (eNCA, 2013; Mail&Guardian, 2013); target playing audience have indicated that they liked the audio-visual quality and story
Darfur is Dying 2006	Browser	Adventure role-playing game	Winner of three awards at the time of its release (Take Action Games, 2006); users give it a rating of 7.4/10 on the *Games for Change* website (Games for Change, 2015)
FinMan 2013	Browser	Arcade style adventure game	Moderate teacher impressions about the game; target playing audience were somewhat underwhelmed by the gameplay and learning experience
DragonBox Elements™ 2014	Mobile	Mobile puzzle game	Winner of the *best education and learning serious game of 2014* at the Fun and Serious Game Festival 2014 (Fun & Serious Game Festival, 2015) and other awards

Four BSc Honours in IT students (hereafter referred to as *testers*) volunteered to perform the SGG's initial formative testing. The four games were randomly (by means of drawing from a dark container) assigned on a one-to-one basis to the testers for testing. The students were not asked to individually test all the games because the researcher was concerned that they might compare the games to one another instead of scrutinising each of them by their own merits. The testers were asked to play the games; each played for about thirty to forty minutes in the presence of the researcher. After gameplay, the testers were asked: (a) two questions about their own gaming habits; (b) to give the game they just played a percentage rating for learning and fun; and (c) to mention the two gameplay experiences (positive or negative) that struck them most. The testers then set about rating the respective games via the SGG's Likert-style questions. Once this was completed, the researcher asked the testers some questions about the SGG and requested them to fill in the Perceived Usefulness Questionnaire of Davis (1989:340). The questionnaire was used without any adaptations. Addendum XIII presents the questionnaire and tester responses. The testers were asked to answer the questionnaire from a serious games designer point of view. This was not an unfamiliar role to them since the testers have all been involved with their own serious game projects. The questionnaire contributed to the overall purpose of the pilot test (to explore whether the SGG should be developed further) by providing a first impression of the SGG's usefulness. Table 6 provides a brief gameplay exposure profile of each tester as well as the game that was randomly allocated to each of them.

Table 6: SGG tester profiles

	How often do you play video games?	At what age did you start playing video games?	Game used for SGG testing
Tester 1	20 to 25 hours per week	6 or 7 years old	Mandela27
Tester 2	2 to 4 times per month	5 or 6 years old	FinMan
Tester 3	25 to 35 hours per week	7 years old	Darfur is Dying
Tester 4	Almost never	Played games in primary school	DragonBox Elements™

The two online games were played via the testers' preferred web browsers; the offline game was played on laptops; while the mobile game was played on an iPad®.

3.2 Data sources

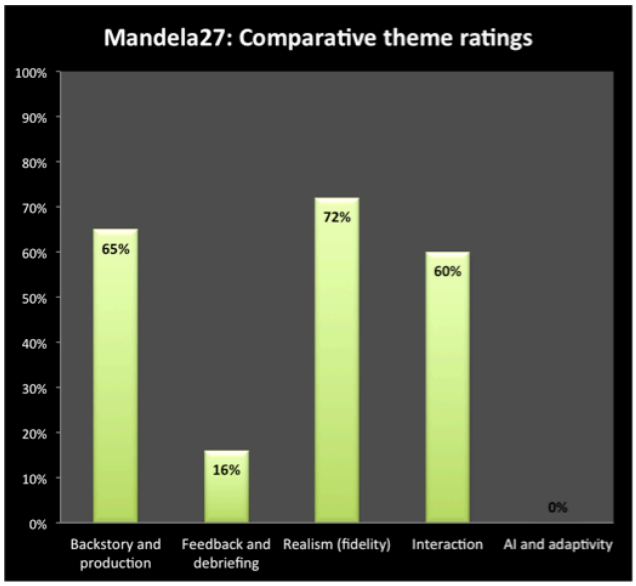
The researcher would like to reiterate that the data collected from the testers (both from the additional questions and the SGG results) was not used to analyse the games, but rather to offer a basis for further ensuring the SGG's test validity. When the testers had finished playing, they were asked to express two memorable experiences (positive or negative) about the game. They were also requested to give a perception rating of the game's learning and fun dimensions. Table 7 provides each tester's top two sentiments regarding the respective games they tested as well as their perceptions (as a percentage rating) about that game's learning and fun dimensions.

Table 7: SGG tester gameplay experiences and ratings of the test games

Game	Memorable tester gameplay experiences	Learning rating	Fun rating
Mandela27	High quality graphics and well suited to the context Storyline was appropriate and liked the voice-over	75%	65%
FinMan	Easy to play Frustrated by lack of keyboard shortcut to inventory	80%	80%
Darfur is Dying	Textual explanatory paragraphs were too long Game is very repetitive and this makes it boring	60%	20%
DragonBox Elements™	Enjoyed that NPC shape matches the shape being learnt Liked the colourful gameplay environment	80%	75%

The testers were not asked to give a perception rating of the dynamics dimension because it is an undercurrent that the testers found difficult to isolate and rate for the games that they played. The reason for this is that the testers were not the designers (or programmers) of the games they played during the pilot-testing of the SGG. Dynamics comes about through the interaction between the game's mechanics, which is under the control of game designers and programmers (Sicart, 2008), and user inputs (Hunicke *et al.*, 2004:3). The SGG is aimed at the design and early development stages and therefore, does rate the dynamics dimension. In short, there is no tester perception of dynamics to compare with the rating the SGG gives to this dimension for each of the games. Also, since the SGG questions were targeted at the design phase, the testers found some of the questions

difficult (even impossible) to answer. For example, the testers could not have known to what extent the end-users were involved in the respective game designs; they also cannot be certain what level of progress tracking takes place. This is something to bear in mind when regarding the SGG dashboards (Figures 1 to 4) for each of the games.



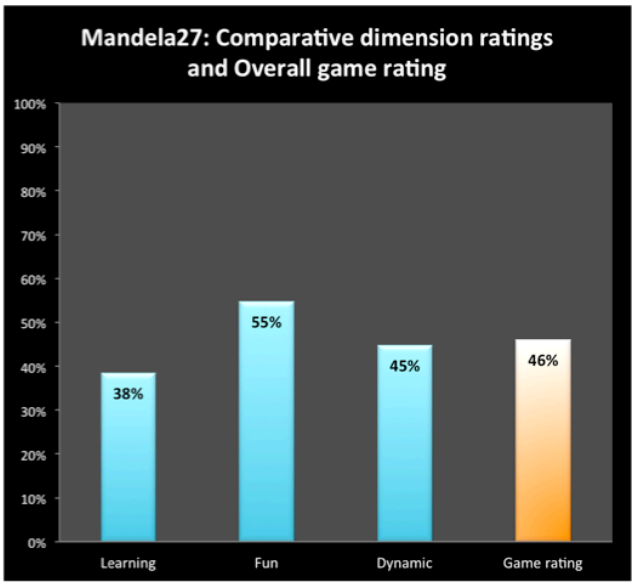
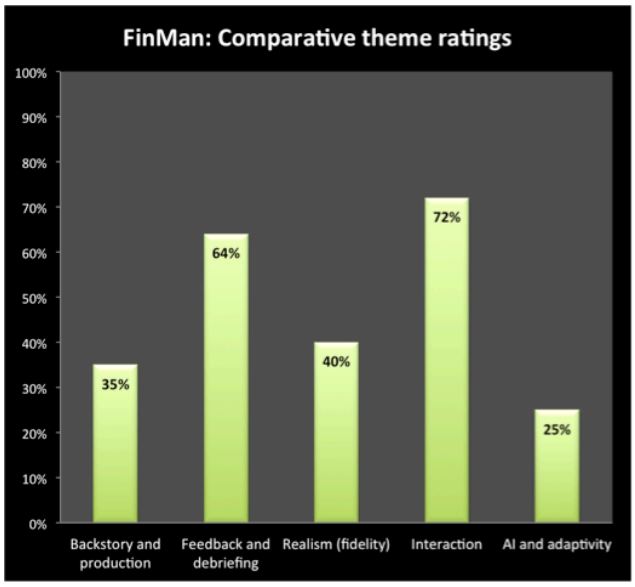


Figure 1: SGG dashboard for Mandela27



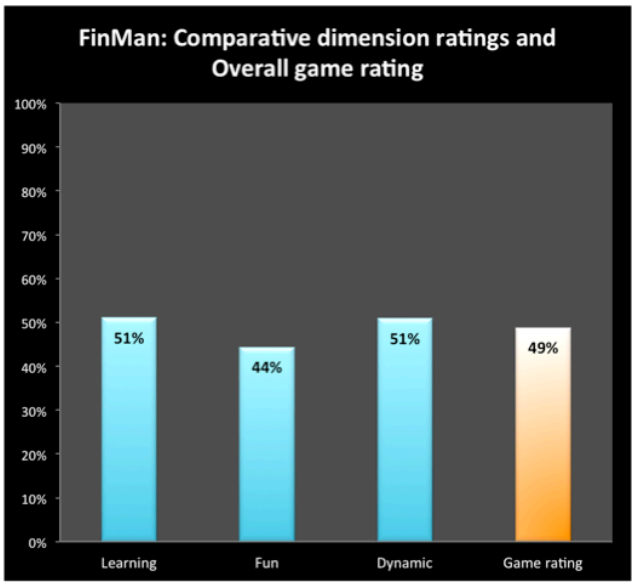
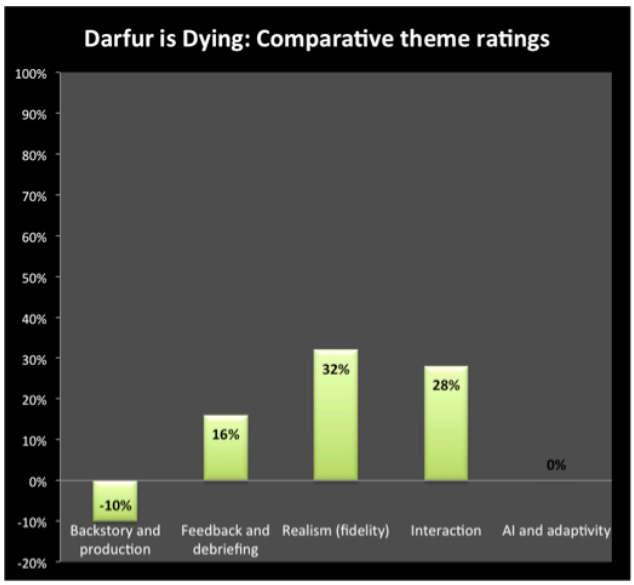


Figure 2: SGG dashboard for FinMan



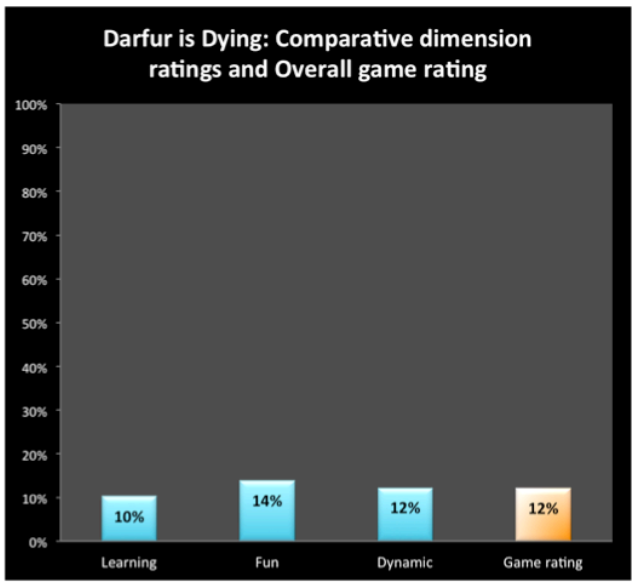
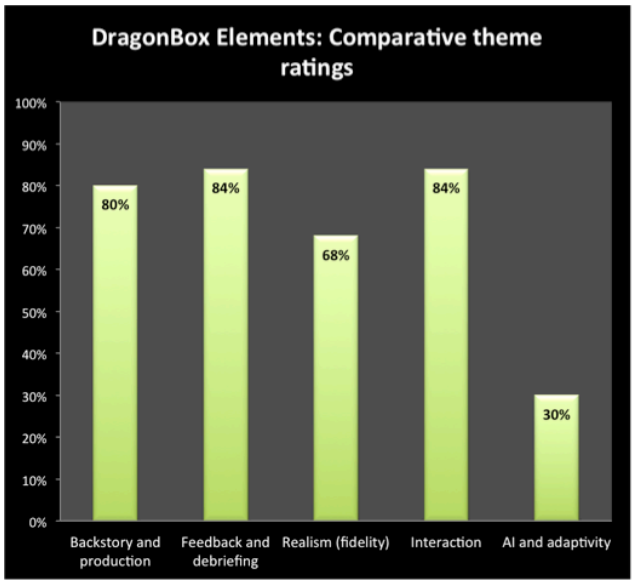


Figure 3: SGG dashboard for Darfur is Dying



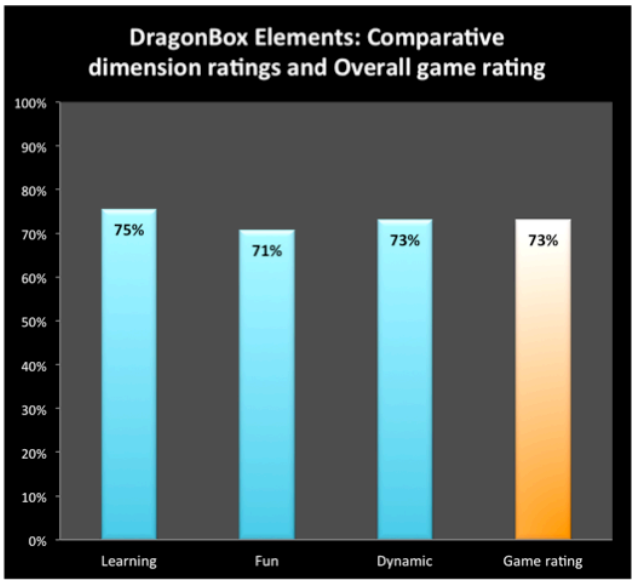


Figure 4: SGG dashboard for DragonBox Elements™

3.3 Discussion

The SGG prototype testing was purely exploratory and made use of only four testers playing one game each. This is clearly not enough data for rigorous statistical analysis. This also holds for the perceived usefulness questionnaire analysis. The researcher's reasoning is built on observations, openly visible qualitative parallels and impromptu questions posed to the testers. This does not however, make the conclusions less noteworthy and this pilot test securely aided the intention of establishing the SGG's way forward.

The testers' top memorable gameplay experiences did not just slot comfortably into overarching themes, but were closely matched to individual questions or factors (Table 8).

Table 8: SGG tester gameplay experiences matched to SGG questions

SGG question	Memorable tester gameplay experiences
The game's environment and objects are closely tied to the learning material	High quality graphics and well suited to the context
The story provides a fitting context for the learning material	Storyline was appropriate and liked the voice-over
The control mechanics are easily mastered	Easy to play (uncomplicated interface)
The game resources are clearly shown and easily accessible throughout	Frustrated by lack of keyboard shortcut to inventory
NPC-to-player interaction is by means of	Textual explanatory paragraphs were too long
The game tasks become gradually more complex	Game is very repetitive and this makes it boring
NPC-to-player interaction is by means of	Enjoyed that NPC shape matches the shape being learnt
The game's graphics, animation and sound are	Liked the colourful gameplay environment

The first of the two highlighted pairings, although well matched, may be somewhat misleading owing to the ambiguity of the tester's "easy to play" comment. The comment could have referred to the interface or to the controls (the researcher neglected to ask for clarification). The second highlighted pairing is somewhat (but not entirely) incompatible as NPCs were not the source of the game's explanatory paragraphs. The SGG question, *NPC-to-player interaction is by means of*, nevertheless provided the tester with an opportunity to select *explanatory text*.

The Mandela27 dashboard (Figure 1) indicates a much lower rating for learning and fun than the tester assigned to it before utilising the SGG. The researcher posits the primary reason is that Mandela27 is essentially a graphic novel with limited interaction opportunities—by extension, the in-game feedback and AI is also limited. Graphic novel evaluation criteria (Griffith, 2010:183) show that Mandela27 rightly relies on its backstory and graphics to immerse players. Given the tester's memorable gameplay experiences and initial ratings, Mandeal27 appears to do this well. The SGG however, for cases such as Mandela27, does not make provision to exclude irrelevant factors (in this instance pertaining to feedback and AI) from its calculations. Returning to the weights matrix (Table 1) adds to this argument in that feedback and debriefing have the highest impact on learning, while dynamics is strongly influenced by both feedback and AI. Therefore, a low rating for both these themes is bound to lower the SGG's learning and dynamics ratings for any game. The researcher maintains though, that the SGG was able to highlight the themes (backstory and production, and realism) responsible for Mandela27's success (as a graphic novel) and that it could be a much better (than 46%) serious game if its feedback and debriefing theme is addressed. The researcher suggests that work on the AI and adaptivity theme of Mandela27 should only take place after the SGG reveals a new rating (with feedback being addressed) and a cost-benefit analysis based on this rating is performed.

A similar pattern of discrepancy is noticeable between the FinMan dashboard (Figure 2) and its initial tester ratings—causing the researcher an element of disquiet. The researcher observed several exclamations and utterances of enjoyment during the tester's engagement with FinMan. Given the underwhelming reception FinMan received from its target audience, the researcher was somewhat surprised. When asked about this, the tester revealed being a fan of "simplistic adventure games" and that FinMan fits neatly into the tester's realm of fun games. The tester also stated that the learning material addressed some prior forgotten knowledge of financial management. These two statements appeared to explain the relatively high tester ratings for learning and fun. This comes as no surprise since adventure games are often utilised for learning (Amory, 2001:251; Annetta *et al.*, 2014:64; Couceiro *et al.*, 2013:539) and are one of the top five most played video game genres (ESA, 2015:10). After using the SGG though, the tester admitted that "my rating for learning was purely based on memories about accounting" and requested to revise the initial rating (this was denied). Turning back to the tester's fun rating, the researcher felt this was a genre preference rating rather than an objective one. The researcher therefore, places greater confidence in the SGG's rating that is in line with sentiments from FinMan's target audience (Table 4), than the tester's personal ratings. Herewith dismissing earlier concerns about the disproportion between the two.

Darfur is Dying received the lowest fun rating of all the games by far, both by the SGG and the tester. Moreover, there is clear agreement between the tester and the SGG dashboard (Figure 3) that Darfur is Dying is not fun. The researcher attempted to verify these ratings, both in academic and generic literature, but was only able to locate one sensible review (Lesser, 2014) (rating it two teacher and three expert stars out of five) or criticism that did not evolve into a badgering about the frivolity of using games for serious matters. Nonetheless, the tester gave the narrative-related questions such low scores that the backstory and production theme as a whole had a negative impact on the overall ratings. It can be argued that the tester's negative gameplay experience may have led to cognitive bias when using the SGG. The researcher, based on the FinMan experience that the SGG appears to counteract tester opinions, has chosen to disregard this possible bias. A further argument may be that because this tester is an avid (25 to 35 hours per week) gamer, the expectations the tester had of Darfur is Dying would have been high. This is corroborated by Virvou and Katsionis (2008:174) who learnt that experienced players are more likely to demand an elevated number of objects, sounds and adventure. Also, Darfur is Dying (a Flash™-based game released in 2006) cannot be compared to high-end games the tester is familiar with, making the argument almost irrefutable. Still, the researcher found that the tester's memorable gameplay experiences counter the notion of high expectation. The experience that the game is repetitive and

has overly lengthy texts is not born out of game technologies, but rather game design—the phase intended for SGG utilisation. The realism and interaction themes that the SGG unmasks (through the tester experience) have the highest and third highest impact (Table 1) on the fun dimension. The researcher concludes that the SGG correctly assigned a low fun rating to Darfur is Dying. The large divergence between the tester and SGG learning ratings originated with the surrounding web material. The tester, out of observed boredom during the allotted gameplay time, decided to investigate more of the Darfur is Dying website. In doing so, the tester learned about the conditions the refugees in Darfur experienced. Hence the relatively high initial learning rating. The SGG emphasises the importance of in-game feedback to promote learning and as such, judges ex-game learning material unfavourably (Table 2), leading to a low SGG learning rating. In short, Darfur is Dying may appear to promote learning, but the SGG exposed that it does not take place while playing the game.

The DragonBox Elements dashboard (Figure 4) closely reproduces the tester's initial ratings of the learning and fun dimensions, while the memorable gameplay experiences further corroborate the positive ratings. Once again, as with Mandela 27, the AI scoring may have produced an element of measurement bias. The tester explained that the game has perceptibly little AI and felt the SGG questions unjustly lowered the game's ratings. All-in-all, the researcher confidently maintains that the SGG would have predicted, if it were used during the design or initial prototyping phases of the game's production cycle, an award-winning DragonBox Elements.

The perceived usefulness questionnaire comprised six questions on a seven-point Likert scale; seven being the most positive answer. With only four respondents, the researcher reduced the analysis to calculating the questionnaire's overall mean ($\bar{x} = 6.29$) and standard deviation ($s = 0.69$). Only one question, *using the SGG in my job would increase my productivity*, was more than one standard deviation ($z = -1.14$) from the mean. The comparably lower score is attributed to two of the testers reasoning that a game designer's productivity is a measure of the number of games he/she designs. They further stipulated that *the SGG would certainly improve the quality of a design*, but not reduce the time taken to design a game. The researcher expands this view in stating that a quality design would have a positive productivity knock-on effect later in the production cycle—attributing increased productivity to the SGG after all.

During the post-SGG prototype testing discussion, the testers thought it would be valuable to have an extra layer of feedback (beyond the dashboard) that highlights the exact factors responsible for lowering the rating. The testers mentioned that the look-and-feel should not remain Excel™-based

and transforming it into a mobile application would probably be well-received. There was agreement amongst the testers that the dashboard was easy to understand and succeeded in conveying a concise summary of the game's ratings. In the same breath, they recommended that the bar chart dashboard should be converted into something more appealing (two testers suggested dials). The testers' parting opinion was a sentiment of appreciation toward the SGG's capability to point out underlying as well as blatant serious game flaws. They stated that if the SGG gave their game designs a low rating, they would certainly re-evaluate the design theme(s) responsible for the low ratings.

4. Conclusions and recommendations

The researcher views Table 8 as a fair initial indicator of the SGG's content validity. This allows a tentative conclusion, that the first step towards substantiating the SGG's content derived from the SLR has been taken. The SGG's construct validity will greatly benefit from a procedure that excludes extraneous factors from its calculations. Yet, the SGG prototype did show some initial construct validity by imparting a rating that is in line with its intended purpose as illustrated through the learning ratings of Darfur is Dying. Rating FinMan's fun dimension bolstered the SGG's criterion validity in that the SGG showed its ability to negate a tester's preconceived game genre preference to deliver an unbiased verdict that reflects the expected results (in this case, the subdued response by FinMan's target audience). The researcher concludes that (in light of these early indications of criterion, content and construct validity) the SGG prototype has, to a large extent, met the core test validity constructs, making the SGG's further development a worthwhile endeavour. Of course, further validation and reliability testing should be part of the SGG's evolution. Furthermore, the weighted grids that formed the basis of the calculations held fast, and cause for a deeper search for accuracy and reliability of the weights has been presented.

Viewed through the eyes of a game designer, the testers gave the SGG an average rating of 6.29 out of 7 for perceived usefulness. That is, the testers regarded the SGG prototype as a useful tool for serious games designers. Further exploratory questions echoed that future renditions of the SGG must have the ability to exclude questions that could lead to measurement bias. The testers did feel that some further look-and-feel work is required to make the SGG a truly appealing tool, but they enthusiastically conceded that the SGG's serious game ratings should nevertheless be taken seriously.

The positive tester feedback and the SGG prototype's demonstrated pilot-testing gives the researcher grounds to state that further development of the SGG is justified. Through this

continued development, the researcher projects that the SGG will become a useful tool with the means to accurately predict the success rate of envisioned serious games. Additionally, the use of the SGG would result in the production of more quality serious games and as such, take a first step to dispelling the critique of a disjointed serious games field.

The next portion of the study addresses the research aim and questions posed, and gives an overview of the research journey.

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Conclusion and reflections on the success factors of serious games

1. Introduction

Defining the scope of the serious games field seems to be a slippery slope. There appeared to be no way to pinpoint an acceptable definition without: (a) excluding a vital component; (b) construing a misconception of the purpose of serious games; or (c) offending someone. With this, the researcher understood why the proclaimed generally accepted safety-net definition that serious games are more than mere entertainment, "with deliberate educational intent" (Abt, 1970:9), is an accepted go-to.

Serious games do not just span across a number of disciplines, but also reach out to a formidable array of sectors (Sawyer & Smith, 2008). Further assertions are made that serious games are steadily finding favour amongst academics and professionals (Connolly *et al.*, 2012:662). The 2015 Horizon Report (Johnson *et al.*, 2015:22) highlights that students prefer to learn with games. All of the above prompted the researcher to dig a little *less* deep. A brief Internet trawl revealed a plethora of serious games conferences (Serious Play Conference, Fun and Serious Play Conference, Serious Games Summit at the Game Developers Conference, Serious Games Conference) and official bodies (Serious Games Association, Serious Games Society), that over the past three to four years promoted serious games as the panacea of contemporary learning. This convinced the researcher that serious games have not just gained a toehold amongst scholars, but have garnered an expectation amongst the population at large—rendering a practical contribution from this study, invaluable.

Delivering a practical contribution meant acquiring a better understanding of the fun, learning and dynamics of serious games. A discourse on game dynamics, or rather, the run-time result of interaction between the mechanics and user inputs (Hunicke *et al.*, 2004:3), in the context of serious games, could not be found. The researcher was compelled to turn to entertainment game discussions to determine the true value of game dynamics. The most concise and purposeful explanation of dynamics came from LeBlanc (2006:440), who states that dynamics is the game's behaviour exhibited during gameplay. This was interpreted as no matter what kind of game (be it entertainment or serious) is being produced, dynamics plays an integral part in the gameplay experience. With this, the researcher placed dynamics alongside fun and learning as another primary dimension of serious games and continued to keep it at the forefront of this study. Conversely, the fun and learning dimensions are widely discussed in serious games literature. The researcher soon established that fun is a positive emotional state flowing from engagement with a game and that a constructivist approach best supports learning through games.

2. Problem statement

In spite of literature paying abundant attention to fun and learning, cracks began to show when an attempt was made to ascertain the relative importance of fun versus learning in a serious games environment. No clear-cut answers could be found. The researcher surmised that this stems from leading authors in the field not harmonising whether serious games should be developed from the entertainment over pedagogy corner (Zyda, 2005:26), or from a point of view that education is the primary goal of serious games (Michael & Chen, 2006:17).

At this point, the researcher decided to rather delve into something more tangible. That is, the question of how much audio-visual realism should go into a serious game—only to be confronted by a continuation of the same discord that is evident between fun and learning. At one end of the spectrum, Bellotti *et al.* (2009) are finding success with highly realistic environments, while Kiili (2005:192) is at the other end, making a statement that players do not require audio-visually rich games. To make matters worse for serious games producers, high fidelity detracts from intended learning (Ke & Abras, 2013:233) while players are imploring more realistic game environments (Papastergiou, 2009:10). The end-result was yet another unanswered question.

It was clear that probing the game dimensions in isolation would not deliver an answer to the question, *what makes a serious game successful?* The researcher thought of satiating this curiosity by looking outside the game (i.e. at the production team) to try and determine the importance of each game element through the significance assigned to each team role. The different roles were unmasked and the researcher found that pedagogical experts and consumers are equally important (Mitgutsch & Alvarado, 2012:123)—amplifying the predicament encountered when investigating realism.

As a last ditch effort, the researcher searched for consolidated evidence (in the form of reviews, syntheses, overviews, systematic reviews and meta-analyses) that could convey what makes serious games successful. No such amalgamated literature could be found and the researcher was left to sift through more scattered accounts of individual ideas that gave an unsynchronised first impression.

3. Objectives

These exposed discrepancies left the researcher pondering how to go about constructing a single address for serious games success factors. More so, being a functionalist, the researcher wanted to create something over and above the academic contribution a literature consolidation would

provide. A prototype guidelines review tool appealed to the researcher and the necessary planning for this commenced. Part of this preparation involved unscrambling the field of serious games and synthesising the criteria for rating the success of serious games. A small-scale pilot-test showed the consequent rating tool's value and concluded the study with a well-defined way forward for the tool's development and a much-needed first step toward organising the field of serious games.

4. Process

The researcher did not take the task of unravelling the dissonance of serious games literature into a common set of success factors lightly, and decided that the only suitable way of achieving this was through a rigorous systematic literature review (SLR). Seventeen literature databases were subjected to a broad set of search terms resulting in over 13500 unique Anglophone hits. The inclusion of generic literature, theses, books, conference papers and proceedings explains the sizeable list of literature that required thinning out. During this exercise, the researcher soon realised that academic journal articles are the only sources that can facilitate the pursuit of a high-quality answer. In addition, he quickly learned that academic institutions have limited access to literature. When embarking on future reviews, the researcher will only search, from the outset, amongst journal articles that are accessible by the academic institution from where the study is taking place. Regarding the search criteria, the researcher's impression was that the term *gamification* is used interchangeably with serious games and hence it was incorporated as part of the search terms. However, every article that discusses gamification was systematically removed from the study due to the articles inappropriately addressing the research question. The researcher safely concluded that gamification, when discussed in academic literature, has a very distinct definition and should not have been part of the search criteria to begin with.

After employing a variety of removal strategies, the researcher was still left with over 1200 articles, and concern crept in over the impractically large number of articles that might remain for final analysis. With the help of the study leaders, the researcher devised a strategy that identified and retained the work of primary authors in the field of serious games for the inclusion and exclusion phase. The researcher was somewhat apprehensive about removing the papers of less established authors, as some of this work was well-suited to the research question. He felt that removing this work may threaten the SLR's trustworthiness. This concern remained until the end of the coding and synthesis phase. However, applying the constant comparison method (Boeije, 2002) for analysis, revealed the serious games kaleidoscope, convincing the researcher that a reliable representative sample of serious games literature was used for the SLR. Focussing on prominent

authors is a strategy that does not undervalue the work of others, but can undoubtedly be utilised to reduce the number of papers for analysis without damaging a review's credibility.

Abstracts were carefully examined and formed the basis for consideration against a pre-determined set of inclusion criteria. The remaining 72 articles were considered as the SLR's definitive source material. During the coding phase however, a further nine articles were removed. The misalignment between these articles and the study's objectives came about through faulty impressions of the respective abstracts. The researcher deliberated over this and decided that a possible mitigation would have been to read each article attentively while carrying out inclusion and exclusion. Though, this would either have required significantly more time or substantially more researchers. In conclusion, a final list of articles can only be determined through in-depth reading of these articles and if time, or other resources are limited, researchers should accept that further removal of primary evidence while coding, might occur.

The time frame (2000 to present) for the included studies appeared to become exposed during the coding phase. This SLR examined a technology-reliant field that is constantly evolving in the advent of such advancements. The researcher postulated that current serious games audiences would probably not appreciate a 2005 cutting-edge game, hereby wandering about the value of including studies from more than five years ago. However, through comparing comments of players from older studies with players of a recent era, it became evident that the parallel lies between expectations and technology; and that a game *faux pas* that existed before is still relevant today. That is, the factors that bring about serious game success persist through time. For example, navigational difficulty influenced learning with games in 2008 (Virvou & Katsionis, 2008:166) and still does today (Chittaro & Sioni, 2015:512).

4.1 Systematic literature review

Atlas.ti™ mediated the fusion of abundant evidence that serious games are a vehicle for enhanced learning into discernable success factors. The researcher quickly learned that every study, and hereby every game, has a unique playing audience with one-off demands regarding the games. It is not a wonder that the realm of serious games is deemed fragmented, and scrutinising studies in isolation is bound to exacerbate this notion.

The SLR process uncovered five themes (backstory and production; realism; AI and adaptivity; interaction; and feedback and debriefing) that would prove to be containers for the various success factors that were also uncovered. These five themes were studiously rotated, unfolded and

disassembled in the researcher's mind. Thinking back to the work of Hunicke *et al.* (2004) and explanation from Marsden (2013) about game dimensions, the researcher theorised that the five themes had an impact on fun and dynamics. Since the study revolved around serious games, including learning as a third dimension went without saying. In short, five themes impact on three (learning, fun and dynamics) dimensions. Although this was a major leap in the right direction, the themes in themselves remained largely non-descript empty vessels. The researcher set forth to classify the pertinent serious game success factors, unearthed during the SLR synthesis phase, according to the five themes.

If the researcher would be asked to pick a single theme with the highest comprehensive impact, backstory (narrative) and production would be it. The backstory takes on a great degree of responsibility for learning since this is where real-life and virtual skills must be matched (Soflano *et al.*, 2015:198) within a relevant virtual context (Couceiro *et al.*, 2013:547). It is imperative for a serious game's storyline to be without distinct breaks between gameplay and learning (Hwang *et al.*, 2015:16) or (by the researcher's interpretation of game dynamics) the game's behaviour will exhibit a staccato learning-enjoyment personality. The backstory drives the fun dimension by keeping players engaged long after fidelity has lost its original lustre (Ke, 2008:1614).

Realism or fidelity was a far trickier proposition and the question of *how much realism is enough?* was not something the researcher wanted to get caught up in any further. The notion that realism has a strong influence on the fun dimension was sufficient. Players are excited about creating avatars (Ke & Abras, 2013:234) and, given their demands, delve more enjoyment out of an audio-visually realistic ambient environment (Papastergiou, 2009:10). The researcher was surprised to learn that high realism in games causes distraction and may place the learning dimension under pressure (Virvou & Katsionis, 2008:163). The answer to this was found in eliminating unnecessary fidelity aspects so that the learning dimension is least affected (Annetta *et al.*, 2009:80). At this point, the researcher began to appreciate the magnitude of the challenging learning-fun serious game balance Giessen (2015:2241) refers to. He found another balance that realism must maintain; in a learning context, competition is discouraged, yet it motivates players to play games (Zin & Yue, 2013:12) and is even recommended for serious game environments (Cagiltay *et al.*, 2015:40). Time constraint (36% of the SLR studies used it) appeared to be that balanced nondescript adversary. The researcher now regarded fidelity as the cosmetics of serious games and concluded that the psychological fidelity of time pressure is most responsible for the small impact realism has on the dynamics dimension.

The interaction theme was much more balanced. Complex controls and overwhelming interfaces are able to raise the frustration levels (Kiili, 2005:195) of players to the extent that they show little interest in the game (Zin & Yue, 2013:22). The researcher relates to this response, electing not to play games that do not have the option of decreasing their level of required navigation dexterity to four fingers or less. The complexity of moving a PC and making sense of the interface has a tremendous impact on the game's dynamics dimension (Van der Spek *et al.*, 2013:156). The researcher felt that this is a root cause indirectly affecting the learning (by walking away from the game) and fun (through high frustration levels) dimensions. The inference from this is that the interaction theme has the highest impact on dynamics and a low (because it is not direct) impact on both learning and fun.

Thus far, all the themes pertained to either the physical appearance of games or the gameplay experience. Increasing of points or seeing things exploding as a result of some action, in the eyes of the researcher, is tangible feedback. This is gameplay experience that has somewhat of an influence on the dynamics dimension. The strength of feedback and debriefing as a true theme for serious game success factors was becoming questionable. This chain of guesswork was out of sync with the work of Gee (2005:34), Cheng and Annetta (2012:204) and Kuk *et al.* (2012:8058), who point out the cause-and-effect value of appropriate and well-timed feedback. The researcher now acknowledged the worthwhile direct impact that feedback has on the learning dimension, while further data analysis exposed more of his flawed first reaction to feedback. The game does not have exclusive rights to feedback. Post-game debriefing (discussion) is recommended (Thompson *et al.*, 2010:602) and is viewed as vital to the learning dimension of serious games (Crookall, 2014:420). Though this period is out-of-game, the game itself could once again provide the central success factor—progress tracking and chat logs are certain to supply the fuel for these discussions (Hwang *et al.*, 2013:123). The researcher was cognisant of the extra costs and time involved in such reporting ability and reasoned that utilising the underlying database technology for pointing out game errors could extrude additional value. Games with errors are not liked (Virvou & Katsionis, 2008:176).

Another case for underlying database technology is AI and adaptivity (Squire, 2013:108). The researcher took personal interest in this theme to find out how serious games have taken advantage of the possibilities AI might offer— disappointingly however, only a low number of games appear to make use of AI. It was speculated that the cost-benefit analysis often probably seems unfavourable. If this is the case, then serious games producers are not aware of this theme's simultaneous (and equal) impact on: (a) the learning dimension via the possibility of adapting to

player learning styles (Hwang *et al.*, 2012:624) and ability (Bellotti *et al.*, 2012:11); (b) the fun dimension by means of realistically tailored NPC responses to previous gameplay activity (Thompson *et al.*, 2010:597); and (c) the dynamics dimension through the game's reaction to user input without disrupting flow (Kickmeier-Rust & Albert, 2010:97).

The researcher now had a trunk full of neatly classified, according to theme, deliberate success factors and three dimensions that all gelled together. A three-dimensional summary of the inter-relationships between the themes and the dimensions (Figure 1) came about as a result of theory building (Merriam & Tisdell, 2016:13). Note that this graph is only a theoretical indicator of the relative impact each of the themes has on the respective dimensions and the origin should not be interpreted as (0; 0; 0). That is, feedback and debriefing has a smaller (*not* negative) impact on the fun dimension than the backstory or realism has.

Reflecting on all the themes and their respective factors made for contemplation over the production teams that bring this all together. Knowing what is required for successful serious games meant the researcher was now capable of readily listing the ideal production team requirements: (a) sound engineers and artists; (b) programmers; (c) subject matter experts; (d) learning design specialists; (e) a game designer; and (f) storyboard writer(s). An endless internal debate ensued about which of these is the most significant team component and it was eventually decided that the single most important serious game protagonist is not even on the list—the *player*. Players need to be involved early on in the design process and their input needs to be taken seriously because the choice of playing the game ultimately lies with them. Adhering to their requests will produce a well-liked serious game that is *played by choice*. The researcher maintains that this is the true measure of serious game success.

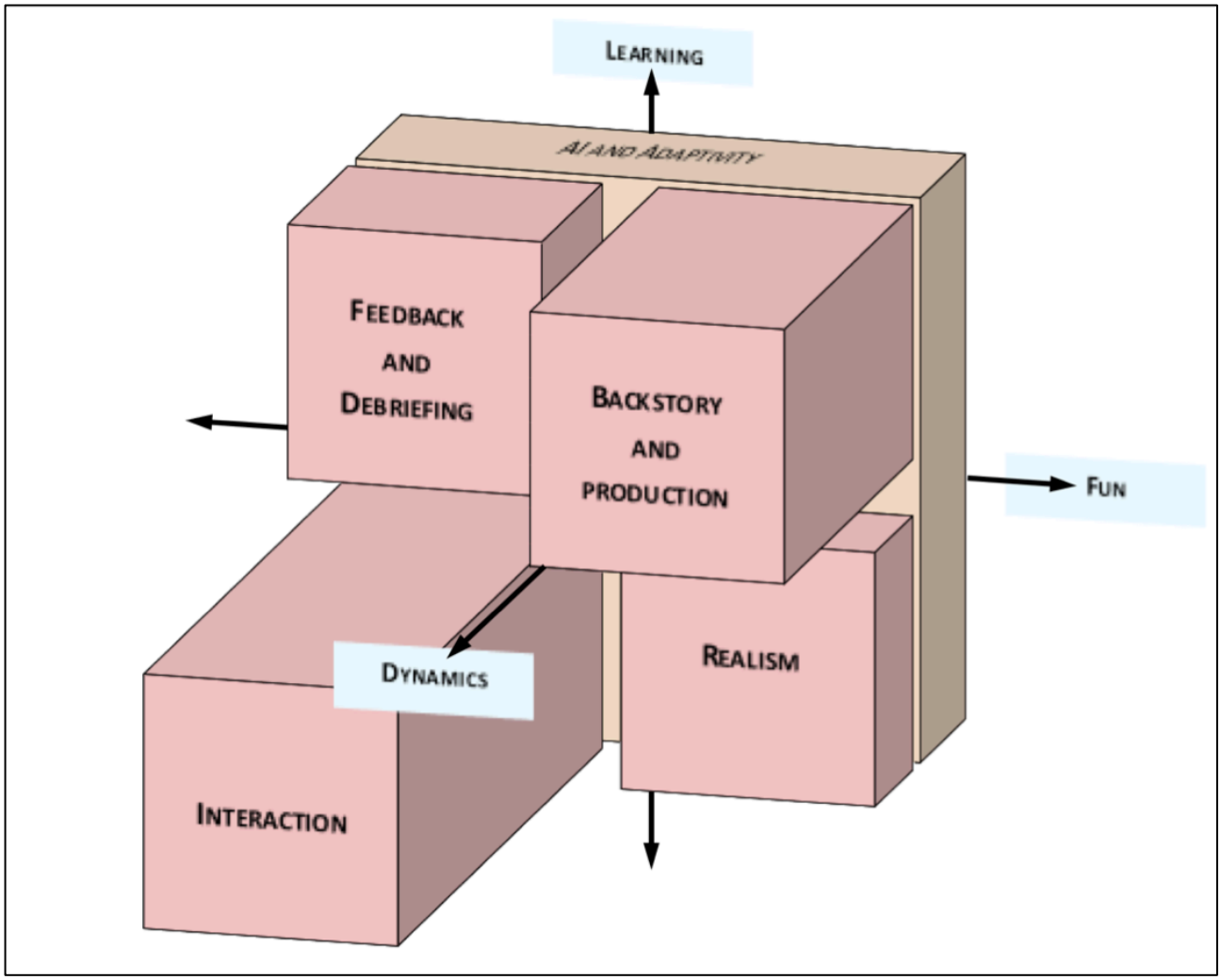

Figure 1: 3D summary of the inter-relationships between serious game themes and dimensions

The empirical contribution was only deemed complete once the researcher had shared months of arduous work with the research community at large—another learning curve with a particular set of challenges. It was advised to find a potential home for the planned article before committing the SLR to paper and the researcher promptly set about the task. The number of serious games academic journals to choose from was overwhelming and the researcher, still in systematic mode, decided that the best course of action was to: (a) determine which were the most prevalent journals for serious games research; (b) find out which of them would be willing to accept, what was known would be, a lengthy systematic review; (c) obtain and examine the chosen journal's style sheet; (d) discover what the chosen journal's preferred writing style and angle of approach is; and (e) start writing the article. This process went smoothly and these steps were shared with other starting-out researchers. Writing the article was intense and the researcher was amazed that a 55-page table (the original data from the SLR synthesis phase) could be reduced to eight pages. Regardless, the article was completed and the journal's editor was contacted to ascertain whether the journal would be

interested in the work that was done. A gratifying moment arrived about a week later stating the go-ahead to submit the article to Simulation and Gaming. More preparation and involvement of critical readers resulted in the submission of the article.

4.2 Serious Games Gauge

With the empirical broadcast submitted, the researcher was excited to translate the SLR findings into practical significance. The idea of an evaluation review tool was a good one, except that very little value was seen in making a *post facto* evaluation tool—especially given the time, money and other resources required to produce serious games. The researcher opted, instead, for a *prediction* tool that would be used during the design phase of a serious game production cycle and called it the serious games gauge (SGG). The original envisaged purpose of the SGG was to provide an overall rating for a game design in order to predict its success. After some paper-based design concepts, the usefulness of a single number remained lost on the researcher and a deeper layer of SGG feedback was conceptualised. Theme and dimension ratings were added to the SGG's forecasting arsenal. The researcher was satisfied that serious games producers would now be able to hone in on possible serious game design weaknesses. Continued paper trials, this time to solidify the mathematics behind the SGG, were undertaken and completed—development proper began. All the paper and desktop work delayed the start of the SGG's development, but the paper model proved robust and the task was completed timeously. Old-school pen-and-paper designing came to the fore.

It was long decided that the SGG prototype would be Excel™-based since Excel™ encompasses all the tools that the SGG needed: (a) a grid template for easy layout; (b) calculation capabilities; (c) a programming environment; and (d) graphing utilities. Moreover, the researcher believes that Excel™ is probably the most comprehensive and familiar software available for this type of work.

With only four games being allotted for testing, choosing these games proved to be somewhat of a lottery. For example, the researcher wanted to include America's Army™, which is acknowledged as the kick-off for mainstream recognition of serious games (Susi *et al.*, 2007:2). This inclusion was promptly abandoned. America's Army™ enjoyed an expenditure of around US$10.9 million for it's first release and a further US$22 million for subsequent releases and maintenance until 2009 (Edwards, 2009)—this is totally unrealistic for the academic and professional target audiences of this study. After much head-scratching and further searching, the researcher was satisfied with the game-spread of genres and platforms included for testing—the SGG's versatility could be determined. Four BSc Honours in IT students (with serious games projects of their own) were

approached for the testing task and readily agreed. Having had the students each test one game was sufficient for drawing conclusions about whether the SGG should be pursued or abandoned; this included checking the SGG's usefulness with the aid of a perceived usefulness questionnaire. The reason for not letting each student test all the games was that the researcher was concerned that the students would be drawn into a game comparison exercise, rather than applying the SGG in its own right to each of the games. However, the SGG appeared to shrug off tester opinions that could easily have influenced the outcome of a less steadfast tool. In other words, the SGG prototype was resolute and the researcher's initial concern was unfounded—a feather in the cap of the SGG. The students made some comments and recommendations at the end of the testing phase for the further improvement of the SGG and a consensus of "the SGG is really good and useful" was concluded. The unintended value of utilising the SGG for *what-if analysis* was also uncovered. Further development of the SGG is already underway.

5. Contributions of the study

The researcher is confident that the objectives for this study were brought to a satisfactory close and that an empirical, theoretical and practical contribution to serious games research was made:

- *Empirical*: a systematic literature review towards theory building aspects of serious game success factors was disseminated to the serious games research community;
- *Theoretical*: the empirical work shaped a three-dimensional conceptual understanding, through theory building of the inter-relationships between serious game themes and dimensions; and
- *Practical*: the theoretical comprehension was translated into a practical application that can assist serious games producers to improve their game designs.

These contributions provide serious games standards that the researcher foresees can take on the challenge of consolidating the field of serious games. With diligent consideration of the serious game themes, dimensions and factors identified by this study and employing the SGG at the pre-prototyping phase of production, successful serious games can come about without the US$11 million it took to produce America's Army™.

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