LINKING GAMIFICATION, LUDOLOGY AND PEDAGOGY: PRINCIPLES TO DESIGN A SERIOUS GAME

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ABSTRACT

Education is shifting towards a more technology focused mode of delivery, or at least combining technology use with standard methods. A potential effect of this could be the introduction and use of games in classrooms. This study looks at the possibility of adapting various domains of knowledge into digital games referred to as serious games. The implementation of serious games within teaching may help keep certain students engaged with the content being presented and create further interest in the topic. However, before reaching this stage the means to transform these knowledge domains into serious games must be studied. This is done by focusing on three fields: gamification, ludology, and pedagogy. Through the use of a literature analysis, both a literature review and a focus on previous implementations, several key principles for the design of a serious game were identified, namely reflection, feedback, a story-based environment, and thorough structuring of content. These principles stem from the design choices of the previous implementations and pedagogical theories - Merrill's First Principles and the ARCS model. The aim of the study is to investigate the possibility of using digital games as a means to encourage learning in teaching environments.

KEYWORDS

Education, Gamification, Ludology, Pedagogy, Serious Games

1. INTRODUCTION

In the years leading up to the new century there was a shift into the "information age". This age is characterised by the fact that information is being transmitted and generated at an ever-increasing rate due to further technological developments (Gibson *et al.*, 2006; Reigeluth, 1996). The most notable changes from the previous "industrial age" are that the previous focused on conformity and compliance while initiative and diversity – where greater value is placed on each individual's strengths and contribution to a project or organisation – is the focus of the information age (Reigeluth, 1996).

Due to these aforementioned paradigm shifts between the ages, and in what requirements are desired by most organisations in the information age, a shift in instructional theory is also taking place. With the recent developments in technology and the fact that technology in general is becoming more accessible, many institutions have adopted some forms of digital learning or supplemented traditional teaching with digital assistance such as having virtual sessions of a class and having courses entirely online (Tîrziu & Vrabie, 2015).

Deshpande and Huang (2011) state that the current generation of students is the first to grow up with abundant access to technology. On average, these students spend almost double the time playing video games that they do reading (Deshpande & Huang, 2011). Virvou, Katsionis and Manos (2005) echo the point that computer games are popular among individuals who are in schools and as such could provide a means to deliver content in an interesting and engaging manner. The movement for the inclusion of digital games to be used in teaching and training environments first started in 2003, two years after the field of *ludology*, the study of games, began to gain traction in academic literature (Annetta, 2008). This initiative is what started the concept of a serious game as one that can be used in an academic sense to relay information. Furthermore, gamification has recently garnered focus from a technology specific view and due to the use of game elements, it can have an impact on how a serious game is designed albeit the result of a digital gamified environment differs to a serious game (Kalogiannakis *et al.*, 2021).

As such, the motivation behind this study is to further investigate the possibility of using digital serious games as a means to encourage learning in teaching environments due to the aforementioned interest and uptake of digital technologies in education as well as the potential improvements they can bring (Zourmpakis *et al.*, 2022). This study aims to present a set of design principles for serious games through answering the question *what qualities are required for a serious game to be effectively used in an educational environment on several topics*. This will be accomplished through a literature analysis focusing on the fields of ludology, gamification, and pedagogy with a focus on Merrill's First Principles and the ARCS Model resulting in the synthesis of design principles.

2. RESEARCH METHODOLOGY

This research study primarily made use of a literature analysis to answer the aforementioned primary question. This was done is two major phases. The first is that of a literature review on the fields of ludology, gamification, and pedagogy while the second focused on previous implementations of serious games. Firstly, the three key fields were studied, and notable definitions and theories were selected. These were used to provide an informed background on what design principles to look for. Following this, the design principles of the previous implementations were noted down and then compared with each other and the major ones identified and then, with the information from the literature review, expanded upon.

3. LITERATURE REVIEW

3.1 Serious Games and Ludology

Ludology is the formal and academic study of games and has roots in studying games through a cultural and social lens by discussing how each interacts with the so-called "spirit of play" (Huizinga & Hull, 1949). The field also encompasses the study of digital computer-based games and has a focus on discussing and understanding the individual elements of games as well as creating models to explain the various mechanics and rules of games (Frasca, 2013). As such, this study will use the definition that, *"Ludology can be defined as a discipline that studies games in general, and video games in particular"* (Frasca, 2013, p. 222). Serious games were introduced as a concept in 2002 with the intention of them to be used as a means of training certain tasks and skills which was typically done through simulation type games (De Gloria *et al.*, 2014).

Simulations attempt to model reality in a consistent manner usually through modelling physical or social systems through another system which in this case would be a computer and the digital video game (Squire, 2003). There are two main types of simulations – high fidelity and low fidelity. High fidelity simulations attempt to model every interaction in a given system, phenomena, or environment as accurately as possible (Squire, 2003). In contrast, a low fidelity simulation will make use of a fair bit of abstraction as it aims to only demonstrate a few key characteristics of the phenomena or environment (Squire, 2003). Games as simulations would comprise of both of these types depending on the content that it attempts to simulate.

The endeavour to create serious games has yet to reach schools due to certain criticisms about games in general that hinders this (Virvou *et al.*, 2005). While this was previously due to the fact that discussions around games by educators focused on the social consequences of playing games (Squire, 2003) it may now be due to the resources required for a serious game to be developed (Helms *et al.*,2015). Thus, the study of serious games became more theoretical and discussion-based at lower levels and more applied with actual use at higher levels. This can be seen by implementations in several fields including medical rehabilitation, ecological studies, learning languages, and business studies (Burke *et al.*, 2009; Costanza *et al.*, 2014; Ranalli, 2008; Tao *et al.*, 2009). These types of games have already had an impact on the military, medical, and higher education sectors early in their conception and this trend continues to this day with serious games being used within the medical fields specifically (Annetta, 2008; De Gloria *et al.*, 2014).

3.2 A Pedagogical Understanding

Pedagogy is the field that deals with the transferral of knowledge in an educational environment through several lenses such as social, political, and cultural (Li, 2012). As such it encompasses the themes and discussions of instructional design and theory as well as any learning theories.

Learning by doing functions on the principle that skills can be improved through practice and self-perfection on a particular topic or knowledge base (Fisch *et al.*, 2009). This means of instruction has become increasingly popular amongst companies where they are able to make use of "on the job" training as it allows for a person to be productive immediately as well as become more proficient at tasks gradually (Fisch *et al.*, 2009). The learning by teaching method works under the assumption that learners are able to increase their understanding of a certain topic by teaching it to other learners (Fisch *et al.*, 2009). This method of learning garners more usage in environments with too few teachers and increases the overall learning process (Fisch *et al.*, 2009). Learning methods that place the learner in control are very flexible and as such can be incorporated when attempting to teach various and different fields or subjects (Ackoff, 1991).

Gibson *et al.* (2006) list several learning and instructional design theories that have the potential to be applied to a game used for learning. This study will, however, only look at Merrill's *First Principles of Instruction* as it is the most recent (Gibson *et al.*, 2006). Before discussing the principles that the name refers to in this theory, Merrill (2002) provides a few definitions for the terms that are used. A *Principle* in this context is a relationship that is always true regardless of the environment it is applied within. A *Practice* is any instructional activity. A *Program* is a means of instruction that makes use of several practices (Merrill, 2002). These first principles described are able to be implemented in any instructional system or environment as they are "design-oriented" and as such relate more to creating learning environments rather than describing the means of knowledge transfer. Each of the following principles is also accompanied by three "corollaries" each of which Merrill (2002) likewise explains:

The first principle is that the learning is problem centred. This principle describes three corollaries, the first of which being "Show Task" which states that learners should be shown the types of problems they will be able to solve with the knowledge that they attain. The next is the "Task Level" which explains that the problems presented should keep learners engaged due to the complexity and not just the action of solving it. The last corollary, "Problem Progression" describes that the problems presented should have some form of increasing complexity while still being comparable to the previous iteration of the type of problem (Merrill, 2002).

The second principle is "Activation" which means that learning happens whenever previous experiences are used. The first corollary, "Previous Experience", states that the learning process is enhanced when a learner is able to draw upon relevant past experiences and apply the associate knowledge as a foundation for new knowledge. "New Knowledge" is the second and explains that learners should be provided with a relevant experience as an additional foundation to add to their knowledge base. The last corollary is "Structure" and details that learners should be encouraged to organise new knowledge according to some relevant structure (Merrill, 2002).

The third principle, Demonstration, proposes that learning takes place when the activities that are undertaken impart the knowledge instead of stating the information. "Demonstration Consistency" explains that any examples or visualisation should be kept in line with the original learning goals. The next is "Learner Guidance" and states that learners should be shown where the relevant information for problems can be found be it in the form of comparative examples or various representations of one source. "Relevant Media" explains that when media is used as a means of demonstration, distinct types can be used provided that they do not fight for a learner's attention (Merrill, 2002).

The fourth principle is Application which states that learning takes place when learners actively solve problems with the new knowledge they have acquired. "Practice Consistency" is similar to Demonstration consistency but with a focus on the application of knowledge. "Diminishing Coaching" is where the learners are provided with relevant feedback, but it is slowly lessened over time. It is also important that the problems provided to learners for practice have a good variety, defined under "Varied Problems" (Merrill, 2002).

The fifth, and final, *principle* is Integration which is when the knowledge a learner has acquired is used by them in their everyday life. The first corollary, "Watch Me", explains that learners are provided to showcase the new knowledge or skill they have acquired. "Reflection" deals with giving learners time to be able to

debate with others on the topic involved. Lastly, "Creation" states that learners should be able to make use of their new knowledge or skill in some personal capacity (Merrill, 2002).

The principles and corollaries provided by Merrill (2002) provide an expansive and detailed structure to be used when developing any learning opportunity making it an exceptional choice to adapt specifically for a digital game learning environment. It does, however, lack a comprehensive discussion on how to keep learners engaged with the content and, as such, this will be discussed with some theories pertaining to the role of motivation in learning.

One model for motivating learners is the **ARCS** Model which was developed by John Keller (1987) which is frequently referenced in the aforementioned field of instructional design (Kapp, 2012a). It comprises four main elements with each focusing on designing instruction in a different way (Kapp, 2012a; Keller, 1987).

The first of these is Attention and it is an element that is concerned with gaining and then keeping the learners' interest. There are three main methods to accomplish this: gaining **A**ttention through the use of examples, create curiosity within the learners through means such as role-playing or hands-on examples, and variability which means periodically changing the method of delivery (Kapp, 2012a; Keller, 1987).

Relevance refers to having the content be relevant to the learner (Keller, 1987). Kapp (2012a) mentions that this can be done through orienting the environment around achieving goals, creating a link between the motives of learners and that of the instruction means, displaying that the content is familiar to the learners and finally developing a model of the results of learning the presented knowledge (Keller, 1987).

Another element of this model, **C**onfidence, is the expectations of success set by the learner and as such when they meet these expectations, they are confident in their ability to do the work (Kapp, 2012a; Keller, 1987). This can be aided by providing learners with clear expectations and requirements upfront about the required skill or knowledge. It is also helpful to provide smaller opportunities to succeed as with each success the learners will become more confident (Kapp, 2012a; Keller, 1987).

The last element in the ARCS model is **S**atisfaction and is concerned with giving learners a sense of accomplishment and that the effort in the learning process has some value and weight to it (Kapp, 2012a; Keller, 1987). This can be accomplished by allowing learners to see how their new-found knowledge can be used, either through the use of a real-world demonstration or via some form of simulation (Kapp, 2012a; Keller, 1987).

3.3 Gamification and the Knowledge Domains

Gamification can be defined as making use of game-like mechanics, aesthetics, and thinking to create motivation, solve problems and produce a more suitable learning environment (Kapp, 2012a). Kapp (2012b) states that while gamification makes use of game elements, it only makes use of a few of them as in a gamified system. In a gamification context, learners are not constantly engaged in playing the game as there are sections of respite from this, such as video explanations. While elements such as points and achievements are found in most games, gamification strives to add more than just these to a classroom. The absence of other elements contributes to a resulting system that is dull (Kapp, 2012b).

Gamification is often not implemented within a classroom but is rather presented to learners through some external means (Kapp, 2012b). It should be noted, while a digital gamified environment is the result of gamification and differ from serious games (Kapp, 2012a), the use of game elements within one such environment results in this field being one of interest when discussing serious games as the understanding of these systems from a gamification standpoint may prove beneficial to the design of a serious game such as with the ability gamification provides to create problems relative to a students' skill level (Zourmpakis *et al.*, 2022). The main difference between these two systems is that learning is more direct in a serious game as the content causes learning while in gamification learning is done indirectly (Kalogiannakis *et al.*, 2021).

Kapp (2012a) describes various types of knowledge and how to begin developing a gamified system to effectively teach each of them. This provides the groundwork for answering the question this study poses and as such allows for a more in-depth discussion on how to implement serious games. Table 1 describes the knowledge domains.

One important aspect to note about these knowledge domains is that they are not mutually exclusive as one particular topic can be placed in several of them as the components of that topic may require multiple domains to be properly contained under them. Kapp (2012a) also provides some ways that each domain can be taught to best relay that particular type of knowledge. While these recommendations are derived under a gamification perspective (Kapp, 2012a), they can also be applied for a digital game as shown in Table 1.

Table 1. Knowledge Domain Recommendations (Kapp, 2012a)

Knowledge Domain	Description	Recommendation
Declarative Knowledge	Facts and jargon within a topic	Sorting games
Conceptual Knowledge	Grouping of related information with an underlying common descriptor	Demonstrations and sorting type games
Rules-Based Knowledge	Strict statements linking concepts	Demonstration of failure when not complying with the rules
Procedural Knowledge	Progression-based path to reach an outcome	Working through the procedure
Soft Skills	General strategies for dealing with various social interactions	Repeated application of a skill within various scenarios
Affective Knowledge	Subjective phenomena	Immersing the learner within a phenomenon
Psychomotor Domain	Making use of cognitive knowledge through physical skills	Observation

4. ANALYSIS OF PREVIOUS IMPLEMENTATIONS

In addition to looking at the aforementioned academic fields, it is also vital to look at how previous serious games were designed, and which principles are most commonly used. Several studies (Allers *et al.*, 2021; Dincelli & Chengalur-Smith, 2020; Sheng *et al*., 2007) were examined in which some form of a gamified system or serious game was developed in addition to the author(s) detailing what design principles were followed during the development process.

The first of these is titled, "*Choose your own training adventure: designing a gamified SETA artefact for improving information security and privacy through interactive storytelling*" and focused on developing a gamified system to teach employees about security issues with a focus on social media and social engineering (Dincelli & Chengalur-Smith, 2020). For the development of the artefact, Dincelli and Chengalur-Smith (2020) made use of literature from instructional theory and gamification and, as a result, made use of a few key design principles. The first design principle followed is that the gamified system should make use of a story-based agent (Dincelli & Chengalur-Smith, 2020). This means that a game should include some figure or character to guide users through the content as well as making use of storytelling in some capacity which is found to create curiosity within users (Dincelli & Chengalur-Smith, 2020; Kapp, 2012a). The second design principle used was that of reflection which states that users should be given a moment of respite to comprehend on what has been presented to them (Dincelli & Chengalur-Smith, 2020; Sheng *et al.*, 2007). Feedback on various metrics of a user's performance is also a design principle which allows for users to perform self-evaluation (Dincelli & Chengalur-Smith, 2020).

The findings of this case study were that making use of a gamified system that used either visual stimuli or text were better at relaying information than traditional means. Visual stimuli were better than text in terms of recognition, recollection and ease of learning and they performed similarly in terms of recall, satisfaction, and usability (Dincelli & Chengalur-Smith, 2020).

The next case study is titled "*Anti-phishing Phil: the design and evaluation of a game that teaches people not to fall for phish*" and focused on teaching people about phishing and how to avoid becoming a victim to these attacks (Sheng *et al.*, 2007). Sheng *et al.* (2007) made use of learning science theories in the development of the game and to refine the various iterations throughout the development process. The first two design principles discussed are reflection and story-based agent environment. These have already been mentioned in the previous case study. Additionally, feedback is also discussed in this study but specifically how it was implemented. Anti-phishing Phil makes use of feedback both during, though displaying a short message for each choice made, and after a round of the game, through a score sheet and brief explanation of the links used. The next design principle followed is the procedural-conceptual principle. This principle states that these two knowledge domains, conceptual and procedural, hold a mutually supportive influence over the other. In practice, and thus the development of a serious game, this means that learners should be given context to the processes they are being taught as without the context they may incorrectly apply them (Sheng *et al.*, 2007).

The findings of Anti-phishing Phil showed that the serious game approach made users more knowledgeable on the topic and how to go about dealing with phishing. While the game was a success it falls behind in the aspect that some users may become more susceptible to phishing as the game provided a fixed number of indicators to be aware of (Sheng *et al.*, 2007).

The final case study used is titled "*Children's Awareness of Digital Wellness: A Serious Games Approach"* and was targeted towards teaching children, particularly pre-schoolers, about digital wellbeing and fostering cyber security awareness through a mobile-based serious game, which will be referred to as *Digital Wellnests* (Allers *et al.*, 2021). This case study focused on the design and research needed for such a serious game and stated that future work could include the development and deployment of the game (Allers *et al.*, 2021).

While this case study (Allers *et al.*, 2021) made use of instructional theory targeted towards preschool children (Callaghan & Reich, 2018; Matthews *et al.*, 2007) some of the frameworks and learning theory used can also be applied to all serious games. The first design principle followed was simplicity as it allows a user to follow the content adequately and as such learn effectively (Allers *et al.*, 2021). The study goes on to cite Matthews *et al.* (2007) on the ways children tend to learn which includes Observation, Listening Exploring, Experimentation and Asking questions. Learning through play, such as a serious game, is an effective way to implement all of these methods (Allers *et al.*, 2021) and as such provides an additional framework targeted specifically at younger children as opposed to the previous studies (Dincelli & Chengalur-Smith, 2020; Sheng *et al.*, 2007) which were focused on adults. While this does not provide direct principles to follow during the design process, including ways for these methods of learning to be present in a serious game should be taken into consideration. In addition to the above, the study also made use of several elements identified by Callaghan and Reich (2018) which are based on how young children learn. The first of these is clear and simple goals which is concerned with presenting a user with concise outcomes to work towards (Callaghan & Reich, 2018). Similarly with Anti-phishing Phil (Sheng *et al.*, 2007), is the element of quality of feedback and rewards which deals with how feedback is presented to a user - for example, pre-schoolers may not yet be able to read and as such, the feedback must be structured accordingly (Allers *et al.*, 2021). The next element is structure of the challenge consisting of setting the difficulty of tasks and changing the difficulty depending on how the user is performing (Callaghan & Reich, 2018). This element can also be described using some of the corollaries from Merrill's First Principles (Merrill, 2002) - which will be discussed in the following section. The last element Callaghan and Reich (2018) is that of Motion based learning which describes the physical interaction a user will have with applications which in this case would be designing larger touch controls to account for a preschool child's current level of motor functions. This particular aspect is certainly vital when dealing with any knowledge from the psychomotor domain.

As previously mentioned, this case study has not yet developed the serious game and as such cannot be evaluated by users. However, an expert review was conducted on the design of this serious game of which the outcomes were positive as the reviewers "found the implementation of each element was satisfactory, but there is still room for improvement" (Allers *et al.*, 2021).

The following table visualizes the major design principles of each case study.

Table 2. Design Principles Defined by Case Study (Allers *et al.*, 2021; Dincelli & Chengalur-Smith, 2020; Sheng *et al.*, 2007)

SETA Artifact	Anti-Phishing Phil	Digital Wellnests
Story-based	Story-based	Simplicity
Reflection	Reflection	Clear and simple goals
Feedback	Feedback	Quality of feedback
	Conceptual-Procedural	Structure of the challenge
		Motion-based interaction

5. SYNTHESIS FROM RESEARCH

From the literature and case studies examined, there are several key qualities that are common either under the same descriptor or with similar descriptions with different names. It is these qualities that will form the basis to answer the research question of this study.

The first quality, reflection, is shared amongst Merrill's First Principles (Merrill, 2002) and two of the case studies (Dincelli & Chengalur-Smith, 2020; Sheng *et al.*, 2007) and is vital to a serious game if intended to be used in an educational environment. Reflection is described as giving a user time after being presented with new knowledge or a task to garner a better understanding through internalisation.

The second quality a serious game should make use of is that of feedback. All of the case studies (Allers *et al.*, 2021; Dincelli & Chengalur-Smith, 2020; Sheng *et al.*, 2007) and Merrill (2002) refers to it under the diminishing coaching corollary. A user should be presented with feedback on how they are progressing on a given set of tasks within the game. As they progress, the amount of feedback should be slowly diminished. The feedback amount should also be tied to the performance of the user - increasing if they begin to struggle and decreasing if not. Since feedback can take on many different forms, the type of feedback, as well as the method of delivery, is dependent on the topic being taught. As part of this quality, a serious game should also be designed to create an environment in which users are able to complete smaller tasks and are rewarded for these smaller successes as per the ARCS model (Keller, 1987).

Another quality that should be implemented is that the serious game should showcase and teach topics through the use of storytelling. The case studies (Allers *et al.*, 2021; Dincelli & Chengalur-Smith, 2020; Sheng *et al.*, 2007) all mention the use thereof. The ARCS model (Keller, 1987), specifically under the attention element, also states that this is a proponent of keeping users engaged. A game should then allow for a story to take place during the teaching of a topic which can also be done in several ways - such as contextually with *Anti-phishing Phil* (Sheng *et al.*, 2007) or as the main focus of the topic as with the SETA artefact (Dincelli & Chengalur-Smith, 2020) and *Digital Wellnests* (Allers *et al.*, 2021). Another means to accomplish this is to make use of an agent that guides the user through the game which can be used in accordance with the "Learner Guidance" corollary from Merrill's First Principles (Merrill, 2002).

The last major quality a serious game should possess is that of structuring. This quality refers to the content the game will deal with in terms of the instructions given as well as how the difficulty of problems could progress. It is derived from both Merrill's First Principles (Merrill, 2002), the ARCS model (Keller, 1987), and the framework by Callaghan and Reich (2018). From the ARCS model (Keller, 1987), specifically Confidence, and Callaghan and Reich's (2018) framework it is clear that a serious game should be structured with simple goals and clear expectations for the user and by structuring a game's instructions in this manner the user will be motivated to continue playing and therefore learning. The problems and tasks within the game should be increasing in difficulty as a user gets them correct and lowering the difficulty when they are struggling to keep engagement once again with the game at a high level. Merrill's First Principles (Merrill, 2002) discusses this quality in several principles and their subsequent corollaries with some referring to the difficulty scaling mentioned above. As such, a serious game's structure should be centred around the problems themselves or the knowledge being taught when dealing with affective knowledge and soft skills. The tasks given to a user should be both varied to keep the users' attention as well as be consistent in the ways the user interacts with them. This approach should keep users motivated to use the game according to the ARCS model (Keller, 1987) as it makes use of both the Attention and Relevance elements.

While the remaining aspects of the pedagogical theories and design principles from the case studies are also useful in the implementation of a serious game, they are specific to the content being taught and as such should be considered in greater detail if a similar game to those were to be developed. Kapp's (2012a) recommendations are a helpful starting point on how to effectively teach content relating to the knowledge domains. Referring back to Squire's (2003) descriptions of games as simulations - both high fidelity and low fidelity - these types of serious games are certainly the most useful for teaching content found in the affective, soft skills, and psychomotor domains since the best means to teach these is through immersing the user in the phenomena, repeated application of skills and observation respectively (Kapp, 2012a). Simulation-type serious games can also be used in the other domains (teaching physics as described by Deshpande and Huang (2011)). These types of games are also the most effective means for the psychomotor domain as shown by various studies (Burke *et al.*, 2009; Costanza *et al.*, 2014; Ranalli, 2008; Tao *et al.*, 2009).

The remaining knowledge domains tend to have some heavy overlap depending on the topic being covered. Sheng *et al.* (2007) discussed the Conceptual-Procedural principle in their game's development. To reiterate, it simply states that a topic cannot be fully understood from only the procedures or context - both are needed for a deeper understanding. As such, if the recommendations for one domain do not translate well into a digital game, the recommendations for another may.

Earlier works attempting to accomplish something similar have also identified some of the above principles. Helms *et al.* (2015) provide a "Educational Game Element Database" which includes mentions of a storyline, challenge, and feedback where challenge can refer to the structuring principle mentioned above. Additionally, Quinn (2005) discusses many approaches to designing e-learning game simulations and mention the importance of a storyline, adjusting the challenge, feedback, and reflection all of which are above.

6. LIMITATIONS AND FUTURE WORK

This study made use of various fields of academia as well as studies of serious games and their design in order to answer the research question. The current limitations on answering this question centre around the amount of literature sourced. The fields (pedagogy, ludology, and gamification) discussed seem to be sufficient in terms of what literature can be used and as such it is the specific literature used that imposes limitations. There are many more instructional theories that could be considered and as such future research could delve into more theories and expand the supporting knowledge base. Another limitation comes from the case studies used. All of the main case studies discussed in this article had a focus on computer security to varying degrees. Due to this, future research could include case studies on the design, implementation, or development of serious games in other fields as the findings may not generalise to certain topics or domains. These design principles provide the possible foundation for a further framework that could be devised and used for serious game design in general as opposed to specifically for one type of game. The principles presented account for major sections of serious game design but lack specifics on the more intricate aspects.

In terms of future research, a more practical approach could include the development of a serious game on a topic based on one of the knowledge domains mentioned. This could include the development of an artefact for user testing, similarly to *Anti-phishing Phil* (Sheng *et al.*, 2007), based on the findings of this study or the designing of such an artefact more in line with the *Digital Wellnests* game (Allers *et al.*, 2021). Future research could also include looking at several types of games and how they could teach content in the different knowledge domains to build upon Kapp's (2012a) recommendations.

7. CONCLUSION

This study discussed the shift educational institutions are making towards including more technology in the teaching process. As such, research into how serious games can be used in an educational environment was conducted with a specific focus on the fields of pedagogy, ludology, and gamification in order to answer the question, what qualities are required for a serious game to be effectively used in an educational environment on assorted topics. Furthermore, several research papers were used as case studies to discover what design principles are typically followed in the development of serious games. This information was then used to identify what are the major qualities which a serious game should have in order to be effective in an educational environment as well as provide specific recommendations for various knowledge domains. The qualities identified were allowing for reflection, providing feedback, making use of story elements and a well thought out structuring of the game.

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