Healthy Competition

Multiplayer Digital Games in Health Education

Anna Beatrice Janssen

A thesis submitted in fulfilment of the requirements
for the degree of Doctor of Philosophy.

Sydney Medical School
The University of Sydney
2018

Abstract

The focus of this dissertation is on the role of multiplayer digital games in adult education, with a particular emphasis on health education. Although interest in the use of digital games for serious applications has been increasing since the early 2000s, there is a significant gap in understanding on the use of multiplayer digital games in adult education. In the context of health education, there has been a large amount of research conducted in to the use of repurposed commercial games for predicting performance of trainees and health students on surgical simulators. However, beyond this niche research into game based learning is notably less cohesive. There has been some research into the use of digital games in areas such as for delivering insulin management training, but understanding of the processes for widespread application of games based learning in the health sector is limited. Additionally, almost no research has been undertaken into the use of multiplayer digital games in health education, whether it be for tertiary or adult learners.

In this dissertation two digital games were developed, implemented and evaluated to explore the value of multiplayer games for supporting cooperation and collaboration in health education. The first game, They Know: Anatomy, was a real time team based strategy game designed to

support anatomy revision by second year medical students. The second game, the Qstream: Cancer Cup Challenge, was a team based asynchronous online program designed to reinforce understanding of how to identify and manage adverse events by oncology registrars. A design research framework informed the methodology used in this dissertation. This framework emphasises the need to use multiple iteration cycles to develop a comprehensive understanding of player experiences with the digital games they encountered. Data on participant experiences with the digital games was collected using qualitative methods, including post-game surveys and semi-structured interviews. Between iterative cycles data on participant experiences with the digital games were analysed so that future implementations of the game could be modified to maximise cooperation and collaboration between players. At the conclusion of the study period data collected across all implementations of the digital games were analysed to increase understanding of how multiplayer digital games supported cooperation and collaboration between learners.

Findings from this dissertation demonstrate that multiplayer digital games can be used to engage medical students in anatomy revision and medical oncologists in adverse events retraining. This is the first study to look at the use of digital games for either of these demographics. Additionally, this dissertation identified four ways through which multiplayer digital games foster collaboration between players: through the development of a team strategy to win the game, by facilitating shared decision making, by working towards a shared goal, and by creating a sense of investment in a team. Finally, findings from this dissertation contribute to the literature on the implementation of game based learning in adult education. This is an under researched area, but one that warrants further focus in future if game based learning is going to be successfully incorporated into curricula and training activities for adult learners.

This dissertation adds to the literature by presenting new knowledge on how and why multiplayer games support collaboration between learners. Additionally, it appears that multiplayer digital games offer diverse, flexible and immersive experiences to adult learners in a way that single player digital games may not. Finally, multiplayer digital games provide new avenues for support self-directed learning by encouraging cooperation between large groups of students in a manner that is not normally achieved in online learning environments.

Table of Contents

Index of Figures and Tables

Acknowledgments

Capstone Editing provided copyediting and proofreading services, according to the guidelines laid out in the university-endorsed national ‘Guidelines for Editing Research Theses’.

I would like to thank the early career doctors and medical students who participated in my dissertation study. Each participant gave up their time in support of my dissertation, and I will be forever grateful.

I would also like to profoundly thank my primary supervisor, Tim Shaw, and my two associate supervisors, Peter Goodyear and B. Price Kerfoot, for their tireless efforts to guide me throughout my dissertation. Your feedback and advice guided me throughout this process and has helped me grow as a researcher. I would also like to thank my colleague Tracy Robinson, for the many conversations we had about my dissertation study when I was putting together ethics for my dissertation study, as well as my colleagues Charlotte Pointeaux and Sarah York for their assistance coordinating the game sessions I conducted during my dissertation.

Thank you to my parents, Maryann and Ray, for their ongoing support of my dissertation over the years. A special thank you to my friends who gave up their time to play testing early versions of the strategy game I used in this dissertation, so that I could work out time limits for later sessions with medical students.

Finally, a special thank you to my partner, Leon, for standing by me, encouraging and supporting me during my entire dissertation. Thank you for all the time you volunteered to share your game design knowledge and experience with me. Thank you for always being by my side for the late nights, the discoveries, the ups and down of peer review feedback and being so patient in the final stages of submission for this dissertation. Your love and support made this possible.

Publications arising from this dissertation

Journal Articles

Janssen, A., Shaw, T., Bradbury, L., et al. (2016) A mixed methods approach to developing and evaluating oncology trainee education around minimization of adverse events and improved patient quality and safety. BMC Medical Education

Janssen, A., Shaw, T., Goodyear, P., et al. (2015) A Little Healthy Competition: Using mixed methods to pilot a team-based digital game for boosting medical student engagement with anatomy and histology content. BMC Medical Education

Janssen, A., Shaw, T., & Goodyear, P. (2015). Using video games to enhance motivation states in online education: protocol for a team-based digital game. *JMIR research protocols.*

Janssen A, Robinson T, Shaw TJ. (2014) The Evolution of a Professional Practice Forum: Balancing Peer-to-Peer Learning With Course Objectives. JMIR Research Protocols

Conference Presentations and Papers

Short Article: Using multiplayer digital games to support collaboration in Health Education. IRLn 2017.

Conference Paper: The Cancer Cup Challenge: An international program in safety and quality. CINSW Innovations Conference 2015.

Poster: Harnessing digital games to engage and impact on learners. HERDSA 2016

Poster: The Cancer Cup Challenge: Running an international program in safety and quality in oncology. CPMCC Symposium 2015

Poster: How can collaborative online educational environments be developed for busy health professionals. AMEE 2013

Prologue

Over the last decade I have worked in the area of health education. During this time I been inspired by how dedicated health students and health professionals are to continuing training and education, in response to a constant wave of new evidence and technologies that need to be implemented in to their workflow. I have also had an ongoing interest in the history of digital games and their increasing prominence in society. Over the course of my lifetime digital games have become a global phenomena, rivalling television and cinema as a widespread form of digital recreation. They have transitioned from something that could only be played in an arcade, to something most people can play on a device that fits in their pockets. Through my work I have witnessed a parallel trend to the one in mainstream society, towards the use of digital games in the education sector. The rise in prominence of digital games-based learning in education has made me increasingly curious about how they can be implemented effectively in health education. It is that question that I set out to answer when I started this dissertation in 2012. To answer this question I undertook a combination of practical research with medical students and early career doctors, and an exploration of the literature on digital games. It is my hope that my dissertation takes the reader on a journey similar to the one I went through to understand how digital games are used in the health sector, and how we can improve their implementation in health education. This includes introducing the reader to some of the key touch points about commercial digital games, into the literature on their use in education and onwards towards a narrative exploration on how digital games have been used in health education. The chapters in this dissertation have been structured to support the reader on this journey.

In the opening chapter of this dissertation, Chapter 1, I present the reader with a broad overview of the role of digital games in modern society, along with some descriptions of what characterises digital games and different types of commercial digital games. This chapter aims to provide the reader with a broad overview of commercial digital games, to act as a foundation on which I can build my further exploration on the usage of digital games in health education, the implementation of my study anda discussion of findings over the course of this dissertation. This opening chapter flows in to Chapter 2, which presents a scoping review of the literature on the use of digital games in education. The scoping review of the use of digital games in education provides the reader with a broader understanding of the educational audiences digital games have been used to deliver learning material to. Additionally, this scoping review provides some illustrative descriptions of studies undertaken with these audiences, to give the reader an understanding of some of the ways digital games have been researched for a range of audiences. Finally, the scoping review of the literature introduces a number of higher level categories that can be used to identify different types of digital games used in the research into serious games. These categories are then mapped against the literature on digital games in health education, in order to more thoroughly understand the gaps present in the area. This is followed by a narrative review of the literature on the use of digital games for facilitating training of health professionals and students, presented in Chapter 3.

In addition to a review of the literature, I have undertaken practical research on the implementation of digital game-based learning for health professionals and students. Much of the research currently undertaken on digital games in health has been focused on the outcomes of using digital games to deliver subject matter rather then the processes through which they do. I feel that the lack of understanding of how digital games deliver immersive and motivating learning experiences to adult learners is a limiting factor in understanding how digital games can be implemented usefully in health education. To address this gap I have undertaken a learner-focused study exploring interventions relating to two digital games - They Know: Anatomy and the Qstream: Cancer Cup Challenge, detailed in Chapters 5, 6 and 7. Over the course of the two interventions I tested the games, observed participation with the game, and got feedback from learners about their experiences with the digital games and iterated on features in the design of the two digital games to understand how the design of the games could facilitate different learning experiences. In the first intervention I worked closely with medical students in a computer laboratory setting to observe multiple cycles of They Know: Anatomy implementation. The results of this intervention are presented in Chapter 6 of this dissertation. The later intervention is smaller in scale then the former, as I was provided a unique opportunity to undertake an intervention using digital games with health professionals, rather then students as a result of my work in health education. This was a wonderful opportunity to obtain data on the attitudes of health professionals towards the use of digital games in learning, and explore how the use of digital game-based learning motivated this group of learners. However, as the research was not undertaken in a laboratory setting (as the They Know: Anatomy intervention was), I had less scope to run multiple iterations of the intervention and so the amount of data on this intervention, presented in Chapter 7, is noticeably smaller than the data on They Know: Anatomy.

Digital game-based learning is increasingly popular in health education, but there is so much about its design and implementation that remains unanswered. I have combined findings derived from practical research implementing digital games for health professionals and students, and exploration of the literature to make a contribute to this gap in knowledge on the use of digital games in health education.

An introduction to digital games and their place in adult education

Chapter 1

In this first chapter of this dissertation the reader will be presented with an overview of the thesis, including a chapter by chapter summary. Furthermore, this chapter will provide the reader with an overview of the landscape of commercial digital games, by introducing some of the definitions of digital games, game mechanics and game genres. Finally, this chapter will introduce some of the key concepts relating to adult learning and the role of online learning within it. This will include exploring the potential application of digital games to support immersion and cooperation in online learning and exploring the theory that underpins cooperative learning.

1.1 Setting the scene

The use of digital games and gamification to augment education has been growing in popularity over a number of years. Recently, this interest has included the use of digital games and gamification (digital game-based learning) in the delivery of adult education, particularly in the health sector. Although using digital game-based learning in adult education has become increasingly popular, popularity does not translate to high-quality digital game-based learning experiences. Designing and implementing digital game-based learning encounters that can facilitate high-quality learning experiences requires a better understanding of what constitutes a good digital gameplay experience for an adult audience than is currently available in the literature. Increasing understanding in this area is a first step towards improving the implementation of digital game-based learning in online learning and developing a deeper understanding of the role and benefits of multiplayer digital games and gamification platforms for use in adult education.

1.2 Chapter Overview

1.2.1 Chapter 1

In this first chapter of this dissertation the reader will be presented with an overview of the thesis, including a chapter by chapter summary. Furthermore, this chapter will provide the reader with an overview of the landscape of commercial digital games, by introducing some of the definitions of digital games, game mechanics and game genres. Finally, this chapter will introduce some of the key concepts relating to adult learning and the role of online learning within it. This will include exploring the potential application of digital games to support immersion and cooperation in online learning and exploring the theory that underpins cooperative learning.

1.2.2 Chapter 2

This chapter of the dissertation provides an overview of the literature related to serious applications of digital games. Specifically, this chapter provides an introduction to the literature related to serious digital games and gamification in the area of education. The chapter also provides examples of the ways in which serious digital games have been used in education and how they have been researched.

1.2.3 Chapter 3

This chapter presents a narrative review of the literature on the use of digital games for the delivery of education to health professionals and health professionals in training. The structured review identifies six categories in the literature that digital game-based learning in health education can be classified in to. Finally, the chapter will draw conclusions on the state of the literature on the use of digital game-based learning in health education and where further research remains to be done.

1.2.4 Chapter 4

This chapter introduces the concept of design research. It begins by providing an overview of what design research means across a number of research areas. It then outlines the methodology used in this study. Finally, it sets out the primary and secondary objectives of this study.

1.2.5 Chapter 5

This chapter introduces the two digital game platforms examined in this study. Specifically, it details how each platform works and why each platform was selected for the study. It then describes the development process for each of the platforms used in this study. Finally, this chapter outlines how each of the platforms were evaluated. It notes that evaluation methods were selected to ensure that meaningful insights would be gained into (i) how the players interacted with each of the game platforms; (ii) how players interacted with other players in the multiplayer digital games; and (iii) how digital game-based learning can be implemented in adult education.

1.2.6 Chapter 6

This chapter presents the results for the 'They Know: Anatomy' intervention that was conducted in 2014 and 2015. It begins by providing an overview of the structure of the intervention. It then describes the process used to develop the program, the recruitment approach adopted and how the program was delivered. Finally, this chapter sets out the findings related to the program, including observations, the results of the post-program evaluation surveys and comments made by participants in interviews. It also explores participants' engagement with the 'They Know: Anatomy' intervention and outlines their perceptions of the effects of the learning and revision approaches adopted by the study.

1.2.7 Chapter 7

This chapter presents the results of the 'Qstream: Cancer Cup Challenge' intervention that was conducted in the final quarter of 2014. It begins by providing an overview of the structure of the intervention. It then describes the process used to develop the program, the recruitment approach adopted and how the program was delivered. Finally, this chapter sets out the findings related to the program, including the results of the post-program evaluation surveys and comments made by participants in interviews. It also explores participants' engagement with the 'Qstream: Cancer Cup Challenge' intervention and outlines their perceptions of the effects of the learning and revision approaches adopted by the study.

1.2.8 Chapter 8

This chapter considers the results of the study conducted for this dissertation and the literature review undertaken to explore the role of digital game-based learning in health education. Three major themes are explored: 1 - Creating immersive experiences for learners using digital games, 2 - Fostering cooperative learning using multiplayer digital games and gamification platforms and 3 - Designing digital game-based learning environments to support adult learners. The chapter also considers the processes used in multiplayer digital games to support cooperative learning, learners' perceptions of the effects of such processes and the elements of digital games that support cooperative learning. Finally, this chapter discusses findings relating to the use of co-design to enable learners involvement on the development of content and game layout in digital game-based learning environments. The findings of this research are analysed in relation to previous relevant findings on cooperative learning, online learning and digital game-based learning. Due to the exploratory nature of this research, it was necessary to introduce some new literature in this chapter to further contextualise the study's findings.

1.2.9 Chapter 9

This chapter summarises the study's key findings and outlines the novel insights that this study has provided in relation to specific issues in the research area. This chapter also makes a number of practical recommendations to non-game designers, particularly health educators, who are interested in the use of digital game-based learning in adult education. Finally, this chapter outlines a number of questions that need to be addressed and require further research in the future.

1.3 An overview of the digital games landscape

Digital games emerged for the first time in the 1950s. During their early history digital games were limited to a handful of computer games developed by university research teams who had access to computers, or individuals with the same privilege. By the 1970s digital games had become widely available via public video game arcades. By the mid-1980s the growing popularity of personal computers and the rise of home video game consoles saw digital games enter the home for the first time [1]. As video game consoles became household items, the digital game industry grew exponentially in response. As of 2015 the digital games industry was valued at $61 billion worldwide [2]. It is clear from the data on the sale of digital games globally that playing digital games is as common a recreational activity as watching television or playing a sport. A notable study of 8 - 18 year olds showed that the age group spent 20 minutes a day, seven days a week playing digital games [3]. The authors of the study identified it as one of the most comprehensive sources of data on the media habits of American adolescents and young adults at the time of publication, because it collected data from over 2000 youths and the data was collected from a wide age range of adolescents (8 - 18 year olds) [3]. Another study found that in the United States of America alone there were around 150 million digital game players. Of this group, only 26% were under eighteen years of age. Eighteen to thirty-five year old players made up 30% of the digital games market, and a 44% of game players were over thirty-five [4]. In Europe, statistics on the recreational use of digital games shows a similar trend as in the USA. A survey of 2000 individuals across five European countries (Germany, France the United Kingdom, Spain and Italy) found that two thirds of video game players in Europe play for at least an hour a day, or approximately nine hours per week [5]. Finally, a major recent report out of Australia identified that 68% of Australians play video games, 78% of players are over 18 years old, and 39% are 65 years and over [6]. From the literature, it is clear that digital games are a major form of recreation in many countries around the globe. Furthermore it is clear that digital games are a popular form of recreation for adults of all ages, rather than just children and adolescents.

The term digital game is an umbrella term that covers arcade, computer, console/video and mobile games. Further, the term encompasses a diverse range of products that are not unified by genre, format, content or any other single factor. Broadly speaking digital games can be considered a means of providing a player with a thematically consistent experience in a single game world. However, it can be challenging to find a single, all encompassing definition of what digital games are. The difficulty settling on a single definition of what a digital game is has been identified in the literature as a significant barrier to researching games, regardless of the research focus [7]. In spite of this challenge, there are definitions of digital games which can be used as a foundation to explore the parameters of what is and is not a digital game. Rosas et al describe games as having "properties, rules and procedures that must be mastered" [8]. This description is not talking specifically about digital games, but instead is describing characteristics of games in general. The literature has identified digital games as having the same characteristics as analogue ones, but also relying on both hardware and software to deliver the gameplay experience and that "the latest game software takes advantage of technical improvements and offers vivid imagery that comes (comparatively) close to reality" [9]. Furthermore, digital games attempt to be engaging enough to motivate players to keep playing the game until they reach an end goal. Several commentators use the term engaging to describe digital games, with Prensky (2001) going so far as to describe video games as "potentially the most engaging pastime in the history of mankind." [10]. However, the term engaging is ill defined and its use in the literature has the potential to obscure the specific player experiences fostered by individual digital games, thus limiting the ability of researchers to understand the processes through which digital games truely engage players. Prensky also identified a number of elements of digital games that characterise what makes them engaging: they are a form of fun; they are a form of play; they have rules and goals; they are interactive and adaptive; they have outcomes and feedback; they have win states; they have conflict, competition, challenge and opposition; they support problem solving; they have interaction; and they have representation and story [10]. Based on Rosas' and Prensky's descriptions, as well as additional definitions in the literature [9-17] there appears to be agreement on a number of characteristics that describe digital games. In this dissertation, informed by the literature, digital games are being described as an item that uses a combination of software and hardware to deliver the player an immersive gameplay experience, through the use of a range of different elements which motivate the player to participate in ongoing interactions with the game, until the end goal of the game is achieved. *Refer to Table 1.1 for an overview of different descriptions of digital games present in the literature.*

Table 1.1: Descriptions of digital games in the literature

Table 1.1: Descriptions of digital games in the literature			
Article Title	**Author (s)**	**Date**	**Description**
Fun, play and games: What makes games engaging?	Prensky, M.	2001	"potentially the most engaging pastime in the history of mankind."
Games, Motivation, and Learning: A Research and Practice Model	Garris, R et al.	2002	"we would propose that simulations can contain game features. We argue in the following sections that there are six key dimensions that characterize games: fantasy, rules/goals, sensory stimuli, challenge, mystery, and control. Simulations that incorporate these features become more game-like."
Application of computer games in the field of education."	Jayakanthan, R.	2002	"In general, it can be said that games offer many types of pleasures: agency, immersion, challenge, reward, immediacy, a dialect of repetition and variety, physical and mental engagement, and multi-sensory stimulation. Computer games raise the yardstick of immersion and interaction even higher as they 'suck in'' the player."
Explaining the enjoyment of playing video games: the role of competition.	Vorderer, P et al.	2003	Computer and video games are the 'most' interactive among the so called "New Media", and the various opportunities to participate actively in the ongoing events is certainly the characteristic that makes such games distinct from other entertainment offerings

Live in Your World, Play in Ours: The Spaces of Video Game Identity.	Murphy, S C.	2004	"video games potentially draw gamers into the screen space of the game through their storytelling devices and highly interactive game play, I argue that these video game sys- tems also significantly extend televisual space outside the TV screen through 'force feedback' technologies on handheld game controllers that allow gamers to actually *feel* the rumble, shock and action of the game as corporeal sensations linked to onscreen game play. Instead of just drawing gamers *into* the virtual worlds represented onscreen, contemporary video games also extend the space of the game out into the space traditionally reserved for televisual spectatorship and consumption. In doing so, contemporary video game systems mark that space out as one of *action* and *engagement*, rather than inaction and passive reception."
The Motivational Pull of Video Games: A Self-Determination Theory Approach	Ryan, RM et al.	2006	"the integration of the Internet into mainstream society, has given birth to numerous gaming environments and "virtual worlds," that are increasingly complex, immersive, engaging, and enabling of a wide range of activities, goals, and social behavior."
Gameplay and game mechanics: a key to quality in videogames.	Fabricatore, C.	2007	"while playing a game, the player interacts with a virtual universe, which receives player's inputs and responds by changing its status."

A review of applications of computer games in education and training.	Arango, F., et al.	2008	"A remarkable feature of video games is their power to motivate. Computer game features such as active participation, intrinsic and prompt feedback, challenging but achievable goals, and a certain degree of uncertainty and open-endedness contribute to these games' appeal."
Develop your strengths by gaming: Towards an inventory of gamificationable skills.	Oberdörfer, S and Latoschik, M E.	2013	"Computer games motivate users, in this context also known as players, using a variety of different techniques and game design strategies potentially resulting in a high feeling of immersion and a state of "flow" for players. One key element is to constantly challenge players in a well-balanced way."

One of the fundamental elements of digital games that helps immerse players in the gameplay experience is a sense of *mastery* [8, 18]. The pursuit of mastery is one of the ways digital games motivate players to continue tasks regardless of the number of attempts that are needed to complete them. Digital games do this by adapting task difficulty in response to an individual player's strengths and weaknesses. In older digital games this process was done by allowing the player to progress forward through harder levels, a progression which often correlated with the player's avatar (their representation within the game world) learning new skills or gaining new weapons as they progressed through the game, which allowed them to respond to the increased difficulty of the game. Contemporary games are much more likely to use algorithms to adapt in real time to a player's level of skill, rather than just using level progression. Game designers refer to this technique as dynamic game difficulty balancing [19, 20]. Through the use of dynamic game difficulty balancing, players are prevented from reaching their goal too easily ensuring they feel accomplishment when it is reached. However, digital games avoid making completing a task so difficult the player gets frustrated and quits. The pursuit of mastery is one way in which digital games motivate players to continue progressing through the game.

Mastery is just one of several elements that digital games use to motivate players. The use of *progression* throughout a game to motivate the player is another important element. The player progresses through a game by completing a number of objectives which, once achieved, will allow completion of the overall goal of the game. These objectives do not necessarily have to be completed in a linear manner, and the player often has a choice of when and how to achieve them. In some instances, completion of all objectives may not be required to complete the game, and it is up to the player if they wish to attempt them. This structure provides the player with a range of choices to make while playing the game, increasing their motivation and immersion in the game world. These choices remain framed within the overall goal of winning or completing the game which means the player continues to feel their choices have a purpose behind them. They are not choosing for the sake of choosing, rather they are choosing to alter on the game world, progress through the game world and ultimately complete the game. This is important because the literature on motivation has demonstrated that it is more likely to occur when an individual is provided with choices of how to complete a task. The act of choosing how to complete a task creates engagement in the specific environment that choice was made in, motivating the individual to continue with the task regardless of any external reward [21].

Another aspect of digital games that should contribute to an immersive gameplay experience is a sense of *challenge.* Digital games use a balance of risk and reward to challenge the player as they progress throughout the game, this forms part of a game loop. A game loop describes the series of choices a player is faced with in the world. With every choice they must weigh risk and reward and use this to choose a path. These choices continue throughout the game until a final goal is reached. By incorporating a loop of this nature, digital games lower the player's perception that failure has dire consequences and thus encourage risk taking and exploration of the game world [22]. This phenomenon is referred to as 'graceful failure'. Specifically, 'graceful failure' describes an assumption that failure is an expected outcome of a game, and one that is often a necessary step in the learning process, before the player can re-attempt a challenge and move on.

1.3.1 Game mechanics and gamification

In order to create an experience for players that motivates them to continue progressing through a game world, digital games are built around a range of game mechanics. Game mechanics have been defined as "commonly reoccurring parts of the design of a game that concern gameplay" [23]. Sicart (2008) describes mechanics as the grammar of digital games, which provides game designers with tools to "predict courses of interaction, but not to determine how the game will always be played, or what the outcome of that experience will be" [24]. Although there are several definitions of game mechanics, most descriptions frame game mechanics as traits within the game that motivate the player to interact with the game world. Digital games rarely use a single mechanic, instead they build a complex world that integrates a range of mechanics with the ultimate aim of creating an immersive and engaging experience for the player. A comprehensive library of game mechanics was put together by Järvinen (2008) which defined forty game mechanics present in many digital games. The mechanics identified by Järvinen (2008) included: attacking/defending, building, buying/selling, conquering, information-seeking, upgrading/downgrading, transforming and voting [16]. Other game mechanics identified in the literature include action points, levels, tokens, game turns, time pressure, resource management, and selecting/collecting [17]. Furthermore, the literature suggests that there are primary game mechanics which are directly related to reaching the end goal of the game, and secondary game mechanics which are less direct [24]. Ultimately, game mechanics are a component within digital games that help support the gameplay experience. So, if digital games are a form of entertainment that provides a fun or immersive experience to the player, then elements such as a sense of challenge or mastery are the experiences the player gets out of the game, and game mechanics are the tools the game designer uses in an attempt to facilitate an immersive gameplay experience for the player.

Game mechanics are frequently defined and described from the technical game design perspective [23]. Much of the literature on game mechanics speaks to an audience who have an interest in understanding how to design better digital games, often from a commercial game design perspective. There is notably less literature speaking to an audience of researchers, educators or individuals who want to understand how game mechanics affect player behaviours or how they can be adjusted to encourage players to behave in a certain way. However, the growing popularity of gamification is beginning to address the gap in the literature around the affect of individual game mechanics on players.

The term gamification, or gamified platforms, refers to the use of individual game mechanics, such as leader boards, in order to enhance non-game environments such as online courses [25]. Gamified platforms are related to digital games, but not the same as them, though the boundary between a digital game and a gamified platform can be blurred [23]. As was noted at the start of this chapter, an individual digital game typically offers a player a thematically consistent experience within one game world. As the player navigates through an individual digital game's world, they should feel connected with the game world as a result of their experiences within it, and eventually reach an end point where they win the game and are rewarded. Combinations of game mechanics are used within a game world to create the gameplay experience for the player, but they often don't have any value outside of the particular game environment. It can be difficult to identify the effect of a specific mechanic within the game environment due to the large number of mechanics that work together to create the player's experience overall. In contrast to a digital game, gamification takes individual game mechanics out of the context of a game environment and uses them to motivate the player/user/learner to continue interacting within a non-game environment. Typically, this involves taking a platform such as an online course and incorporating an individual game mechanic, such as a scoring system to create an additional set of goals for the learner in addition to the primary goal of learning the subject matter of the course. In the context of an online course that uses gamification, a learner may receive points for each question they answer correctly and be rewarded with a badge when they receive a certain number of points. The overall reward for the online program is to complete it and learn the subject matter, which can be achieved whether the program uses gamification or not. However, it is anticipated that by adding rewards such as badges learners in an online program will be more motivated to complete the program than they would be without such rewards. The use of gamification in modern society is likely a response to the popularity of commercial digital games, as gamification is the distilling of elements of digital games. Although there is a difference between digital games and gamification, as gamified environments have become more advanced, the clear line between a gamified platform and a digital game has become more blurred.

Gamification is a popular way to increase interest in a non-game environment. However, effectively developing gamified systems can prove complicated, particularly when it comes to balancing reward with challenge [26]. There has been some criticism of gamification as focusing too heavily on player rewards and not enough on providing the player with a challenge, which can compromise the player's immersion in the gameplay experience [27]. Another limitation of gamification is ensuring learners continue to feel motivated by the use of individual game mechanics in the long term, once the initial novelty of the experience wears off. Gamified systems have also been criticised for being too strongly focused on goals, rather than playful encounters that can be maintained long term [28], and for only taking the most engaging mechanics from games to embed in gamified environments [29]. An alternative to taking game mechanics and designing a learning environment around them is first to identify learner behaviours that are being targeted through the use of gamification and then choose mechanics that are demonstrated to change those behaviours [30].

1.2.3 Digital game genres

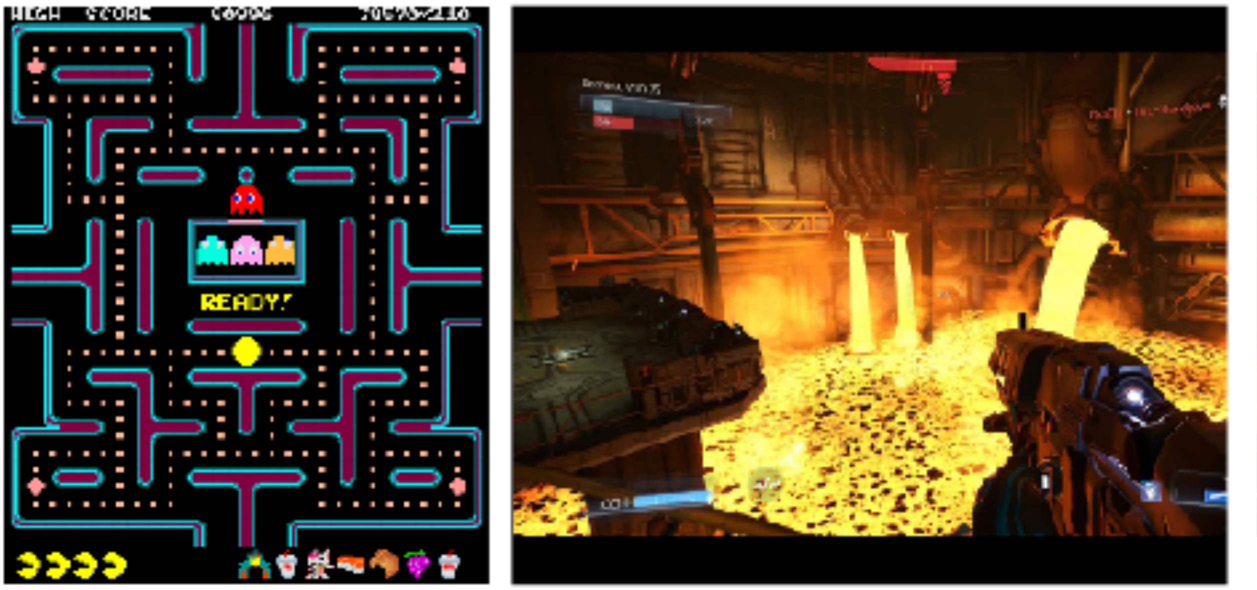
Game genres are commonly used to categorise commercial digital games, as they can provide end users with an idea of what to expect from the game. Game genres typically categorise digital games by similar traits, such as grouping games that use game mechanics in a similar way. Although game genres can be a useful tool for analysing certain aspects of games, such as game mechanics, there is one significant challenge to this approach: genres for games are no more strictly defined than they are in any other form of recreation. It is exceedingly difficult to find a definitive list of digital game genres, in part because contemporary digital games often combine multiple genres within one game and overlap with each other [31]. In the literature, there are multiple definitions of the number of genres of digital games. For example, Gros (2007) defines seven categories: Action, Adventure, Fighting, Role Playing, Simulation, Sport and Strategy [32]. Alternatively, Wolf (2001) identifies upwards of twenty genres, from the more typically seen commercial game genres: Adventure, Puzzle, Strategy to less common genres such as Maze, Artificial Life and Text Adventure [31]. Although there is debate as to exactly what the main digital game genres are, there are genres that come up repeatedly such as Action, Fighting and Simulation. Digital games of the late 1970s and early 1980s often had a single defined genre because of the technical capabilities of the hardware used at the time. Whilst contemporary digital games still use the main genres that have been inherited from the early era of digital games, there is a much greater complexity in the digital games themselves, and it is very common to see games that are listed across multiple genres. For the sake of simplicity, discussion in this chapter will be limited to the six representative genres: Action, Adventure, Role Playing, Simulation, Strategy and Puzzle. A brief description of each genre follows.

Action

The Action genre is one of the oldest and most broadly utilised genres. Many arcade games of the early 1980s were classified in the Action genre, including Pacman and Space Invaders. There are some contemporary digital games that are in the Action genre. However, it is much more common to see contemporary digital games categorised into Action sub-genres such as Platformers, Beat 'em ups and even Rhythm Action games. Rhythm Action games are music themed action games that require players to demonstrate their sense of rhythm. The Action genre is often identifiable by its reliance on player skills to progress through levels, such as requiring quick response times or good hand eye coordination. *Refer to Figure 1.1 for screenshots of exemplar games in the Action genre.*

Games in the action genre typically rely on levels to progress the player through the game. The player controls a single avatar and uses this to navigate a level. Each level is populated with various enemies and ends with a boss battle: a fight with a particularly strong enemy. As the player progresses through the levels, the challenge can increase in multiple ways. Typically, enemies get stronger, and boss battles get harder, but there continues to be a theme that is carried through from all the levels. Players may get more complex weapons to use as they progress, making it easier to defeat enemies, though they require more skill to use.

In addition to the incremental increase in level difficulty, Action games also often rely heavily on player life limits and a scoring system. Players will get points for defeating enemies, which will contribute to their overall score. At the end of the game, their score will be added to a leader board, which may be populated with the scores of other players. There will also be a limit on the number of lives a player has to complete all the levels of a game. If they do not complete all the levels within that limit, they will have to start again, and lose all their points and weapons.



Pacman (Namco, 1980) DOOM! (Id, 2016)

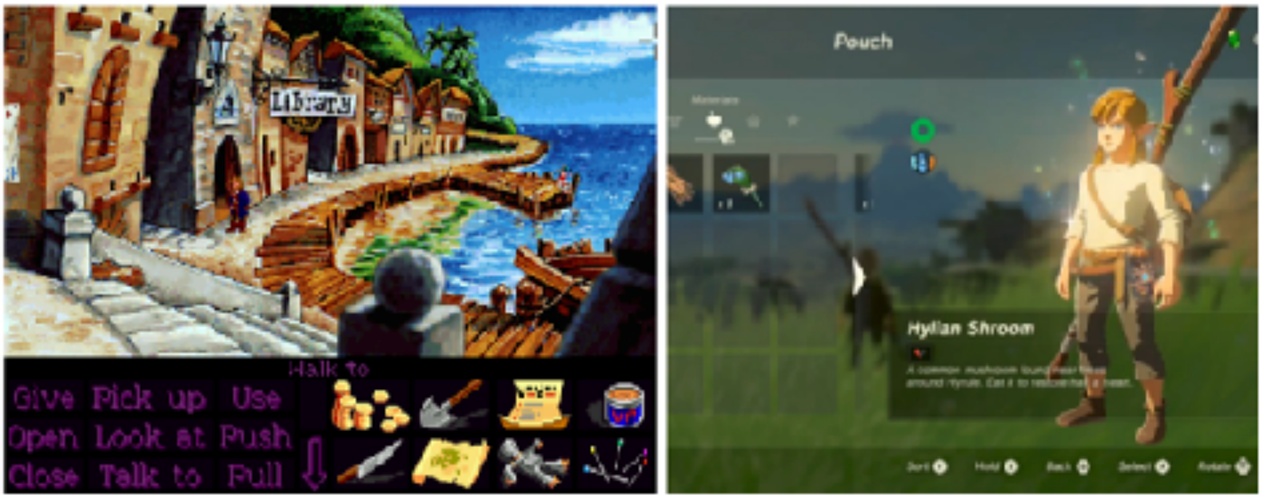
Figure 1.1.: Examples of games in the Action Genre

Screenshot of a seminal game in the action genre: Pacman (NAMCO, 1980), alongside a contemporary example: DOOM! (ID, 2016). The player's score can be seen at the top of the screen for Pacman, and the life total of the player has remaining are indicated in the bottom left of the screen for both Pacman and DOOM!.

Adventure

Unlike all the other game genres the Adventure genre is not named for a descriptive reason, but rather takes its name from a specific game, *Colossal Cave Adventure* that was published in 1976. The Adventure genre has frequently been reimagined as is evidenced by the diversity of adventure sub-genres including action-adventure and puzzle-adventure. *Refer to Figure 1.2 for screenshots of exemplar games in the Adventure genre.*

The Adventure genre is typically focused on the single player experience, but there are modern digital games in the Adventure genre that are multiplayer. Typically, the player controls an avatar which is used to immerse them in a strongly narrative driven game world, which they explore to complete the game. The narrative is central to the Adventure genre, but games also incorporate a significant amount of puzzle solving. Players solve puzzles throughout the game in order to access new parts of the story. As such, the challenge of solving puzzles is interwoven with the immersion of the game's story. By solving all the puzzles, the player is rewarded with a complete narrative and items with which they can progress through the game. Although early Adventure games were often text based, modern Adventure games are often graphically intensive. Spectacular 3D and 2D graphics are used as key elements for immersing the player in the world.



The Secret of Monkey Island (LucasArts, 1990)

The Legend of Zelda: Breath of the Wild (Nintendo, 2017)

Figure 1.2: Examples of games in the Adventure Genre

Screenshot of a seminal game in the adventure genre: The Secret of Monkey Island (LucasArts, 1990), alongside a contemporary example: The Legend of Zelda: Breath of the Wild (Nintendo, 2017). Both screenshots show items the player has collected during the game, which should assist them in progressing the game narrative forward.

Role Playing

This genre has some similarities to the Adventure genre, and for modern digital games, it is very common to see role playing/adventure and/or action genre digital games. Like the Adventure genre, the Role Playing genre is strongly narrative driven and progressing through the game is a means for unlocking a complex story. The player's desire to follow the game narrative has a significant role in immersing a player in the game world. The player may control a single avatar, but they can also be in charge of a game part made up of two to five players. *Refer to Figure 1.3 for screenshots of exemplar games in the Role Playing Game genre.*

This genre typically allows players to progress through the story using combat focused challenges, rather than puzzle focused ones. Players also often have an inventory for which they collect items during the game. Inventory items get more powerful as they progress through the game in order to help players overcome challenging combat scenarios.

In addition to inventory items increasing in power as the player progresses through the game, the player's character often also increases its skills and abilities. This process of levelling up allows the player access to more in-game skills and abilities, which are necessary to overcome more complicated game challenges. Role playing games typically use character levelling instead of mechanics such as a level score and leader boards like those used in action games.

Dragon Quest (Chunsoft/Enix, 1986)

Persona 5 (Atlus, 2017)

Figure 1.3: Examples of games in the Role Playing Game Genre

Screenshot of a seminal game in the role playing genre: Dragon Quest (Chunsoft/Enix, 1986), alongside a contemporary example: Persona 5 (Atuls/SEGA, 2017). Both screenshots show a combat sequence in both games, including the option to access collected items.

Simulation

The simulation genre is often difficult to fully define due to the widespread usage of the term simulation. While there are digital games that clearly fall into the simulation genre, there are also plenty of examples of simulations that are in no way digital games. Examples of the use of simulators that are not digital games can be found in aviation training [33] and surgical skills training [34]. One of the most distinctive aspects of simulation digital games is that they are often not as clearly goal oriented as other genres. The reason simulation games are less goal oriented than other genres is often because the player has a large amount of autonomy in determining their own objective for the simulation. Game designers who develop simulation games give considerable thought to how the game can be structured to give the player a high level of freedom, without compromising the sense of reward and achievement that should come from progressing through a digital game. *Refer to Figure 1.4 for screenshots of exemplar games in the Simulation genre.*

Digital games in the simulation genre do what the name suggests: they simulate. Typically simulation games allow players to simulate real world activities or environments, but some are entirely fictitious simulations. Simulation games rarely use any sort of scoring or levelling system, nor is the use of an avatar common. Instead, players interact with the simulation through the use of a mouse pointer or a controller and are never directly portrayed in the game world.

Simulation is a very broad genre, but most simulations fall into a few categories. Some of the oldest simulation digital games were construction focused, where a player created a city or a theme park. There are also simulation games that simulate everyday life and allow the player to explore how certain actions change the lives of the beings within the simulation. Finally, there are sports simulations. Whether sports games are in the simulation genre or their own genre is a point of contention, but they do aim to simulate the experience of being an athlete or managing a professional sports team.

Sim City SNES (Maxis, 1991)


Euro Truck Simulator II (SCS Software, 2012)

Figure 1.4: Examples of games in the Simulation Genre

Screenshot of a seminal game in the simulation genre: Sim City SNES (Maxis, 1991), alongside a contemporary example: Euro Truck Simulator II (SCS Software, 2012).

Strategy

There are two sub-genres of games in the Strategy genre: Turn Based Strategy and Real Time Strategy. Both sub-genres have a similar overarching structure which is focused on the player making decisions that will have long term payoffs for the game. All strategy games provide players with challenges in the game world that are tactical or strategic. They offer the player a game experience that emphasises their individual skills and the need to plan to win the game. *Refer to Figure 1.5 for screenshots of exemplar games in the Strategy genre.*

Players are often trying to defeat an opposing player or team, either one controlled by a non-player character (NPC) or more often an opposing player. Although strategy games with NPCs allow strategy games to be played single-player, these games are often less challenging than when there is a human opponent. To win a strategy game the player has to defeat the opposing team or player (regardless of whether the opponent is another person or a NPC). Defeating the opposing team/player frequently involves decreasing the size of the enemy army or taking control of enemy territory. The enemy is usually trying to do the same to the player, adding to the level of challenge.

Starcraft (Blizzard Entertainment 1996) Civilization 5 (Firaxis, 2010)

Figure 1.5: Examples of games in the Strategy Genre

Screenshot of a seminal game in the strategy genre: Star Craft (Blizzard Entertainment, 1998), alongside a contemporary example: Civilisation 5 (Firaxis, 2010).

Puzzle

The puzzle genre is one which relies on the use of problem-solving skills such as pattern recognition and sequence identification to solve puzzles. Although the primary focus of games in the puzzle genre is on problem-solving, many games add additional challenge elements such as time limits or limited attempts to solve a puzzle. Games in this genre often present a range of puzzles that share a theme so that the player can transfer skills they learnt from easier starting puzzles to more challenging puzzles as the game progresses. The puzzle genre incorporates many different types of games and has a long history. The genre continues to be popular today, and it is a particularly common genre for smart phone games. *Refer to Figure 1.6 for screenshots of exemplar games in the Puzzle genre.*

Tetris NES (Nintendo, 1989)

Puzzle & Dragons (2012)

Figure 1.6: Examples of games in the Puzzle Genre

Figure 1.6: Screenshot of a seminal game in the puzzle genre: Tetris NES (Nintendo, 1989), alongside a contemporary example: Puzzle & Dragons (GungHo Online Entertainment, 2012).

1.4 Using digital games in adult education

1.4.1 The role of online learning

During the last 40 years, computers and related digital technologies have become accessible on a wide scale, and their use in everyday life has become increasingly ubiquitous. This widespread use of digital technologies has become particularly apparent in the last decade, due to the growth in popularity of smartphones, personal computers (particularly laptops and tablets), video game consoles and high-speed internet. The availability of computers and tablets, alongside improvements in technologies for ensuring reliable and high-speed internet access, has resulted in a growth in the delivery of education via the internet, most frequently referred to as online learning. Online learning has also expanded to include the use of digital games and digital game-based learning to deliver subject matter via the internet. The use of online learning is particularly prevalent in adult education, professional development and tertiary level training [35]. The popularity of online learning in adult education is likely due to its ability to support approaches to learning that align with the needs of adult learners. Adult learners have different expectations of education and training, whether they be at a tertiary level or higher, including a desire to have self-direction over their learning experience and flexibility of access to training [36]. Online education has been used to deliver professional training across sectors as diverse as hospitality education and training [37], real estate practitioners completing professional development [38] and teacher education [39]. Online learning is also popular due to its ability to deliver just in time content [40].

Although online learning is increasingly prevalent, there are a number of challenges that need to be overcome if it is to be used effectively. One significant barrier to the use of online learning is the financial burden of developing and delivering high-quality online programs, and an unwillingness by organisations to adequately invest in the development of high-quality online education activities. Delivering training online also changes the way knowledge is controlled, due partially to its student centred nature, which has been viewed with some caution by tertiary institutes. The internet allows anyone to obtain information, where once teachers and academics could be seen as gatekeepers of knowledge. Concerns have been raised that this new dynamic has a negative effect on learning as students cannot distinguish between high and low-quality information [41]. Furthermore, critics of online learning have argued that it isolates learners and cannot offer the level of social connectedness afforded by the traditional classroom, thus making it less effective than face to face learning [42]. In spite of many of these concerns about delivering education online many organisations view it as a panacea for maintaining high standards of learning with smaller budgets [43]. However, the combination of barriers to development of high quality online educational programs often results in the delivery of poorly designed online learning activities, which may not have clear learning objectives and/or merely deliver audio recordings of lectures online.

1.4.2 Online learning in health education

The explosion of digital technologies has been transformative in the health sector. There are many areas in the health sector that have been early adopters of technology, and the uptake of technology by the sector has been so pronounced that in the early 2000s researchers coined a term to describe it: eHealth. The term eHealth describes the intersection between technology and healthcare [44]. Almost every aspect of healthcare is being transformed by emerging technologies, and their prevalence will likely only become more dominant in all aspects of healthcare in future [45]. One of the transformations being ushered in by the technology revolution is a movement towards a more patient-centred health system as new technologies enable people to take a central role in their health care [46]. New technologies are also reshaping the way care can be delivered. The roll out of electronic health records (EHRs) on a global scale is making it easier for health professionals and patients to access clinical data and this is supporting more personalised healthcare. The intersection between technological innovation and the health sector is also playing an integral role in supporting the data revolution sweeping the sector, as it enables the collection and analysis of big data sets [47]. Technology is also changing the delivery of education to health professionals and health professionals in training, henceforth referred to as health education. A recent survey of emergency medicine residents in the United States of America estimated that they undertook two to three hours of online training each week [48]. Similar findings have been found in other literature about the delivering of Continuing Medical Education (CME), where online learning is viewed as a dominant means of delivering education and training [49]. The literature shows that there is a similar trend towards the use of online learning in the delivery of tertiary medical education, with one study of 1160 medical students reporting 49% used a internet based learning program once a month and 42% undertook online quizzes of their knowledge regularly [50].

Online learning has been repeatedly demonstrated to provide learners with educational outcomes that are equivalent to traditional methods of delivering education [51-53]. The delivery of well designed online education has been shown to be effective for changing knowledge when used to deliver continuing professional development for health professionals, and that this knowledge change can be sustained for at least three months [54]. Additionally, it has been shown that health education delivered online is not just effective at changing knowledge, but can also positively alter on clinical behaviours across a range of health specialties including training clinicians how to educate patients on proper pain management for chronic conditions [55], translating guidelines into practice in ovarian cancer [56] and improving long term retention of diagnostic skills in surgical training [57]. It has been identified that a key component in engaging health professionals and students in online education is ensuring the program is accessible and easy to use [58]. Furthermore, in line with the larger body of research on online learning, the literature on the use of online health education identifies the ability of online training to be accessible flexibly regardless of physical location or timing of participation as a significant advantage for learners [59]. For organisations, the delivery of education online has the potential to reduce the cost of developing training for organisations as individual components of courses or entire programs can be widely shared and reused to avoid replication of similar training activities [60].

Although there are many advantages of delivering health education online, and it being clear that online education is capable of delivering an equivalent learning outcomes as other methods, there are many barriers to its effective use. One notable challenge is that some aspects of online courses that enhance the student experience and increase interactivity cannot be scaled easily and are not easy to support, such as online discussions [61]. Additionally, there can be a considerable up front development cost for organisations wishing to develop online learning environments. Upfront costs for developing online learning environments can be particularly burdensome in the health sector when there can be a need to incorporate elements such as virtual patients into training activities [62]. Designing effective online learning environments that have strong pedagogical foundations can also prove challenging, and many online health courses do not have good educational design and merely consist of PowerPoint slides or textbooks online [63]. One approach to addressing this problem is through the use of online education models and frameworks which can be used to inform the design of health education programs. However, there are few models available on how to develop online learning programs that incorporate effective pedagogies and different learning strategies, including active and passive learning approaches. When models are available to inform the design of online health education, there is evidence that the resulting programs can offer high quality learning experiences to participants [64].

A key component of effective online health education and one that is highly valued by learners is its ability to support interactivity between learners, learners and tutors and/or learners and content [58]. The use of next-generation online tools such as blogs and wikis could strengthen engagement and collaboration of health students, clinicians and patients themselves in online programs [65]. One means of embedding interactivity into online environments is through the use of digital game-based learning, as it has been established that digital-games can be an effective means of promoting cooperation and learner engagement [32]. Additionally, embedding digital games has the potential to overcome other challenges in online education such as providing user-centred and adaptive experiences for learners. Elements of digital games that could support the delivery of user-centred online education include their ability to support passive assessment of progress, and use this to deliver automated but adaptive feedback to the learner [66]. Although digital games may be a useful means of increasing adherence and immersion in online learning activities, their use in health education appears less common than in the larger educational field . At the very least there is no readily available literature on the use of digital games to augment online health education. As a result, there is a gap in understanding of the benefits and disadvantages of using digital game-based learning for supporting health education.

The researcher has decided to focus on this area of research for a number of reasons. Firstly, the use of digital games and gamification to enhance adult education and training has been identified as one of the top trends to watch in education due to their ability to support cooperative learning as well as positive learning outcomes for delivering specialised skills [67]. Secondly, the health education literature has identified that students themselves are interested in seeing digital games used in the delivery of their training [68]. Finally, the researcher feels there are under-explored aspects of digital games-based research in health education, including how to design and implement them effectively in online and blended environments. The thesis aims to help contribute new knowledge to some of these gaps.

1.5 Supporting cooperative learning in online education

1.5.1 Theoretical perspectives on cooperative learning

There is a long history of cooperative learning both formally and informally in education. The term describes educational activities where students work together, often in small groups, with the aim of learning with and/or from each other. The learning may be focused on specific knowledge and skills, or development of relationships and shared understanding, enhancement of generic skills such as communication and team-working, or a mixture of these things. As described previously cooperation is a key feature of many digital game genres and can be facilitated through the use of gamification.

There is a large body of research into the psychology of cooperation and communication in learning, with roots going back work by Jean Piaget (1896 - 1980) and especially Lev Vygotsky (1896 - 1934). Building on these and other foundational works, there is also a considerable amount of literature on the theory behind cooperative learning, and literature which provides practical insights on activities that can be used successfully to encourage group cooperation or academic achievement through cooperative learning. There is now very little debate as to whether cooperative learning is effective, but there is still some disagreement about how and why it works [69]. In a review of the literature, Slavin (2014) identified four broad theoretical perspectives on cooperative learning that effect academic achievement: cognitive-developmental, cognitive-elaboration, motivationalist, and social cohesion. The first two perspectives are heavily underpinned by the idea that cooperative learning provides specific structures that lead to cognitive improvement, while the latter two perspectives focus more on the concept that more motivated students will participate in more learning activities and thus perform better academically. Each of the four perspectives will be briefly explored in the following paragraphs.

The cognitive-development theoretical perspective builds on the assumption that the process of cooperating and interacting around specific tasks improves performance on them and ultimately supports the development of mastery [70]. Activities that have been identified in the literature as being effective in support the cognitive-development process of cooperation include group discussions and sharing of multiple viewpoints between learners [69].

As with the social-cohesion theoretical perspective, the cognitive-elaboration perspective is focused on the inherent cognitive benefits of cooperative learning. Proponents of this perspective argue that cooperative learning facilitates a cognitive-restructuring of new ideas, which is required to learn them and remember them in the long term [71]. One of the key tasks that has been demonstrated to be effective at supporting this process of cognitive-restructuring is asking a learner to explain ideas to someone else: an activity that is beneficial to both parties involved [72, 73].

The social-cohesion theoretical perspective on cooperative learning suggests that students help each other learn because they feel a connection to the members of their group and their identity is linked to membership in the group [74]. Proponents of this perspective emphasise the role of group interaction in ensuring individuals perform well academically and retain what they have learnt [75]. Activities that are used to support cooperative learning from the social-cohesion perspective include team-building prior to group work, and self-evaluation during group activities and after them [69].

Finally, the motivationalist theoretical perspective is strongly based on the idea that learning is goal oriented. Proponents of this theory state that learners are driven to achieve the goal of learning, that they are self-interested in achieving it and in a cooperative environment an individual will support the group if they feel it will help them achieve their goal of learning [76]. The literature has identified many activities that can support cooperative learning from the motivationalist perspective. Activities that use grades based on group performance have been identified as an effective means of fostering cooperation in groups, as this approach requires all members of the group to perform well for each individual to receive a high mark [77]. However, rewards for group work have to be structured in such a way that each individual member feels their success is determined by how much they support other members of the group [76].This can be achieved by not just giving a flat group mark, but for rewarding the group based on how much each individual within it has improved their marks over a set time. This approach encourages group members to share notes and support each other as the success of the group is determined by everyone doing well [69].

The research into cooperative learning strongly suggests that it can achieve more favourable outcomes than other forms of learning, including improving the long term retention of subject matter, encouraging the more frequent use of critical thinking skills [78]. However, there is less agreement on whether this is due to the act of cooperating or due to shared goals between group members [79]. Cooperative learning can be implemented in three different ways: formal cooperative learning, informal cooperative learning and cooperative base groups [80]. Formal cooperative learning describes endeavours where learning groups with stable memberships work together long-term [80]. Informal cooperative learning allows learners to work together in small groups for short periods of time such as a fifteen minute activity, or for the duration of a single class [81]. Cooperative base groups are longer-term group structures that may last for several months or a semester, with consistent group membership to provide group members encouragement to make academic progress [80]. Certain activities have been demonstrated to be particularly valuable for enhancing collaborative learning including: argumentation [82], elaborated explanation [83], and seeking and providing help to others [84]. Finally, it has been shown that successful cooperation is more likely to occur in situations where specific forms of social interaction between learners are promoted or pre-structured with such things as collaboration scripts [85].

1.5.2 Cooperative learning in online education

Cooperative learning in online education has been shown to offer learners the same benefits it does in face to face instruction [86]. Benefits of cooperative learning include increasing motivation for learners to achieve an educational goal [76], and increasing a sense of social connectedness to other learners [71]. Additionally, the literature on online learning consistently identifies interactivity and cooperation as factors which are integral to engaging learners in online learning. Key facilitators of interactivity in cooperative online environments are the use of structures, such as rubrics, that reward cooperation and a clear outcome for the discussion which is conveyed to learners [87]. Further to this, one study found that learner-content interaction was the most highly ranked type of interaction in online programs, but that learners felt interaction with other students to share experiences with the content provided a more enriching experience than just reviewing content alone

[88]. Finally, while it is possible to support cooperative learning online, there are differences between how learner interaction occurs face to face and how it occurs online, possibly relating to student familiarity with online learning and their ease using it [89].

Although the literature suggests that cooperative learning online can be as beneficial to learners as it is face to face, structuring cooperation online is challenging [86]. There are three broad approaches to encouraging cooperation in online learning: creating groups, structuring learning activities, and facilitating group interactions [90]. The use of scaffolded activities is a key component of supporting cooperation and collaboration in online learning environments [91, 92]. Additionally, providing learners with access to a variety communication tools, such as online forums or live chat systems, has been shown to increase learner interaction [93]. However, providing learners with tools such as online forums can be insufficient to instigate interaction, as learners have been observed to be disinclined to interact on online forums when there are few other posts [94]. Factors such as the identity of learners online can also increase or decrease interaction. If pseudonyms are used to ensure learners are anonymous when they interact in online courses, it can reduce interaction between them [95], but it can increase the perception that online interaction is non-threatening [96]. However, it has been shown that identifying learners online is more effective at ensuring non-threatening behaviour in online courses and reducing antisocial behaviour [95]. While learners benefit from cooperative learning online, the challenge for developers continues to be identifying and implementing activities that encourage interactivity and cooperation in online learning environments.

1.5.3 Digital games and gamification for supporting immersion and cooperation in online learning

One of the acknowledged benefits of digital game-based learning is its ability to create player immersion and enable cooperative experiences for learners [32]. By embedding digital games into online learning environments it has been shown to be possible to support more personalised, cooperative and immersive online learning experiences [97]. An example of this is the use of the game Second Life to support cooperative learning experiences for students studying a Foundations of Instructional Technology course, as part of a Master of Science degree [98]. The use of Second Life to support the delivery of online training was shown to be effective for encouraging learners to interact more actively with other learners of the course, rather than just relying on the instructor [98]. Although there is some research into the use of digital games in online education, there are still a number of gaps in understanding regarding how they can be used effectively to provide immersive and cooperative experiences in this setting.

One of the challenges of embedding digital games in online learning is the number of gaps in the literature on how digital game-based-learning can be used into online learning in a way that balances entertainment and pedagogy [66]. It has been acknowledged that there are still many areas of digital game-based learning that would benefit from further research [99]. The gaps in the literature include both micro issues that relate to the individual player experience and macro issues around the implementation of digital game-based learning. Regarding implementation of digital game-based learning, it has been noted that there is a need for further exploration of the costs of designing and successfully implementing serious digital games [100] and the challenges of successfully embedding game-based learning into existing curricula [101]. In contrast, on the individual player level, it has been acknowledged that future research needs to explore the nature of the game play experience and how the player and platform interact, rather than focusing on one or the other [102].

Finally, there is also a paucity of research into multiplayer digital games for adult learning, and their potential to support both cooperative learning experiences. This gap is surprising considering the significant amount of literature exploring the benefits of both cooperative and collaborative learning on student outcomes. While, there is a small but growing amount of literature presenting findings on the unique social structures that evolve around multiplayer games, there is little research into how players interact when playing multiplayer digital games in the context of education. Additionally, the potential of certain genres of digital games to support learning communities similar to those which form around eSports is yet to be explored in the literature. Developing learning communities around catalysts such as digital games may hold unique benefits for adult learners. This applies in particular in the context of health education where the use of collaborative learning games around which learning communities can develop may motivate health professionals and trainees to continue undertaking training activities as a form of community interaction.

1.6 Chapter Summary

This chapter has provided the reader with an overview of the digital games landscape, including a brief overview of the some core game genres: Action, Adventure, Role Playing, Simulation and Strategy. Further to this, the chapter looked at the use of digital games for serious applications, with a specific focus on their use for education and learning. The next chapter will provide an overview of the use of digital games to support learning for a range of audiences, as well as how research into digital games in education can be categorised. This introduction will provide the reader with a foundation for a detailed narrative review of the literature on the use of digital games in health education in subsequent chapters.

Digital games and their application in education

Chapter 2

This chapter of the dissertation provides an overview of the literature related to serious applications of digital games. Specifically, this chapter provides an introduction to the literature related to serious digital games and gamification in the area of education. The chapter also provides examples of the ways in which serious digital games have been used in education and how they have been researched. Finally, the chapter provides an overview of the use of serious digital games in health education. (A narrative review of this topic is then provided in the subsequent chapter.)

2.1 Research into serious digital games

Digital games first began to emerge in the 1950s [1]; however, researchers did not become interested in the medium until several decades later. Further, while limited analyses were conducted into possible applications of serious digital games in the 1980s, an extensive analysis on the serious application of digital games to non-recreational activities was not undertaken until the 1990s. In the last decade, there has been exponential and continued growth in the literature on digital games. This growth appears to have coincided with commercial digital games transitioning from a form of entertainment (predominantly used by hobbyists) to a mainstream form of recreation and ubiquitous activity (commonly used by members of contemporary society) [103]. This transition has had a significant impact on the landscape of the commercial games sector. The rise in popularity of eSports represents one of the biggest changes to the commercial digital games industry, as they are transitioning digital games from an experience only accessible to players into something experienced by communities of spectators as well. The term 'eSport' describes a contemporary iteration of digital gameplay. Specifically, it refers to organised multiplayer competitive games that are played before large audiences and are not only for individual entertainment [104]. Due to their focus on player- or team-based competition, certain commercial game genres are particularly suited for use as eSport games, particularly First-person Shooter and Strategy games [105]. In addition to changing the focus of gameplay from a form of entertainment to a form of team-based competition, eSport games have been shown to create communities that extend beyond a single gameplay experience and are similar to those that form around professional sporting events [106].

The use of digital games is quite common in education today [107-109]; however, digital games were used in education as early as the 1980s. Early research into the use of serious games in education focused on demonstrating that such games could be more interesting then delivering subject matter in a traditional classroom environment, and thus may be beneficial in situations were maintaining learning motivation is proving problematic [110]. As the use of digital games in education became more widespread in the late 1990s and early 2000s, the questions researchers asked about serious digital games also expanded. Contemporary research has sought to explore not only whether digital games engage learners, but precisely how [111] and why digital games engage learners. For example, numerous studies have sought to explore specific game mechanics and how different aspects of game design affect the gameplay experience [112, 113].

In the early 2000s, researchers also became interested in the application of serious games in education as a way in which to engage 'digital natives'. It has been contended that digital natives (i.e., younger generations of adolescents and young adults) have different learning requirements than older generations and that consequently tools (e.g., digital games) must be integrated into classrooms to encourage such learners to engage with the curricula [10]. The notion of digital natives has since been discredited, and as such is no longer relevant in the educational literature. However, the term continues to be used in broader discussions around the changing needs and expectations of students in mainstream society and is often used to describe traits of health students. Although the term 'digital native' lingers in mainstream society, research has shown that the there is wide variety in the usage and skills of students when it comes to technology [114]. As such it is unsafe to make assumptions about the needs and understandings of students based solely on their age.

In addition to extensive research being conducted on the application of digital games in education, a considerable amount of research has also been conducted on how players learn from digital games. Research on how players learn from digital games has focused on the learning processes evoked by digital games that allow players to progress from novices to experts as they navigate complex game worlds. As mentioned above, digital games encourage players to enter cycles and repeat failures until they eventually master a task [8]. Previous research has focused on how players learn from digital games and on the processes by which digital games adaptively teach players to achieve mastery. The processes used by commercial digital games are complex; however, the underpinning principles are related to active and critical learning [18]. Digital games support active learning because mere observation will not allow a player to progress in a game environment; rather, they must engage actively in navigating the game world, confronting challenges that entail learning.

2.2 Categorisation of educational digital games by game type

A scoping study of the literature on digital games and gamification was undertaken to understand how digital games had been researched in the educational literature, in order to have a frame of reference for contextualising the use of digital games in health education. This scoping study of the literature identified four different categories related to the use of digital games in education were identified:

1. Embedding repurposed commercial digital games for use in education rather than recreation.

2. Creating and developing bespoke digital games for education.

3. Gamification platforms for education.

4. The educational value of learners designing digital games.

Detailed descriptions of what these categories encompass, and some examples of representative studies in each of these four categories are further explored below.

2.2.1 Embedding repurposed commercial digital games in education

In the context of digital game-based learning, embedding repurposed commercial digital games involves identifying a commercial digital game that has themes relevant to a specific subject matter and embedding that game in the learning context in which the subject matter is being taught. The use of commercial games in serious applications has advantages and disadvantages. For example, repurposing a commercial digital game for educational purposes can provide learners with a polished and high-quality gameplay experience that is likely to align with their experiences of playing commercial digital games. However, educators are also unlikely to have any control over the subject matter for which commercial digital games have been repurposed and thus can only use the games in their current forms or scaffold additional learning around the commercial game.

A significant amount of research has sought to explore the repurposing of commercial digital games for educational purposes. One study investigated the effects of using the game Civilization III to teach world history to high school students [101] and showed that the game was an effective tool for supporting students who struggled with traditional educational approaches, but that students who worked well in traditional classroom structures were sometimes frustrated with the use of digital games in learning. Another study analysed the effects of Massively

Multiplayer Online Role Playing Games (MMORPGs), specifically Second Life, on communication skills and cooperative learning [98] and examined how MMORPGs could be used to deliver online education. It concluded that while MMORPGs offered some benefits in the delivery of training, a significant factor in the success of this type of game-based learning was the ability of educators and educational designers to manipulate such platforms to create serious games that meet the needs of learners.

One limitation in the research on commercial games is the diversity and variety of digital games that are studied for educational applications. Certain digital games, such as Civilization III, are popular with game-based learning researchers; however, other commercial games have been the subject of limited or no research. It is unclear why certain games have been selected for research and this lack of clarity can create problems for other researchers, as it can be difficult to generalise the findings of a study on a specific game to broader contexts.

2.2.2 Creating and developing bespoke digital games for education

Like the repurposing of commercial digital games for education, the development of bespoke digital games is widespread in education. It is particularly prevalent in research on primary and secondary education and has become an emerging area of research in tertiary education.

Bespoke digital games refer to games that have been developed for a specific educational purpose rather than for the purpose of entertainment. There are advantages and disadvantages related to developing bespoke games for education. The most obvious advantage of developing bespoke digital games is that the learning objective is clearly articulated in the design. However, in designing bespoke educational games, it can be challenging to create a suitably engaging experience that does not compromise the learning objectives [115]. Additionally, developers of bespoke digital games typically have smaller budgets at their disposal than developers of commercial digital games and thus cannot always reach the same graphical standards as commercial digital games. This has created a perception that bespoke educational digital games lag behind commercial digital games in terms of quality and gameplay experience [116].

Studies have shown that bespoke educational games can have a positive effect in specific contexts; however, critics have claimed that educational games are frequently sub-optimal and fail to achieve an appropriate balance between entertainment and education [115]. This has been attributed to the fundamental problems related to designing something as complex as a game, as it is a design process that requires the skills of both educational experts and game designers. Bespoke educational games that have been heavily influenced by educational experts are often pedagogically strong, but less effective at entertaining learners. Conversely, bespoke educational games that have been heavily influenced by expert game designers are often immersive, but do not have any clear learning outcomes for players [111].

The literature on the use of bespoke games in education is extensive and covers a range of subject areas, including mathematics [117], economics [118] and science [119]. DimensionM is a bespoke digital game that was developed to increase learners' performance in mathematics [120]. DimensionM teaches algebra to high school students using a three-dimensional immersive environment in which players must complete a series of missions before they can progress through the game story. Mathematical concepts are taught to players as they complete these missions. DimensionM includes a number of single player and multiplayer games that teach different aspects of algebra (e.g., Evolver!, Dimenxian!, Swarm! and Obstacle Course!). One study showed that high school students exposed to DimensionM games significantly improved their mathematical achievements compared to students who did not play DimensionM games [120]. However, while the results showed that exposure to DimensionM games was correlated with improved academic performance, the researchers did not find that students who played DimensionM had significantly higher levels of motivation to learn algebra than those who did not play DimensionM.

In addition to considering the value of bespoke digital games for changing learner knowledge of subject matter, researchers have looked at whether bespoke digital games can more effectively motivate learners than traditional methods of teaching can. One such study examined a digital game, Orbis Pictus Bestialis, that was designed to reinforce and integrate high school students' knowledge of ethology, behaviourism and animal learning [121]. Orbis Pictus Bestialis is a single player, three-level game. In each level, players are required to train a virtual animal to perform a specific task; however, the animals respond differently depending on the actions of the players. An evaluation of students' perceptions of the educational value of the game showed that students felt that the game was beneficial for learning and significantly more engaging than traditional methods used to teach the subject matter.

The use of bespoke digital games is not limited to primary and secondary education. Indeed, many examples in the literature showcase how bespoke digital games have been successfully used in tertiary education. One study, undertaken across three different tertiary cohorts, used three bespoke digital games to teach business and technology, economics and business management students, respectively [118]. The study compared the use of digital games and non-digital games in business and technology, economics and business management courses, respectively. It sought to determine whether students who used digital games performed better in their respective subject areas when assessed. Across each of the bespoke digital game groups, students showed a significant improvement in subject matter knowledge; however, the students' performance was found to vary based on age. Notably, participants aged under 40 in the digital game cohort had higher post-test scores than participants aged under 40 in the non-digital game cohort; however, no differences in post-test scores were found among participants aged over 40.

2.2.3 Gamification platforms for education

In the last decade, the increasing prevalence of digital games in mainstream culture has also led to the widespread adoption of gamification in education [122]. Gamification refers to the use of one or more game mechanics to augment a non-game environment to increase the motivation of the a learner to interact with the learning environment. Much of the literature on gamification explores whether the gamification of non-game learning environments can increase learner motivation to interact with subject matter as well as or better then a non-gamified environment.

As a relatively new field, the use of gamification in education has not yet been widely explored [123]. In addition to the use of gamification being a more recent advancement than the use of repurposed commercial digital games or bespoke games in education, gamification is also more often targeted at tertiary and higher level students than primary and secondary students. The literature suggests that the use of gamification could be beneficial in online education, as it has the ability to and motivate learners to complete activities they would not be strongly enough motivated to complete for other reasons, strengthen social ties and preserve the original focus of learning activities [124]. Due to the use of competition, which encourages learners to interact more with their peers and incentives learners to increase their exposure to course content, the use of gamification elements in online learning has also been shown to improve students' performance in quizzes [125]. Gamification has been successfully used to augment education across a number of subject areas, including computer science, cultural studies and language studies [126].

Gamification has also been shown to be appealing to learners [127]. Indeed, it has been found to increase learners' participation in their learning environments, by an increasing the number of student comments and posts in online activities [128]. However, to date, there is only limited evidence that the quality of participation in learning environments improves because gamification increases the quantity of participation [123].

Designing gamified systems is a complex process and the use of certain game mechanics to engage learners may not always have the desired effect [127]. To date, only a small number of studies have sought to evaluate the effects of individual game mechanics (e.g., leader boards), player engagement and players' enjoyment of gamified platforms. In one study, two revision tools were designed to help teach mathematics to high school students and adults. One online revision tool included an embedded game mechanic, but the other revision tool did not include any such game mechanic. The participants were then randomly allocated into one of two groups (one group had access to the online revision tool with the game mechanic and the other group had access to the revision tool without the game mechanic) [129]. The results showed that the group that had access to the gamified platform enjoyed their learning experience more than the other group, but there were no performance differences between the groups. Although the type of research undertaken by Attali et al contributes some interesting findings on the effects of individual game mechanics, it is unable to tell us how individual mechanics would alter the behaviour of learners in more complex gamified systems. The challenges of understanding individual elements effect learner behaviours in complex systems has been identified in the literature [130, 131]. When furthering understanding of the use of gamificaiton in learning, comparisons of a platform with a game mechanic to a platform with a different mechanic, or no game mechanic, fails to take into account that different outcomes may occur when gamified platforms effectively use a combination of game mechanics. The majority of contemporary implementations of gamification use a combination of mechanics to engage learners. To increase understandings of how game mechanics work in the context of gamification, researchers must develop approaches that can be used to evaluate clusters of game mechanics and explore how they interact with each other to create opportunities for specific experiences. To date, little research appears to have been conducted in this area. This may be due to the difficulties related to effectively evaluating how individual game mechanics interact with each other to foster engagement in gamified systems.

Finally, it has been shown that there are at least two approaches to using gamificaiton in learning that can be effective. Firstly, they provide users with different ways to achieve goals so that they can use the means that are the most meaningful to them [28]. Or, secondly, they allow users to set their own goals and rewards for completing activities within a broader program [28].

2.2.4. The educational value of learners designing digital games

The final category of research on serious digital games in education focuses on the process of designing games as an educational experience. Research that seeks to evaluate the process of designing games and how these processes can foster learning has become increasingly popular. Conversely, contemporary research into designing games for learning has tended to focus less on teaching specific skills (e.g., learning) and instead sought to evaluate how the process of designing games can benefit learners. For example, a recent study considered how the game design process can improve problem-solving skills and increase adolescents' interest in pursuing careers in science, technology, engineering and mathematics (STEM) [132]. Research has also indicated that the prevalence of learner designed games is likely to increase, as platforms that support the development of such games by non-game designers are becoming more prevalent [133].

A growing body of research has also examined the effects of User Generated Content (UGC) on learners; however, this research has not yet considered serious digital games specifically. Research has also been conducted into using UGC in mobile games, in which players were motivated to collect and share images with participants in a guessing game in exchange for receiving points in the game [134]. Further, the development of UGC by learners has been shown to positively support the process of cooperative knowledge building [135]. However, it should be noted that the quality of UGC developed by learners varies. Quality frameworks [136] or peer review processes need to be implemented to address this issue [137].

Research has shown that learners can be motivated to contribute UGC in digital games if additional rewards such as points are also used. Further, the development of UGC by learners in non-game contexts has been shown to positively affect the acquisition and reinforcement of knowledge. However, to date, little research has been conducted into the use of UGC in serious digital games in education.

2.3 Categorisation of educational digital games by audience

The scoping study of the literature on digital games also revealed that much of the research into educational digital games had been conducted around different audiences of learners. Three distinct educational audiences have adopted game-based learning: (i) primary and secondary education (ii) tertiary education and (iii) adult/lifelong learning. The last audience, adult/lifelong learning, is particularly relevant for this dissertation as health education is delivered to an adult audience. However, in order to provide the reader with an understanding of the wide scope of digital game-based learning, some examples of how digital games have been used for the three different audiences will be provided in the following section.

Digital game-based learning has been used across all three areas; however, it is much more widespread in primary and secondary education. This may be attributable to the now discredited theory that certain learners are digital natives who require the use of new media, such as digital games, to engage with educational materials. It may also be symptomatic of a wider cultural belief that playing and games are synonymous with childhood and youth and should occupy a lesser place in adulthood. If engaging in play is something that becomes less common as children transition to adults, it stands to reason that there would be an equivalent belief that adults are less disposed to digital game-based learning than children. There is still a perception that individuals move away from youthful activities, such as playing games, as they transition into adulthood. However, research has shown that many individuals play digital games well into adulthood. Indeed, one study showed that 44% of American game players are aged over 35 [4].

Finally, the lower prominence of digital game-based learning in adult education and tertiary education may simply be attributable to their later development in these educational areas. If this is the case, it is likely that game-based learning will become as prominent in adult education in the future as it is in primary and secondary education now. In the following paragraphs, examples are provided of how digital games have been applied across the three key game-based learning areas (i.e., primary and secondary education, tertiary education and adult education).

2.3.1 Selected descriptions of research on the use of serious digital games in primary and secondary education

Digital game-based learning is well established in primary and secondary education. The prevalence of digital games in primary and secondary education has resulted in a large body of literature that specifically examines the effects of game-based learning in the delivery of primary and high school education [138, 139]. There is a particularly long history of digital games being used in the delivery of mathematics and science education. A study of 50 primary school students conducted in the mid 1990s identified eight factors in digital games that can effectively motivate students to learn mathematics [117]: (i) meaningful learning (i.e., selecting a subject matter for the game that is highly relevant to children); (ii) goals (i.e., including progressive goals that children have to achieve within a game); (iii) success (i.e., ensuring that students derive feelings of accomplishment from achieving goals); (iv) challenge (i.e., requiring students to expend effort to achieve goals aligned with their abilities); (v) cognitive artefacts (i.e., using interactivity and communication tools to ensure students' comprehend the subject matter); (vi) association through pleasure (i.e., ensuring the long-term retention of the subject matter by linking it with the enjoyment of playing the game); (vii) attraction (i.e., the inherent appeal related to playing a game that arises despite any dislike towards the subject matter); and (viii) sensory stimuli (i.e., using high-quality graphics to increase the fun of playing the game).

In addition to demonstrating that digital games can motivate students to learn mathematics, research has shown that the use of commercial digital games can be as effective as alternative teaching methods at improving the mathematical knowledge of kindergarten students [140]. A study of 1,274 third grade students from disadvantaged schools showed that the use of digital games improved both students' motivation to learn and classroom dynamics [8]. Similar results were also found when digital games were used to teach mathematics to high school students. For example, a pre/post-test study was used to evaluate the effects of a digital game on 437 high school students. The results showed that the use of the digital game to supplement traditional classroom instruction increased students' acquisition of knowledge and their motivation to learn [141]. Further, digital games have been shown to effectively improve the acquisition of knowledge in computer sciences education and increase the motivation of both male and female students to learn computer science more than traditional methods [142]. The use of digital game-based learning in science is quite common; however, digital games have also been used in many other subject areas, including history [143] and geography [144].

2.3.2 Selected descriptions of research on the use of of serious digital games in tertiary education

The application of game-based learning in tertiary education is not as widespread as it is in primary and secondary education, but a variety of examples can still be found. Game-based learning has been particularly popular in augmenting the delivery of STEM training. One study examined whether an online digital game augmented civil engineering training and showed game-based learning was as effective as traditional training methods [145]. A digital game was also effectively used to teach tertiary level students mechanical engineering [146]. Additionally, digital games have been used to augment the delivery of tertiary level mathematics [147] and computer programming courses [148]. Game-based learning has also been used in tertiary education in non-STEM areas. One study of 32 final year business students showed that a digital game was an effective tool in teaching knowledge management [149].

2.3.3 Selected descriptions of research on the use of of serious digital games in adult education

Digital game-based learning has had some use in post-university vocational learning; however, it is not nearly as common as it is in other areas. In adult education, digital games have most commonly been used to augment the delivery of professional development courses in businesses, most notably to transform workplace practices and standards. In relation to the use of game-based learning among adults, gamification is more common than digital games. There are multiple examples in the literature of gamification being used to encourage employees in large organisations to complete internal training courses (e.g., human resource training or fire training). In one study, gamification was successfully used to engage employees in a workplace wellness program [150]. Another study considered whether designing gamified business tools (e.g., process management tools and security tools) would increase the use of such tools by employees [151].

2.5 Chapter summary

This chapter considered the use of digital games in serious applications, most notably their use in education and learning. It also provided a number of descriptions of digital games research that has been conducted for primary and secondary, tertiary and adult audiences. The next chapter sets out the findings of a narrative review of the literature that was undertaken on the use of digital games in the delivery of education to health professionals and health professionals in training.

Digital game-based learning for health professionals and students

Chapter 3

> *This chapter presents a narrative review of the literature on the use of digital games for the delivery of education to health professionals and health professionals in training. The structured review identifies six categories in the literature that digital game-based learning in health education can be classified in to. Finally, the chapter will draw conclusions on the state of the literature on the use of digital game-based learning in health education and where further research remains to be done.*

3.1 Digital games in health education

In the health sector, digital game-based learning encompasses two areas: (i) The field of health education - education and training for health professionals and health professionals in training ; and (ii) Consumer Education - education for patients or people at risk of developing health conditions, or seeking a more healthy lifestyle. The latter area (ii) is quite developed and uses digital games and gamification to deliver education to patients with health conditions or members of the public. Commercial manufacturers have been making digital games for patient education for several decades. In the early 1990s, two console games were released to support adolescents with Type I diabetes to manage their condition: Captain Novolin (1992) and Packy and Marlon (1995). Similar types of commercial products continue to be released (e.g., Glucoboy [2007] a digital game and accessory that was developed for the Gameboy Advance and PediSedate, released in the mid-2000s, and is a similar patient focused game and accessory that assists in the sedation of children undergoing dental procedures). Given the relatively long history of digital games in the delivery of health education to patients, considerable research has been conducted into the use of digital games in this type of health education. This includes research on the use of digital games to support patients with juvenile diabetes, which demonstrated that well designed digital games can be effective for improving patient self-efficacy to manage their condition [152]. Similar findings have been found regarding the use of digital games for adolescent cancer patients, which have been used effectively to improve patient adherence to treatment as well as knowledge of their condition and self-efficacy in managing their condition [153].

Conversely, comparatively little research has been conducted into the use of digital games in the training of health practitioners and students. One paper refers to a digital game being used in medical education in the 1970s [154]; however, the widespread adoption of digital games in health education did not truly begin until the end of the 20th century and structured research into the use of digital games only began to grow in the 21st century [138]. There is less research into the use of digital games to support health students and professionals then there is using digital games to education patients about their health conditions, or for delivering education in non-health contexts. However, the health sector has shown increasing interest in the use of digital game-based learning for delivering education to health professionals and health professions in training in the last five to ten years. Research interest into the outcomes of digital game-based learning in health education has also been on the rise. Although research interest into digital game-based learning for health education has been increasing, the research that does exist is restricted to specific discipline areas such as paediatric training [155] or geriatric training [156]. The exception to this is the literature on the use of digital games to reduce the learning curve for surgeons [157], which has garnered a significant amount of research interest including three systematic reviews in the area. The first systematic review [158], focused on the impact of exposure to commercial digital games on surgical simulator skills. This review concluded that experience with digital games increased the speed of skill acquisition for robotic but not endoscopic techniques. Additionally, training with commercial digital games alongside simulator training appeared to improve performance over time, compared to simulator use alone. The second review also looked at whether commercial digital game exposure impacted on surgical simulator skills but focused specifically at laparoscopic skills

[159]. This article concluded that medical students and trainees with commercial digital game experience had superior skills performing certain tasks on a laparoscopic simulator, and demonstrated improved efficiency and fewer errors than students and trainees with no commercial digital game experience. Finally, the third literature review looked more broadly at the role of serious games in medical education and surgical education for skills training [160]. This review concluded that serious games could be utilised to train technical and non-technical surgical skills. However, further validation of their benefits is necessary before serious digital games can be integrated more widely into surgical education curricula.

Although there is only a small amount of literature on the use both digital and non-digital games for training health professionals and students, a Cochrane review has been undertaken into the use of educational games for health professionals [161]. The aim of the review was to assess the effect of educational games on health professionals performance, knowledge and skills as well as on patient outcomes. Only studies that used a controlled trial methodology were included in The Cochrane review. Although the review identified several thousand unique articles, only two studies met all the inclusion criteria to be included in the review. The first game included in the study was designed for delivering training on infection control and was similar in style to the game show 'Family Feud' [162]. The second game was a board game designed to deliver case based training to health professionals [163]. The overall conclusion of the

Cochrane review was that further research was required to determine the educational value of games to improve health professional practice.

In spite of the growing popularity of digital games and gamification in health education, there is a number of notable gaps in the literature in regard to its use [66, 100]. Of particular note is a lack of research into the process of implementing digital games effectively for health education, an issue that has been acknowledged in the broader literature surrounding digital game-based learning [100]. Furthermore, there does not appear to be any research being undertaken on how to design digital games or gamification platforms for use in health education. A first step towards addressing this gap could involve looking at individual game mechanics and how they affect the player's experience of an educational digital game. Game mechanics are recurring components of a digital game that affect the gameplay experience [23], and often are the means through which the player achieves goals in the game [24]. Finally, educational evaluation frameworks that have been applied more broadly in health education are under utilised in health education. A framework that may be of relevance if applied to health education is Kirkpatrick's framework for evaluating training in organisations [164], due to its versatility when applied to both tertiary learning and professional development. Kirkpatrick's framework consists of four 'levels': Reaction, Learning, Behaviour and Results. *Refer to Figure 3.1 for an overview of the four levels of the Kirkpatrick Model.*

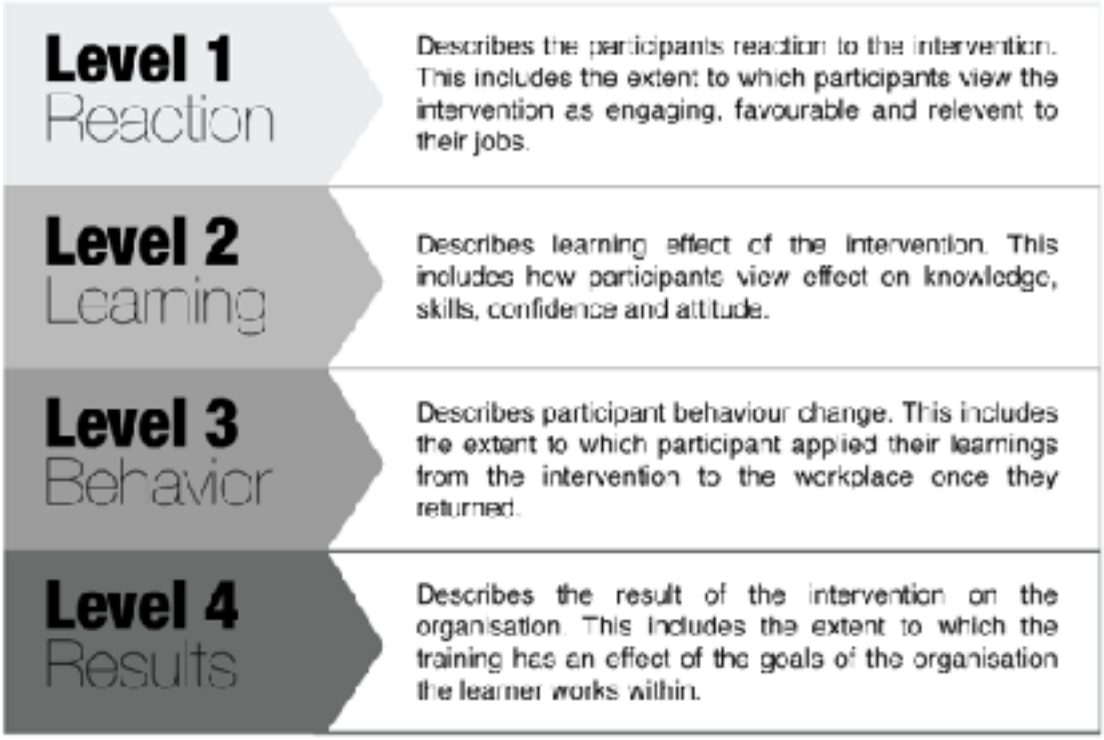


Figure 3.1.: The four levels of the Kirkpatrick Model

Four levels of the Kirkpatrick model.

This review aimed to identify and describe how digital games and gamification platforms have been used in the delivery of education for health professionals and health professionals in training. Additionally, the review aimed to determine the extent to which research had been undertaken into the process of designing and implementing digital game-based learning in health education.

3.2 Methodological approach for literature review

A search of the literature was conducted in July 2014 to identify articles that described how digital games and gamification platforms are being used to deliver education to health professionals and students. To ensure no relevant publications were missing from this review, the search was repeated in October 2016. There was no registered protocol for this review.

3.2.1 Literature inclusion criteria

The focus of the review was on the use digital games for the delivery of education for students undertaking tertiary level training to work in the health sector, and for delivering continuing education and training to health professionals. Only original articles from peer-reviewed journals written in English, conducted on human subjects were included. Health professionals and students were defined as students enrolled in a health degree, hospital trainees and professionals undertaking Continuing Medical Education (CME) activities. This included clinicians and students from the areas of medicine, dentistry, and nursing.

3.2.2 Literature exclusion Criteria

Literature was excluded if it was related to non-digital games such as board or card games, or if it only mentioned the use of digital games for health education peripherally. Literature about the use of digital games to deliver patient education was also excluded. Dissertations and publications that were not original articles such as literature reviews or editorials were excluded from the review. Finally, literature that was not possible to obtain an English language version of was also excluded.

3.2.3 Search Structure

A key word appropriate search of the literature was undertaken in five electronic databases academically recognised in the field of health: MEDLINE (1946 to present), ERIC (1966 to present), PUBMED, Cochrane Database of Systematic Reviews and Cochrane Library. *Refer to Table 3.1 for an example of the search strategy implemented into MEDLINE.* This entry style was modified as required for use in each database searched.

Table 3.1: Example of the search structure used for the narrative review.

Table 3.1: The search strategy in the MEDLINE database on 26.5.2014, which was replicated as appropriate in each other database searched		
Number	**Search Term**	**Number of Results**
1	Games, Experimental	1,415
2	Video Games	2,125
3	"Play and Playthings"	6,915
4	board gam*.tw.	138
5	educational gam*.tw.	81
6	((digital or serious) adj2 gam).tw.	163
7	role playing gam*.tw.	51
8	or/1-7	10,481
9	Education, Medical/	4,7430
10	Education, Medical, Graduate	21,642
11	Education, Medical, Undergraduate	18,109
12	"Internship and Residency"/	34,841
13	Education, Dental/	12,737
14	Education, Dental, Graduate/	1,717
15	Education, Nursing/	28,223
16	Education, Nursing, Graduate/	6,447
17	Students, Health occupations/	1,672
18	Students, Medical/	21,540
19	Students, Dental/	4,770
20	Students/Nursing	16,949
21	medical student*.tw.	22,775
22	dental student*.tw.	3,545
23	nursing student*.tw.	7,912
24	or/9-23	191,225
25	8 and 24	274

3.2.4 Study selection and data extraction

Articles returned from the structured search were exported into the software EndNote for review. Articles were initially reviewed to remove duplicates, and entries that were not from English language journals. After removal of duplicates the remaining articles were reviewed for alignment with the selection criteria based on the title, then title and abstract. Any articles that could not be definitively removed based on a title or title and abstract review underwent a full-text review for alignment with the inclusion criteria.

Data from all articles that met the inclusion criteria were extracted into a Microsoft Excel spreadsheet for structured review. Spreadsheet headers for categorising the data extracted from relevant articles included, but were not limited to Citation, Methods, Results, Conclusions, Game Name and Collaborative Game. Results from this review are presented as descriptive data, due to the high frequency of mixed methods or qualitative only studies undertaken of serious games in health education.

3.3 Results of literature review

The initial database search, conducted in June 2014, returned 1,114 results. Once duplicates were removed 439 results remained. Abstracts for each of the remaining articles were reviewed for alignment with the inclusion criteria. At the conclusion of this stage of review 44 articles remained. The full text of each of these articles was reviewed, which resulted in the exclusion of a further seven articles. The remaining 36 articles were reviewed in full in order to identify themes around how digital games had been used for the delivery of health education. The re-run database searches, conducted in October 2016, returned an additional 58 results. Abstract and title review excluded 40 of the articles, leaving 35 for full-text review. Upon full-text review an additional 25 articles were removed for not meeting the exclusion criteria, leaving ten articles. Thus, a total of 46 articles are included in this literature review. *Refer to Figure 3.2 to see the PRISMA [165] flow diagram of the search strategy.*

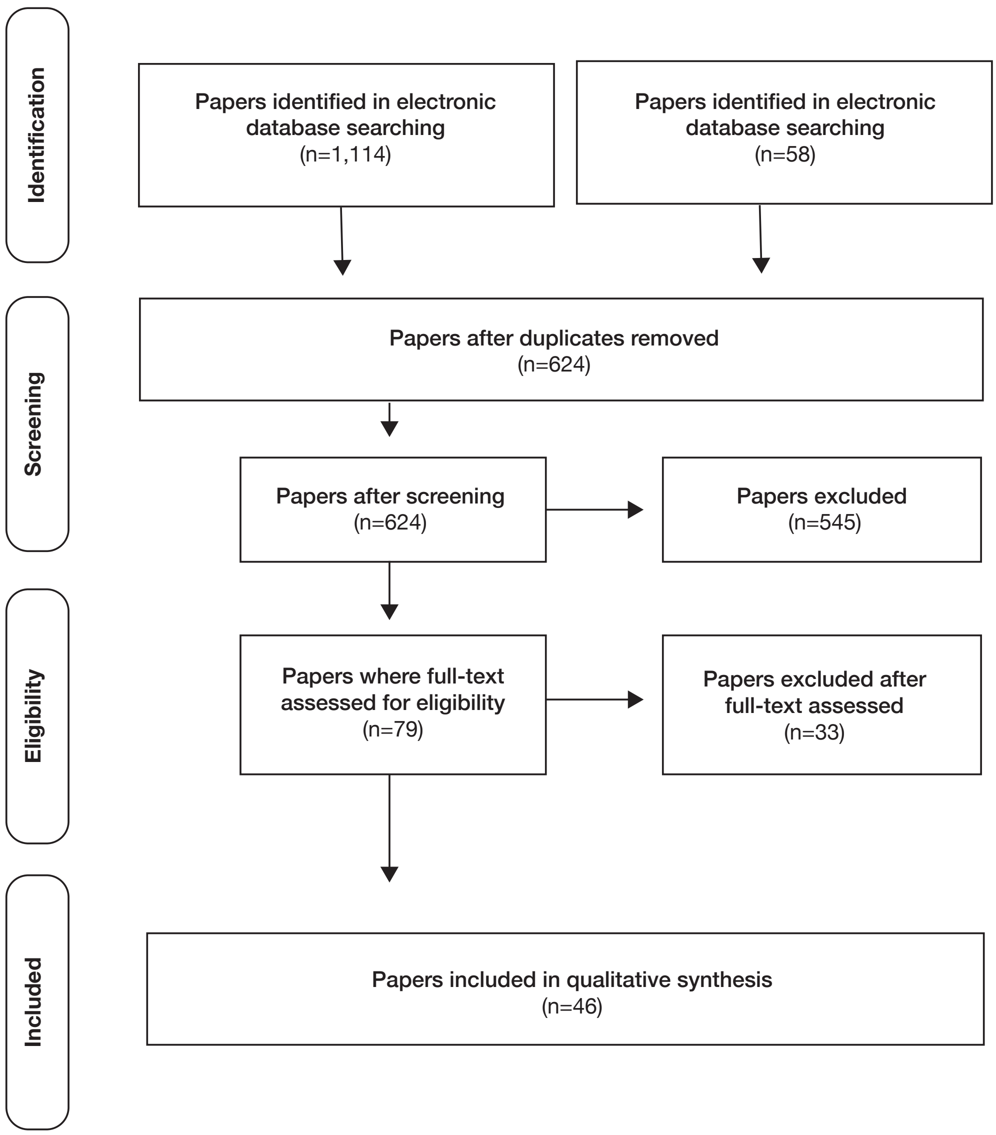


Figure 3.2.: PRISMA flow diagram for the narrative review.

The PRISMA flow diagram for the structured review of the literature on the use of digital games in health education.

The process of analysis of the 46 articles that met the inclusion criteria for this review. *Refer to Table 3.2 for a list of articles identified in the review aligned with their broad themes.* The review resulted in the identification of six broad themes:

1. Digital games and gamification to predict and support skill development;

2. Digital games and gamification as a tool for engagement;

3. Impact of digital games and gamification on knowledge;

4. Attitudes towards competition in digital games and gamification platforms;

5. Attitudes towards cooperation in digital games and gamification platforms;

6. Design and development of digital games and gamification platforms.

Table 3.2: Articles identified in the narrative review of the literature.

Table 3.2: An overview of the articles identified in this review or the literature, sorted by theme.				
Article Name	**Authors**	**Year**	**Game Category**	**Game Name**
Theme One: Digital games and gamification to predict and support skill development				
Does video gaming affect orthopaedic skills acquisition? A prospective cohort-study.	Khatri, C et al.	2014	Repurposed/NA	N/a
Comparing video games and laparoscopic simulators in the development of laparoscopic skills in surgical residents.	Adams, B J et al.	2012	Repurposed	Call of Duty 4: Modern Warfare
Training surgical skills using nonsurgical tasks--can Nintendo Wii improve surgical performance?	Boyle, E et al.	2011	Repurposed	Super Monkey Ball
Impact of video game genre on surgical skills development: a feasibility study.	de Araujo, TB et al	2016	Repurposed	Trauma Centre: New Blood, Resident Evil 4 (Shooter), Need For Speed: Carbon (Racing)
Relationships among video gaming proficiency and spatial orientation, laparoscopic, and traditional surgical skills of third-year veterinary students.	Millard, HA et al.	2014	Repurposed	Skeet shooting, Mario and Sonic at the Beijing 2008 Olympic Games, Archery, Mario and Sonic at the Beijing 2008 Olympic Games and Target Shooting, Mario and Sonic at the London 2012 Olympic Games

Can video games be used to predict or improve laparoscopic skills?	Rosenberg, B H et al	2005	Repurpose d	Top Spin, XSN Sports, Project Gotham Racing 2, Bizarre Creations, Amped 2, XSN Sports on Xbox
Systematic video game training in surgical novices improves performance in virtual reality endoscopic surgical simulators: a prospective randomized study.	Schlickum, MK et al.	2009	Repurpose d	Chessmaster or Halflife 2
Play to become a surgeon: impact of Nintendo Wii training on laparoscopic skills.	Giannotti, D et al.	2013	Repurpose d	Wii Sports Tennis, Wii Sports Table Tennis and Battle at high altitude
Prior video game exposure does not enhance robotic surgical performance.	Harper, JD et al.	2007	Repurpose d	N/a
Surgical novices randomized to train in two video games become more motivated during training in MIST-VR and GI Mentor II than students with no video game training.	Hedman, L et al.	2013	Repurpose d	Half Life and Chessmaster
Comparison of Nintendo Wii and PlayStation2 for enhancing laparoscopic skills.	Ju, R et al.	2012	Repurpose d	Time Crisis 2 and Boomblox
The impact of video games on training surgeons in the 21st century.	Rosser, J C et al.	2007	Repurpose d	Super Monkey Ball 2 (Nintendo Game Cube), Star Wars Racer Revenge (PS2), and Silent Scope (Xbox)
Visuospatial skills and computer game experience influence the performance of virtual endoscopy.	Enochsson, L et al.	2004	N/a	N/a
Should surgical novices trade their retractors for joysticks? Videogame experience decreases the time needed to acquire surgical skills.	Shane, M D et al.	2008	N/a	N/a
Video gaming enhances psychomotor skills but not visuospatial and perceptual abilities in surgical trainees.	Kennedy, A M et al.	2011	N/a	N/a

Nonsurgical skills do not predict baseline scores in inanimate box or virtual-reality trainers.	Madan, A K et al.	2008	N/a	N/a
Video gaming in children improves performance on a virtual reality trainer but does not yet make a laparoscopic surgeon.	Rosenthal, R et al.	2011	N/a	N/a
A serious game for learning ultrasound-guided needle placement skills.	Chan, W Y et al.	2012	Gamificaiton	Ultrasound-guided Needle Placement Game
Impact of a web based interactive simulation game (PULSE) on nursing students' experience and performance in life support training--a pilot study.	Cook, N F et al.	2012	Bespoke	PULSE
3D CPR Game Can Improve CPR Skill Retention.	Li, J et al.	2015	Bespoke	Unspecified
Theme Two: Digital games and gamification as a tool for engagement				
Evaluation of a 3D serious game for advanced life support retraining.	Butussi, E et al.	2013	Bespoke	EMSAVE
Impact of a web based interactive simulation game (PULSE) on nursing students' experience and performance in life support training--a pilot study.	Cook, N F et al.	2012	Bespoke	PULSE
Gamification: An Innovative Teaching-Learning Strategy for the Digital Nursing Students in a Community Health Nursing Course.	Day-Black, C et al.	2015	Bespoke	Outbreak at WatersEdge: A public health discover game AND EnviroRisk
A serious game can be a valid method to train clinical decision-making in surgery.	Graafland, M et al.	2014	Bespoke	Medialis
The impact of specially designed digital games-based learning in undergraduate pathology and medical education.	Kanthan, R and Senger, J L.	2011	Bespoke	Path to success and Path is Right
The evaluation of Game-Based e-learning for medical education: a preliminary survey.	Lin, C C et al.	2005	Bespoke	GBeL (based on MMORPG Well of Souls).
Diagnose: A Medical Computer Game Utilizing Deductive Reasoning.	Nelson, C D et al.	1979	Gamification	Diagnose
Serious gaming and voluntary laparoscopic skills training: a multicenter study.	Verdaasdonk, E G et al.	2009	Gamification	SIMENDO competition module
Appraisal of face and content validity of a serious game improving situational awareness in surgical training.	Graafland, M et al.	2015	Bespoke	Unspecified
Theme Three: Impact of digital games and gamification on knowledge				

Evaluation of a 3D serious game for advanced life support retraining.	Buttusi, E et al.	2013	Bespoke	EMSAVE
Effectiveness of a serious game for medical education on insulin therapy: a pilot study.	Diehl, LA et al.	2015	Bespoke	InsuOnLine
Learning while having fun: the use of video gaming to teach geriatric house calls to medical students.	Duque, G et al.	2008	Bespoke	Riskdom-Geriatrics
The impact of specially designed digital games-based learning in undergraduate pathology and medical education.	Kanthan, R and Senger, JL.	2011	Bespoke	Path to success and Path is Right
An online spaced-education game to teach and assess residents: a multi-institutional prospective trial.	Kerfoot, B P and Baker, H	2012	Gamification	Qstream
A randomized controlled trial on teaching geriatric medical decision making and cost consciousness with the serious game GeriatriX.	Lagro, J et al.	2014	Bespoke	GeriatriX
Theme Four: Attitudes towards competition in digital games and gamification platforms				
Development and evaluation of an interactive Web-based breast imaging game for medical students.	Roubidoux, M A et al.	2002	Bespoke	Breast Cancer Detective
Use of a Web-based game to teach pediatric content to medical students.	Sward, K A et al.	2008	Bespoke	PEdiatric Board Game (modified
Serious gaming and voluntary laparoscopic skills training: a multicenter study.	Verdaasdonk, E G et al.	2009	Gamification	SIMENDO competition module
Theme Five: Attitudes towards cooperation in digital games and gamification platforms				
eMedOffice: a web-based collaborative serious game for teaching optimal design of a medical practice.	Hannig, A et al.	2012	Bespoke	The Business Game: How to start a medical practice
The development of an interactive game-based tool for learning surgical management algorithms via computer.	Mann, B D et al.	2002	Bespoke	N/a
Use of a Web-based game to teach pediatric content to medical students.	Sward, K A et al.	2008	Bespoke	PEdiatric Board Game (modified
Theme Six: Design and development of digital games and gamification platforms				

Exploring design requirements for repurposing dental virtual patients from the web to second life: a focus group study.	Antoniou, P E et al.	2014	Repurpose d	Second Life
Development of the e-Baby serious game with regard to the evaluation of oxygenation in preterm babies: contributions of the emotional design.	Fonseca, L M et al.	2014	Bespoke	e-Baby
Development and evaluation of an interactive Web-based breast imaging game for medical students.	Roubidoux, M A.	2002	Bespoke	Breast Cancer Detective

3.3.1 Theme One: Digital games and gamification to predict and support skill development

A total of twenty articles presented findings on the use of digital games to predict and support skill development in health professionals and trainees, making it the most common area of research interest [2, 12-30]. The literature in this area focused on whether exposure to or experience with commercial digital games predisposes individuals to develop clinical skills. In all but one instance, the literature in this area evaluated repurposed commercial digital games. Most articles did not specify why they selected specific commercial digital games. The studies that stated why they selected specific commercial digital games identified one of two reasons. Firstly, because the games were popular at the time of the research study or secondly, because the commercial digital games required players to use certain skills such as complex motor coordination which seemed well aligned with the clinical skill being developed [166, 167]. Additionally, two articles indicated they chose commercial games developed for the Nintendo Wii console because the device controllers tracked motion gestures [168]. One study evaluated a bespoke game developed to evaluate the value of a serious game for improving CPR skills [169]. Finally, one of the articles exploring digital games to predict and support skill development involved the use of gamification [170].

The majority of articles (n=13) reviewed in this category used a quantitative methodology, almost always a randomised trial, to evaluate the impact of digital game exposure on specific skills [13-30]. Typically, participants in these studies were surveyed to determine the extent of their exposure to digital games, and stratified into a video game or non-video game group, based on the survey response. They were then asked to perform specific tasks and evaluated by an assessor or some other measure. The results for the two groups were then compared to determine the impact of digital game experience on performance of the specific skill. The remaining articles used a mixed methodology to evaluate the impact of digital game exposure to predict and support surgical skills development. Qualitative measures such as non-validated surveys were often used to measure secondary findings such as participant engagement with the game played [157, 166]. It was uncommon for articles evaluating the impact of exposure to commercial digital games on clinical skills development to use other qualitative measures such as focus groups or interviews. A range of study populations were used across the articles. The most common demographic were medical students, who were studied in ten articles [167, 169, 171-178] and surgical trainees, who were studied in six articles [157, 166, 168, 179-181]. The study demographic for one article was preregistration nursing students [182], and one other was third year veterinary science students [183]. A number of articles used a combined demographic of medical students and surgical trainees, or medical students and health professionals such as experienced surgeons.

Due to the significant amount of research in this area, articles in this category have been divided into three additional sub-categories which emerged during the review:

1. How does recreational use of commercial video games improve skills performance?

2. How does exposure to specific commercial games improve skills performance?

3. How can bespoke digital games and gamification systems improve skills performance?

How does recreational use of commercial video games improve skills performance?

A total of ten articles presented findings on the impact of recreational experience with commercial digital games in predicting high performance on surgical simulators [157, 166-168, 172, 175-177, 183, 184]. All but one of the articles in this sub-category returned results indicating that recreational use of commercial digital games improved skills performance, but this improvement was not always statistically significant. The remaining article investigating the impact of recreational use of commercial video games found there was no correlation between digital game use and simulator performance.

The majority of research articles in this sub-category concluded that recreational, commercial digital game use could improve performance on a surgical simulator. Some of the articles also included additional conclusions about the impact of recreational digital game use and skills performance [157, 166, 175, 176, 184]. One article demonstrated a link between exposure to commercial video games and improved performance on simpler simulator tasks, but not on more complex ones [184]. Similarly, another study demonstrated that video game experience improved bead transfer skills on a laparoscopic simulator, but not suturing technique [176]. This study had a sample size of 42 made up of obstetrics and gynaecological house staff. Each participant undertook a pretest on a simulator to establish a baseline for performance. Participants in this study were then randomised into one of two groups to play a commercial video game: Time Crisis 2 or Boomblox, before completing a post-test on the surgical simulator. The researchers did not directly specify why they chose the commercial digital games they did. However, it was stated that the Nintendo Wii game console was of interest because it used a motion controller which required players to use fine motor skills and undertake precise manoeuvres which mimicked those required in laparoscopy surgery. One study demonstrated that experience with commercial video games was a means of predicting how quickly trainees would obtain skills on laparoscopic surgical simulators [157]. A third study reported similar findings, though the authors noted the phenomenon only occurred when the commercial video games participants had experience with had similar interfaces to the virtual reality simulator being used [175]. The final study evaluated how effectively 31 surgical residents performed specific laparoscopic skills on a simulator. In this study participants who had played commercial video games for more than 10 hours a week prior to simulator use had the fastest completion times on the simulator [166]. This study also surveyed the participants about their experiences with commercial video games, with participants stating playing video games were an effective means of easing stress and promoting relationships between colleagues.

The study that found no correlation between video game experience and performance had a sample size of 242 medical students [172]. The students were asked to complete a survey about their recreational activities, including commercial video game exposure. Participants were then allocated to cohorts of 20 and asked to perform a series of tasks on a surgical robot, which were evaluated. The research team used this information to determine whether certain recreational activities correlated with improved performance on a surgical robot. Commercial video game experience did not improve robotic surgical performance, the participants with video game experience fared worse than other recreational activities such as playing a musical instrument. The researchers postulated this might be due to the reliance on 3D hand motions in robotic surgery, which was a skill that might not be well developed in commercial video gameplay.

In summary, results of this review indicate that recreational experiences playing serious digital games may improve performance on surgical simulators. However, this benefit appears to be dependent on the task being performed on the surgical simulator and the types of recreational, commercial games the individual has exposure to.

How does exposure to specific commercial games improve skills performance?

A total of eight articles presented findings on the impact of exposure to specific commercial digital games in improving performance on surgical simulators [171-174, 178, 179, 181]. All but one of the articles in this sub-category returned results indicating that recreational use of commercial digital games can improve the performance of health professionals and health professionals in training on surgical simulators. The remaining article found there was no difference in surgical simulator performance between participants exposed to commercial digital games, and those who were not.

As with the sub-category on recreational use of digital games as a predictor of surgical simulator performance, the majority of articles in this sub-category only indicated whether exposure to specific commercial digital games did or did not impact participant performance. However, some of the articles presented further conclusions or looked at simulators not typically used in the literature. One study demonstrated that experience with commercial video games was a means of predicting how quickly trainees would obtain techniques on surgical virtual reality simulator [174]. Additionally, one article presented information about what level of exposure to commercial video games was required to impact on laparoscopic skills performance. In that study were exposed to different genres of video games to investigate how they impacted on different surgical skills [178]. The article demonstrated that games in the shooter or simulator (surgical) genre were more likely to improve simulator performance than games in the racing genre, even if participants played them less. The authors concluded this effect might relate to the complexity of the game, with more complex games having more impact on surgical simulator performance. Another study demonstrated that video game players performed demonstrably better at psychomotor tests on laparoscopic simulators, but not on perception or visual spatial ones [179]. This study had a sample size of 38, all of the participants were surgical trainees who were stratified into groups based on the amount of time they spent playing commercial video games.

Finally, one article also presented findings on the impact of commercial video game experience and performance on and orthopaedic simulator but found no difference between participants with and without such experience [181]. This study surveyed 38 surgical trainees about their experience with commercial video games and used this to stratify them into two cohorts. Both cohorts completed tasks on a simulator and were compared to determine which group performed better.

To summarise, results suggest that exposure to specific commercial digital games may improve the speed with which individuals learn to use a surgical simulator, as well as their performance in some tasks. However, there is insufficient detail in the literature to determine whether this effect is determined by exposure to specific commercial digital games or not.

How can bespoke digital games and gamification systems improve skills performance?

Of the twenty articles on the use of digital games on clinical skills development only three looked at a bespoke digital game or a gamification system [169, 170, 182]. Of these three articles, two of the articles evaluated bespoke digital games to improve performance of Cardiopulmonary resuscitation (CPR) training [169, 182]. The remaining article looked at the impact of a gamification system on developing needle placement skills [170].

Both of the studies on the use of bespoke digital games to deliver CPR training used a controlled trial to evaluate the impact of the games on participant skills, and both showed a significant increase in CPR performance by the game group compared to the non-game group. One article evaluated the impact of a bespoke digital game on 34 nursing students, with 18 having access to the digital game. All participants were enrolled in a standardised training workshop consisting of lectures, simulated scenarios and small group skills demonstrations. Four weeks prior to the course all participants received access to the course manual and completed an online quiz. Two weeks prior to the course the game group were also given access to the online game. During the workshop, all participants were evaluated across a range of skills stations by experts, and the results compared across the game group and the non-game group. Across eight of the skills stations there was no difference between control and non-control, but across three there was a significant difference showing an improvement in skills for the game group. The second article presented results of a study of 97 medical students who had no prior experience doing CPR. Participants were randomly assigned to one of two groups, a game group and a non-game group. The game group had access to the game for three months, where as the non-game group were advised to complete independent study using resources provided. After three months both groups were tested, and the game group performed better than the non-game group.

The article which presented findings on the use of gamification to improve performance on a needle placement simulator, compared to no-gamification [170]. The study divided 18 participants into two groups of 9, to test the gamification based training process against the simulation based training process. Both groups played five sessions on their respective systems. The performance of both groups was compared to a baseline established by three individuals who were experienced with simulators. There was no difference in performance on the simulator and the gamification based training system for the experienced participants. However, there was a significant improvement in the success rate on the simulator for the game group, compared to the non-game group. The group on the system with gamification also significantly reduced the time it took to complete each task in their system.

In summary, results from the literature indicate that bespoke digital games can be used to improve the performance of skills by health professionals and health students. The available literature indicates bespoke digital games can be effective for delivering CPR training. Regarding improving needle placement skills on a simulator, gamification is beneficial for trainees but offers no benefit for experienced health professionals.

3.3.2 Theme Two: Digital games and gamification as a tool for engagement

A total of nine articles returned from this literature review discussed the relationship between gamification or serious digital games in increasing student engagement in the delivery of health education [15, 31-38]. The articles covered a wide range of health education areas including a digital game to teach deductive reasoning skills [185], surgical training on a laparoscopic simulator [186], clinical decision making in surgery [187], pathology training for medical students [188] and to deliver a virology lesson on Japanese Encephalitis [189]. The majority of research in this area focused on the impact of gamification and digital games on medical students (n = 3). Additionally, an equal number of articles studied surgical trainees (n=2) and nursing students (n = 2). The remaining research article looked at the impact of digital games for engaging nurses undertaking professional training. The majority (n = 7) of games used were bespoke [182, 187-191], with two articles evaluating the use of gamification to engage learners [185, 192]. None of the articles in this category used repurposed commercial digital games. In all of the articles a mixed or wholly qualitative methodology was used to evaluate the serious games used.

Both of the articles presenting findings on the impact of gamification in health education demonstrated it has a positive impact on student engagement with learning material, for both medical students [185] and surgical trainees [186]. In both instances, the gamification aspect of the learning platforms involved the incorporation of leaderboards that showed individual student scores for engaging with the learning system. In the first article it was identified that the medical students found the use of leader boards engaging, increasing their motivation to replay and master the training activity to see their name on the leaderboard [185]. In the second article participants noted that the online leaderboard encouraged them to repeatedly use the virtual reality simulator in order to improve their clinical skills when they would not normally be motivated to do so [186].

A total of six articles looked at the role of bespoke digital games for engaging learners in health education [182, 187-191], with two articles also looking at the impact on participant knowledge [188, 190]. All of the articles found that the use of digital games was an effective means of engaging students in a range of learning activities. Although all the studies concluded digital games had positively engaged learners in education and training, none of them provided details of how the games did this. However, some of the articles included additional findings regarding the positive impact of the serious games on learners. One study concluded that gaming increases students overall motivation to learn, thus increasing the chances of effective transfer of knowledge [191]. In another study participants noted that that playing the serious digital game was a valuable means of assessing the limits of their knowledge, with some students also noting the experience helped them relieve stress [188].

In summary, the literature about this theme indicates that gamification and digital games are an effective means of engaging skills across multiple areas. However, there are gaps in the literature on how digital games and gamification engage health professionals and health professionals in training. It must also be acknowledge that there is only a small number of articles in the literature on the use of digital games for education and engaging health professionals and students, and many of the studies these describe have small sample sizes. Furthermore, there is a notable gap in the literature on the use of digital games and gamification for engaging health professionals in education and training, rather than just health students.

3.3.3 Theme Three: Impact of digital games and gamification on knowledge

Of the 46 articles reviewed, six presented findings on the impact of digital games or gamification on learner knowledge [156, 188, 190, 193-195]. Two of these also presented findings on how participants engaged with digital games [188, 190]. All of the games evaluated in this category were bespoke [156, 190, 193, 194], or involved the use of gamification [188, 195]. There were no studies evaluating repurposed commercial games. Five of the articles used medical students as their study demographic [156, 188, 190, 194, 195], with the remaining articles using nurses as a study demographic [190]. All but one of the articles used a mixed methodology to evaluate outcomes. The remaining article used a randomised controlled trial with a pre-post test to measure knowledge change [156].

The articles presented findings on a wide range of health education specialties including improving delivery of insulin therapy [193] and pathology education [188]. Two of the articles looked at improving teaching of geriatric education to medical students with one focusing on improving the ability of students to make decisions and be cost conscious [156] and the other focused on teaching students how to undertake geriatric house calls [194]. Although these two articles were both in the same speciality area, they did not use the same bespoke digital game.

All but one of the articles demonstrated an improvement in the knowledge of study participants, either through comparison of pre and post test scores or comparison against a control group that did not receive access to the game/gamification platform [156, 188, 190, 195]. These articles included one that presented findings on the use of a digital game for delivering undergraduate pathological medical education to 114 first year and 74 second year medical students [188]. It was concluded that the use of a digital game for pathology education not only improved test scores in participants but provided students with a valuable means of assessing the limits of their knowledge. Additionally, one article presented findings on the use of an online platform augmented through gamification to deliver training to 465 medical students demonstrated an improvement in participant knowledge, and also found the system could reliably help assess the limits of student knowledge [195]. The remaining study demonstrated equivalency between delivering insulin training to medical students using a bespoke digital game and through traditional methods [193]. The researchers further concluded that there were advantages to using the bespoke digital game to deliver training over the traditional method, including easier dissemination of content, and flexibility of use for students.

To summarise, results from this theme indicate a significant interest in the literature evaluating the impact of digital games and gamification on knowledge acquisition when used for delivering health education. Digital games and gamification appear to be effective in supporting knowledge acquisition in health education, and equivalent when compared to traditional methods. However, there is a notable gap in the literature on the use of digital games and gamification for supporting health professionals, with the majority of literature on this theme focusing on health students.

3.3.4 Theme Four: Attitudes towards competition in digital games and gamification platforms

Only three of the forty-six articles analysed as part of this review presented findings on competition in digital games and gamification platforms and how it impacted on students in the health sector. In all three articles, references to competition were presented as secondary rather than primary finding of the study [155, 192, 196]. Competition was always explored in the context of evaluating player engagement, never as an element that could impact on learning outcomes independently. None of the articles in this category evaluated repurposed commercial games, two presented findings on bespoke games [155, 196] and one on the use of gamification [186]. All three studies used a mixed methodology to evaluate the games, and all data collected on competition was measured using qualitative methods. Two of the articles presented findings on the attitudes of medical students towards competition in serious digital games [155, 196], with the third article using surgical trainees and interns as the study demographic [186].

Two of the articles found that students found the use of competition a significant motivator for completing educational tasks [155, 196]. In the article on the use of gamification to engage 31 surgical trainees in laparoscopic skills training, over 50% of participants identified a desire to 'win' on the leaderboard as the major motivator to keep completing the training [186]. In the second article, which used a bespoke digital game to deliver paediatric training to 42 medical students, competition was identified as a fun aspect of the game which engaged them. The remaining article reported students had mixed perspectives on how enjoyable competition was in digital games [196]. Some students felt it had no impact on their engagement and some actively disliked competitive aspects of digital games.

In summary, the literature on this theme indicated that the role of competition in digital games and gamification was not commonly researched. However, literature that did explore learner attitudes to the use of competition in digital game-based learning in health education found it was a significant motivator for most health professionals and students to complete education and training. However, some learners find competition off-putting and may dislike the use of competition in digital games.

3.3.5 Theme Five: Attitudes towards cooperation in digital games and gamification platforms

There is a relatively small amount of literature looking at player attitudes towards cooperative games in health education, which is likely correlated with the small number of serious digital games that support cooperative or collaborative play. A total of three articles in this review explored the role of collaboration or cooperation in the context of digital games in the health sector [155, 197, 198]. Two of the studies reported findings on cooperation only as a secondary objective of the study not a primary one [155, 197]. However, the remaining article had a primary focus on cooperative digital games to support health education [198]. All three articles used medical students as the demographic and evaluated bespoke digital games using mixed methodologies.

The article that presented findings on cooperation in a digital game as a primary outcome involved evaluating a bespoke game for teaching surgical management algorithms to 33 medical students [199]. The researchers used unstructured observation of participants during game play sessions, as well as a post-session survey to evaluate player experiences with the game. During game play sessions participants were observed to engage with their teammates to discuss patient management issues. A review of survey responses showed that participants enjoyed interacting with their teammates to discuss clinical management approaches, rather than just interacting with the computer game alone.

Both of the remaining articles also found a positive relationship between cooperative digital games and player engagement. In one study 41 medical students participated in 90-minute sessions of a game designed to teach optimal design of a medical practice [197]. Participants were in the same room during the session and cooperated with each other to grow a virtual practice and learn the skills required to run such a business when they were fully qualified physicians. A Likert ranking was used to evaluate the game play experience. Students rated cooperation with peers as a highly motivating factor that helped them engage with the game. In the second study 42 medical students were divided into four teams to play an online paediatric education game [155]. In this study collaboration with peers was identified as a major motivating factor that was both enjoyable and engaging. Additionally, some participants noted that collaboration was an important skill to master in clinical care, and it was beneficial to have a game that enhanced those skills.

In summary, the literature on this theme indicated that the role of cooperation in digital games and gamification was not commonly researched. However, literature that presented findings on the role of cooperation in digital game-based learning in health education showed it was consistently highly valued by students undertaking education and training activities. Not only were cooperative digital games viewed as enjoyable and motivating by learners, but they were seen as supporting the development of a skill that would be important throughout their professional careers.

3.3.6 Theme Six: Design and development of digital games and gamification platforms

Although the amount of research into designing and developing digital games is growing in the field of games based research, research into the design of serious games for health education is not as common. In the context of this review of the literature, a total of three articles addressed the design and development of digital games in a variety of formats [196, 200, 201]. Two of the articles described the development of a specific digital game: e-Baby [201]and Breast Cancer Detective [196]. The third article presented findings on designing a repurposed digital game for dental students using the commercial platform Second Life [200]. Different study demographics were used to evaluate all three of the games: dentistry students [200], nursing students [201] and medical students [196]. There were no articles returned in this review relating to the impact of having students design games as a means of reinforcing skills or delivering specialised health education.

All three articles presented different findings on aspects of design for serious digital games in health education. One article presented recommendations for improving the design of serious games for delivering health education (2). These recommendations included: 1) The use of text based instructions and narratives should be minimised in favour of using visualisation; 2) Games should be developed that encourage players to autonomously solve problems, rather than choosing options on a set list; 3) Useful feedback should be provided that players can use to improve their process as they progress through the game. The second article largely described the development process for the game e-Baby, but the authors concluded that the use of a user-centred design model and emotional design should be used more extensively when developing educational technologies [201]. Finally, the remaining article described the process of designing the game Breast Cancer Detective by using an expert content development team and incorporating a user-testing cycle to refine the game [196]. To refine the design of the game the development team undertook an initial user testing pilot with 13 medical students. They completed a game play session and rated the game using a Likert scale afterwards. This feedback was used to make revisions to the game, particularly relating to the instructions players were provided on how to play the game, before a follow-up evaluation session was undertaken with 42 students. These students were broken into three groups, one group played the game simultaneously in the same room, one played the game before a scheduled lecture, and a third group was asked to play the game at any time during the course. All students then completed a survey. This process allowed the development team to obtain insight into aspects of the game that participant found beneficial, and those that required further refinement.

To summarise the literature on this theme, it is clear that the design and development of serious digital games in health education are not a commonly researched topic. What literature does exist provides some insight into aspects of developing digital games for health education. However, there is little literature that could provide educators interested in the design and implementation of digital game-based learning for adult education guidance on how to use it effectively.

3.4 Discussion of findings from the literature

The results of this review indicate that there is not a significant amount of research into the use of digital games or gamification in the delivery of education to health professionals and students. Of the research that is undertaken there is a significant focus on the impact of digital games and gamificaiton platforms for developing clinical skills, particularly in relation to surgical simulators [166, 168, 202]. However, outside the use of digital games and gamification to inform surgical simulator performance, the research into the use of digital games in other areas of health education is much more varied. Some of the areas of health education that have been explored in the literature on digital game-based learning in health education include breast imaging [196], pathology [188] and evaluation of oxygenation in pre-term babies [201].

When considering the types of games used in digital game-based learning in health education, this review identified that bespoke games, games customs built for purpose, as being prevalent. It was uncommon for the same bespoke game to be used in multiple studies, with the exception of geriatric training where the game Geriatrix was used in three studies [156, 203, 204]. Additionally, commercial digital games were repurposed in studies on the impact of digital game exposure on clinical skills development [175]. However, commercial digital games were not repurposed in any other area of health education. Findings from this review also suggest that there is currently less research into the use of gamification for health education than there is into the use of digital games for the same purpose. The lack of research investigating how gamification effects learners makes it difficult to draw firm conclusions about when gamification will be beneficial to support health education and what about it might be effective for engaging learners or reinforcing their knowledge. Finally, it is clear from this review that there is notably more research into the use of single player digital games than multiplayer digital games. Only four in this review described multiplayer digital games, though those that did identify a beneficial outcome for learners from their use. However, there is currently no research evident in the literature looking at how and why multiplayer digital games support cooperative learning experiences in health education.

This review indicates that research into digital game-based learning in health education is heavily focused on outcomes of rather than processes through which digital games and gamification platforms alter the learning experience. With the exception of the three articles looking at the design of digital games for health education [196, 200, 201] none of the articles in this review presented findings about how players interacted with serious games and why the games studied impacted the learners in the way they did. There was also no articles presenting findings on how digital games could be embedded into health cirricula, though one article did present results stating that participants felt a digital game developed to improve situational awareness in medical students and surgical trainees would be useful for surgical fellows if integrated into their training [187]. Although identifying the outcomes of digital games of learners is very important, it seems clear from the literature that under the right circumstances games can improve knowledge of learners in the health sector. However, it is unclear in how digital games can be embedded into learning environments to support high quality game-based learning experiences. Furthermore, there is a gap in the literature on how digital games can be used in blended and online learning environments, an manner in which a notable portion of health education is delivered.

A related gap in the literature is the lack of research into the design of digital games and gamification platforms for health education. This review of the literature returned three studies with findings that related to the design of serious games in health education. However, these articles did not provide a comprehensive picture that could inform the design and implementation of digital game-based learning in health education, either at a tertiary or adult level. Furthermore, there was very little research into other key aspects of digital games and gamification platforms that may impact on learner engagement with digital game-based learning, such as the use of specific game mechanics to support knowledge and skills development or learner engagement with specific game genres. The broader digital game-based learning literature has explored the impact of genre on the learner experience. However, very little of this research from the broader literature has been applied in research on the use of digital games in health education. This review of the literature returned only one article that presented findings on the impact of game genres on player engagement [178]. Beyond this one example, none of the articles on digital games-based learning in health education mentioned game genre and its impact on learners in their discussions of findings. Even when commercial digital games were being repurposed it was uncommon for articles to state the digital game being repurposed, let alone the genre. Additionally, there is no literature that explores the impact of individual game mechanics or how they interact to create an engaging learning experience. The lack of literature presenting findings on the impact of individual game mechanics may be symptomatic of the small amount of research into gamification in health education.

3.5 Conclusion

There is a clear interest in the use of digital game-based learning for delivering education and training to health professionals and students. Furthermore, the evidence suggests that in the right circumstances digital games can improve learning outcomes in health education. However, the circumstances under which digital games can improve learning outcomes remain unclear. Future research is warranted into the processes digital games use to improve learner outcomes in health education and how digital games can be designed and implemented in a cost effective and beneficial way.

3.6 Chapter Summary

This chapter presented a detailed analysis of the literature on the use of digital games and gamification for the delivery of education to health professionals and students. This included identifying some of the under-researched areas in use of digital games for health education, as well as highlighting some notable gaps in the literature. The next chapter will introduce the reader to the concept of Design Research, and provide specific details of the objectives of this dissertation and the methodology used to inform it.

A design research approach to understanding serious digital games

Chapter 4

This chapter introduces the concept of design research. It begins by providing an overview of what design research means across a number of research areas. It then outlines the methodology used in this study. Finally, it sets out the primary and secondary objectives of this study.

4.1 Design research and the evaluation of educational technologies

'Design research' is an umbrella term that encompasses a range of methodologies and frameworks united by a shared use of design principles. The literature identifies design research as encompassing two difference branches: research to create knowledge that is of use to designers of items [205] and research that obtains data through the process of designing and testing items [206]. The later view of design research is most closely aligned with the approach taken in this dissertation. Research that obtains data through the design process often uses design experiments and user-centric, co-design or iterative approaches in the development of interventions or artefacts. The use of these types of design research methods are particularly useful in evaluating the processes related to the development and implementation of new technologies. As research into the development of digital technologies has increased, there has been a corresponding increase in the use of the design techniques and frameworks adopted to inform research methodologies. Over time, a shared understanding has developed as to what design research should encompass, regardless of the which methodology is used [207]. A design research approach is particularly effective to study artefacts and objects that are assumed to be effective in circumstances in which the reasons for the item's effectiveness are not well understood [208].

In the field of education, there has been a growing awareness of the value of using design research approaches to inform understanding of how items change our understanding of learning theory [209]. This type of design research in education is often termed 'Design-Based Research' (DBR). DBR has been described as 'a systematic but flexible methodology aimed to improve educational practices through iterative analysis, design, development, and implementation, based on collaboration among researchers and practitioners in real-world settings, and leading to contextually-sensitive design principles and theories' [208]. This description effectively captures the key points of DBR, noting that it should be iterative, inform educational practices and theory and be conducted in a real-world setting. It has also been stated that DBR researchers should conduct repeated implementation cycles (each of which have been slightly modified in their subsequent iterations) to ensure that findings are developed that can improve local implementation of specific educational interventions. The advantage of such an approach is that new knowledge can be derived from the initial iteration of any cycle and each of the subsequent iterations. However, it should also be noted that researchers are often hesitant to draw firm conclusions from their findings even after many iterative cycles [210]. DBR is a valuable tool for evaluating educational technologies, as it can overcome many of the challenges encountered by alternative approaches (e.g., laboratory findings can rarely be generalised to the classroom) [208].

One challenge that arises in evaluating educational technologies is that both the intervention and the learning environment may be complex. The complexity of the interaction between a digital game and the environment in which it is used can make it difficult to ascertain cause and effect. The inability to identify why an effect occurs is particularly problematic in the study of serious games in education, as the medium itself can vary significantly in terms of genre, content and accessibility. Design research seeks to understand the processes, systems and environments that affect the successful implementation of educational technologies by using complementary mixed method approaches.

The flexibility and iterative nature of DBR has advantages for the study of serious games. In one study, a DBR approach was used to develop the game, Quest Atlantis. This game was then used to teach scientific enquiry skills and concepts to students in grade six. This approach allowed aspects of the game to be refined to ensure that it had the desired effects in a classroom setting [211]. In another study, DBR was used to explore different iterations of the handheld game, Mad City Mystery, which had been designed to help school students develop their scientific enquiry skills. The latter study used different iterations of the game to increase understandings of how the use of digital games affected the learning environment [119].

DBR is not the only approach that has been used to evaluate educational games. One alternative approach that has been used in the design of commercial and serious games is the use of iterative prototyping [212]. This fundamental approach uses repeated play testing cycles similar to some of the processes used in DBR. The key difference between iterative prototyping and DBR is that the play testing cycles used in iterative prototyping focus on collecting data that can refine the design of the game rather than collecting data about human behaviours as players are exposed to a game and using that data to draw conclusions about how the game can be implemented in specific situations. It has been suggested that the use of iterative play testing could be useful in balancing the need for serious games to be both educational and engaging. Indeed, these play testing cycles could be used to ensure that a serious game is neither too pedagogically heavy or too entertainment focused [115].

To minimise development costs, but allow users sufficient access to a game to make evaluations, play testing should be undertaken at the end of the design phase, but before the serious game has been prototyped. Play testing sessions should be structured to ensure that each individual test player has sufficient time to experience a game. A moderator should also supervise each session. The same moderator should supervise each new test player who interacts with the game. Sessions should typically be recorded to enable the game developers to review the test players' experiences at a later point. Multiple cycles of play testing are often needed to finalise a serious game design [212].

One characteristic that unifies the different design approaches is the use of mixed methods to evaluate the development and implementation of educational technologies [210]. The use of mixed methods in research continues to evolve. Consequently, there is a lack of consensus as to what the term encompasses. However, the literature has broadly defined the use of mixed methodologies as an approach to research in which both qualitative and quantitative methodologies are used to collect and analyse data in a single study or program [213]. This approach to study design is particularly valuable in studies that seek to answer 'why' questions (as opposed to studies that merely seek to collect data to determine whether or not a specific intervention has had any effect) [214].

Mixed methodologies are favoured in design research studies that seek to gain a deeper understanding of why certain results have occurred.

4.2 The design research methodology

Developing methodologies that effectively capture how learners interact with technological mediums and not only the results of these interactions is a challenge for researchers across many disciplines [215-217]. The study described in this dissertation sought to investigate the use of two digital game-based learning interventions for use in health education (i.e., 'They Know: Anatomy' and the 'Qstream: Cancer Cup Challenge'). Both the 'They Know: Anatomy' and the 'Qstream: Cancer Cup Challenge' interventions were studied separately, as the platforms and study demographics were different. However, a mixed methodology, informed by a design research framework, was used to evaluate both interventions. Prior to beginning the evaluations of the two interventions, a structured review of the literature was undertaken to identify key research themes in the use of digital games in health education. The structured literature search was conducted between June and August 2014 and identified articles that described the use of serious games in health education. The structured search was re-run in October 2016 to find any subsequently published studies that were relevant to the literature review.

4.2.1 The methodological approach for the interventions

Quantitative measures

Qualitative measures (e.g., self-administered participant engagement surveys and semi-structured interviews) were primarily used in the evaluations; however, some quantitative measures (e.g., metrics collected by the individual game platforms) were also used. The 'They Know: Anatomy' platform collected metrics on how participants navigated the anatomy map and counted the number of times that participants needed to respond to questions to answer them correctly. The 'Qstream: Cancer Cup Challenge' platform collected metrics on the number of participants who completed the program and counted the number of attempts made by participants before they answered questions correctly.

Qualitative measures

Due to their ability to investigate the effects of game design on players' experiences, qualitative methods were used to collect the majority of the data in this study. In relation to the 'They Know: Anatomy' intervention, structured observations were collected to gain insights into player-player, player-platform and player-environment interactions. Observational data were collected from field notes made by the researcher during the gameplay sessions. In addition to field notes, each game play session was recorded, and the recordings were later reviewed by the researcher to verify the accuracy of the field notes. Together with the use of semi-structured interviews, this approach provided a holistic perspective of how digital games can be used to encourage knowledge retention and consolidation. In relation to the 'Qstream: Cancer Cup Challenge' intervention, beyond reviewing the metrics on how accurately participants' answered cases, it was not possible to observe the participants, as they participated in the study remotely. However, semi-structured interviews and post-game evaluations were used to understand how the participants responded to the game.

The semi-structured interviews were audio recorded, transcribed, de-identified and then thematically analysed [218, 219]. For the thematic analysis, an initial reading of the transcripts was undertaken to obtain an overview of their content. The transcripts were then re-read and a structured analysis undertaken. In the structured analysis, each transcript was reviewed line-by-line to any identify key themes reoccurring in the transcript. These key themes were then grouped into categories and subcategories based on their similarity. The transcripts were read and re-read until no new themes emerged. During the thematic analysis, key quotations were highlighted to illustrate each category and subcategory.

4.3 Study objectives

The research undertaken in this dissertation sought to investigate the use of two digital game-based learning platforms in the delivery of health education. The two platforms both enabled participants to participate in team-based games (an under explored area in the games for health education landscape). Both games were also underpinned by the *testing effect* and both used the *spacing effect*. The use of two different digital games provided an opportunity to compare and contrast the implementation of digital game-based learning in two different contexts. Although both game-based learning platforms had some shared features, they also had a number of differences. Firstly, there were both different genres (team based strategy and gamification). Secondly, one platform supported synchronous team-based game play and the second supported asynchronous gameplay. Different platforms were used in order to enable the researcher to look at two different audiences for health education (tertiary students and health professionals). Whilst tertiary students were able to play a synchronous game, health professionals had less time available for education and training and thus were more likely to participate in an asynchronous game. Although different platforms were used for the two interventions, shared objectives were adopted for evaluating both interventions as the researcher wanted to gain insight into the implementation of digital game based-learning for both health professionals and health students.

The primary objective of the research undertaken in this dissertation was to explore the ways in which serious digital games and gamification platforms can support cooperative learning in adult education. The secondary objectives for this research were to:

- Identify how digital game-based learning has been used in the delivery of health education.

- Investigate whether digital games can appeal to learners across different health areas.

- Identify a methodology to research the process of implementing digital game-based learning in health education.

4.4 Chapter summary

This chapter represents the end of the first part of this dissertation. This chapter introduced the concept of design research and discussed how this concept has been applied in the context of education and digital game development. Additionally, the chapter outlined the methodological approach adopted by this research. In the next chapter, a detailed description of both game platforms is provided and the two games developed for use in this study are described.

Designing, implementing and evaluating the interventions

Chapter 5

This chapter introduces the two digital game platforms examined in this study. Specifically, it details how each platform works and why each platform was selected for the study. It then describes the development process for each of the platforms used in this study. Finally, this chapter outlines how each of the platforms were evaluated. It notes that evaluation methods were selected to ensure that meaningful insights would be gained into (i) how the players interacted with each of the game platforms; (ii) how players interacted with other players in the multiplayer digital games; and (iii) how digital game-based learning can be implemented in adult education.

5.1 Introduction

The value of digital games other than as a form of recreation and entertainment is now widely acknowledged. Outside their traditional application, digital games represent a valuable medium for use in serious applications, including in the areas of health and education. In the area of health, digital games have been used to increase patients' compliance with treatment plans [153]. They have also been used in rehabilitation activities (e.g., to improve individuals' fine motor skills) [220] and in the delivery of health education [221].

In the area of health education, a branch of research has sought to evaluate the effects of individual digital games in delivering knowledge-based interventions to health consumers or patients. However, only a limited number of studies have considered the use of digital games in the delivery of training to health professionals and trainees. Further, much of the research that has been conducted has been limited to exploring whether the use of digital games improves medical students' knowledge. Indeed, very few studies have sought to examine whether digital games can be used to change the behaviours of health professionals [222]. To increase understandings and address gaps in the literature, further research needs to be conducted into the game mechanics and characteristics of digital games that make them a valuable tools in the delivery of education to professionals in the health sector. To address the gaps in the literature, this study sought to explore two different digital game platforms that were deemed capable of supporting the delivery of serious games: 'They Know: Anatomy' and 'Qstream: Cancer Cup Challenge'. The researcher did not develop the platforms that 'They Know: Anatomy' and the 'Qstream: Cancer Cup Challenge were delivered via. However, the research did coordinate the content development for the two games and design how the platform delivered the content for the two games to the players.

The They Know platform was developed by a Sydney-based game designer who specialises in the development of team-based educational games [223]. The ‘Qstream: Cancer Cup Challenge’ platform was developed in Boston to deliver medical education [224]. Both game platforms enable players to identify their knowledge strengths and deficits and the areas in which they need to undertake further revision. Both platforms require learners to complete additional revision (a process that allows learners to review what they have learned). Further, both platforms require players to repeat the gameplay cycles until they feel confident in their level of understanding of a subject area and support the delivery of structured learning activities in a short time frame. However, in relation to the use of these game platforms in education, the most important feature that these two game platforms share is their capacity to support cooperative play (a feature supported by very few digital games in health education). Cooperative games allow multiple players to experience a game together and require players to work with their team members to reach a common goal (i.e., to win the game).

As stated above, this study sought to contribute to understandings of how serious games can be used to deliver training to health professionals and students. This chapter begins by describing the two game platforms (i.e., ‘They Know: Anatomy’ and ‘Qstream: Cancer Cup Challenge’). Each platform was selected for two reasons. First, each platform supports the development of multiplayer digital games, specifically team-based games. There is a small amount of research into the use of digital games in the delivery of health education; however, it appears that no study has sought to investigate how digital games support cooperation between players in this area. Second, both platforms are underpinned by the testing effect. The testing effect is based on the theory that the act of being tested is not a neutral experience that merely assesses knowledge, but one that can also be used to extend learners' knowledge and support the long-term retention of acquired knowledge [225-227]. It has been contended that the use of repeated testing in combination with periodic studying is the most effective way of ensuring the long-term retention of knowledge [228]. Finally, both platforms use repetition at spaced intervals to reinforce learning. The use of spaced intervals is underpinned by the spacing effect, which has shown that spacing and repeating information can improve long term retention of knowledge [229, 230].

The two game platforms share a number of higher-level similarities; however, they also offer unique and different methods of delivering digital game-based learning. The most significant difference between the two game platforms is that the 'They Know: Anatomy' platform can be played online synchronously with other players. Conversely, the 'Qstream: Cancer Cup Challenge' platform uses gamification to deliver an asynchronous online learning system. The 'They Know: Anatomy' platform also requires players to work together to complete game matches. Conversely, while the 'Qstream: Cancer Cup Challenge' supports team-based competition, it has fewer structures that seek to actively encourage interactions between players on the same team.

Finally, the ‘They Know: Anatomy’ platform provides players with a short duration gameplay experience in which they interact with the subject matter in a fun and enjoyable way and seeks to encourage learners to replay the game to repeatedly revise the subject matter. Conversely, the ‘Qstream: Cancer Cup Challenge’ intervention is a longer program that runs over several weeks and exposes participants to short duration encounters with the subject matter each day. Thus, it encourages revision by exposing learners to subject matter over a longer period, but requires only a minor time commitment each day.

In the next section the two game platforms are described. An analysis is then undertaken of some of the game mechanics that underpin each game platform and reasons are outlined as to why it was expected that these game mechanics would create engaging cooperative gameplay experiences. Finally, the two platforms used to develop these game platforms are described and the two new digital games created for the two groups of learners in study are evaluated. The first game created for this study used the ‘They Know’ platform to develop a game to assist second year medical students revise anatomy content. The second game used the ‘Qstream’ platform to develop a game to deliver adverse event identification and management training to medical oncology trainees.

5.2 The 'They Know: Anatomy' intervention

The 'They Know: Anatomy' game was developed using the 'They Know' platform. This platform allows users to create educational digital games in the Strategy genre (i.e., team-based Strategy games) across a variety of disciplines. The 'They Know' platform was chosen to deliver the 'They Know: Anatomy' intervention because it allowed a game to be developed that encourages collaboration and cooperation between players. Additionally, the type of gameplay supported by the platform allowed short games to be created that could be played as individual matches. Players were also able to engage in these matches as repeatedly, periodically and frequently as they wished to consolidate their learning. It was anticipated that this process would encourage ongoing cooperation among the team members once the game had ended. The game designer who developed the game was based locally in Sydney, New South Wales, Australia. The game designer met with the researcher to discuss the design process for the 'They Know: Anatomy' platform. This allowed the researcher to gain a unique perspective on the process used to design an educational digital game. 'They Know: Anatomy' was designed as a tool to delivery anatomy revision questions to second year medical students. Health education covers a diverse range of subject areas; however, this study elected to focus on anatomy education, as it is foundational in medical and paramedical education and thus must be understood well by all medical students.

Students studying anatomy have reported that they must overcome a number of challenges, most of which relate to their perceptions that the subject is content heavy and complex to learn [231]. Additionally, anatomy students have reported that the subject is stressful and noted that their lack of confidence with the material creates a barrier to learning [232]. It has been shown that many learners adopt a surface approach to learning anatomy and rely heavily on memorisation techniques rather than the use of deep-learning approaches, such as developing an understanding of the relationships between elements and key concepts [233]. Within the literature, there is also a common perception that medical students do not graduate with sufficient knowledge of anatomy to support their clinical careers [234]. Thus, it is essential to identify effective strategies for teaching anatomy to students. In addition to anatomy being viewed as comprising subject matter that is difficult for learners to retain, students' levels of exposure to this subject matter may also vary depending on their previous education.

5.2.1 Elements of a 'They Know' game

Player avatars

A 'They Know' game is a game in which individual players are brought together and allocated to one of two teams to compete against each other for control of a game map. Each individual player is represented in the game by an avatar. The avatar reflects a player's health total, allows them to interact with the game map and stores their question cards. Players can differentiate between their own avatars and those of other players. A player's own avatar is identifiable by a white health metre that appears around the outside of the avatar. The avatars of players on the same team are identifiable by blue health bars and the avatars of players on the opposing team are identifiable by red health bars.

Each player has a finite amount of 'health'. Players commence the game with full 'health'; however, players' 'health' decreases each time an enemy question card is answered incorrectly or an enemy question card is not answered within a set time limit. If players lose all their 'health', they are returned to their home base and revived at half 'health'. They must then navigate back across the map, re-answering question cards, until they return to the node that they were on when they lost all their 'health'. To regain their lost 'health', players must cooperate with their team members. Players' with low 'health' must navigate to the same node as one of their team members. Team members can target a fellow player's avatar by attacking that player with a card from their hand. If a player answers the question incorrectly, there is no penalty; however, if a player answers the question correctly, they regain some ‘health’.

In addition to using the avatars to ascertain other players’ levels of ‘health’, players can use their avatars to interact with the game map by clicking on the subject node to which they wish to navigate. Once a player clicks upon a node, their avatar moves to the clicked upon node. At each node, players encounter multiple-choice questions related the node’s specific subject area. Regardless of whether a player answers the question correctly or incorrectly, avatars store a copy of each card for use at other points in the game. More detailed descriptions of the game map and question cards are provided below.

The game map

Each ‘They Know’ game is played on a game map. *Refer to Figure 5.1 for a display of the key characteristics of a They Know map.* As stated above, players have their own avatars that they use to interact with the game map, their team members and opposing team members. The game map is populated with a network of subject nodes that comprise information relevant to the overall theme of the map. For example, in a game designed to revise anatomy, a map designer might choose to categorise the questions based on physical regions of the body and thus create ‘Head’ and ‘Foot’ subject nodes. Alternately, a map designer might base nodes on different functions of the body and thus create the ‘Digestion’ or

‘Ambulation’ subject notes or base nodes on different chapters of a textbook and thus create Chapters 1–6 subject nodes.

Each player is allocated to one of two teams. Both teams start the game at a special type of node called a ‘home base node’. To win the game, a team must take control of the opposing team’s home base node. They can do this by moving their avatars to and taking control of subject nodes by answering question cards. Each player can move individually, but team members can derive strategic advantages by coordinating their movements to ensure that their team controls as many subject nodes as possible.

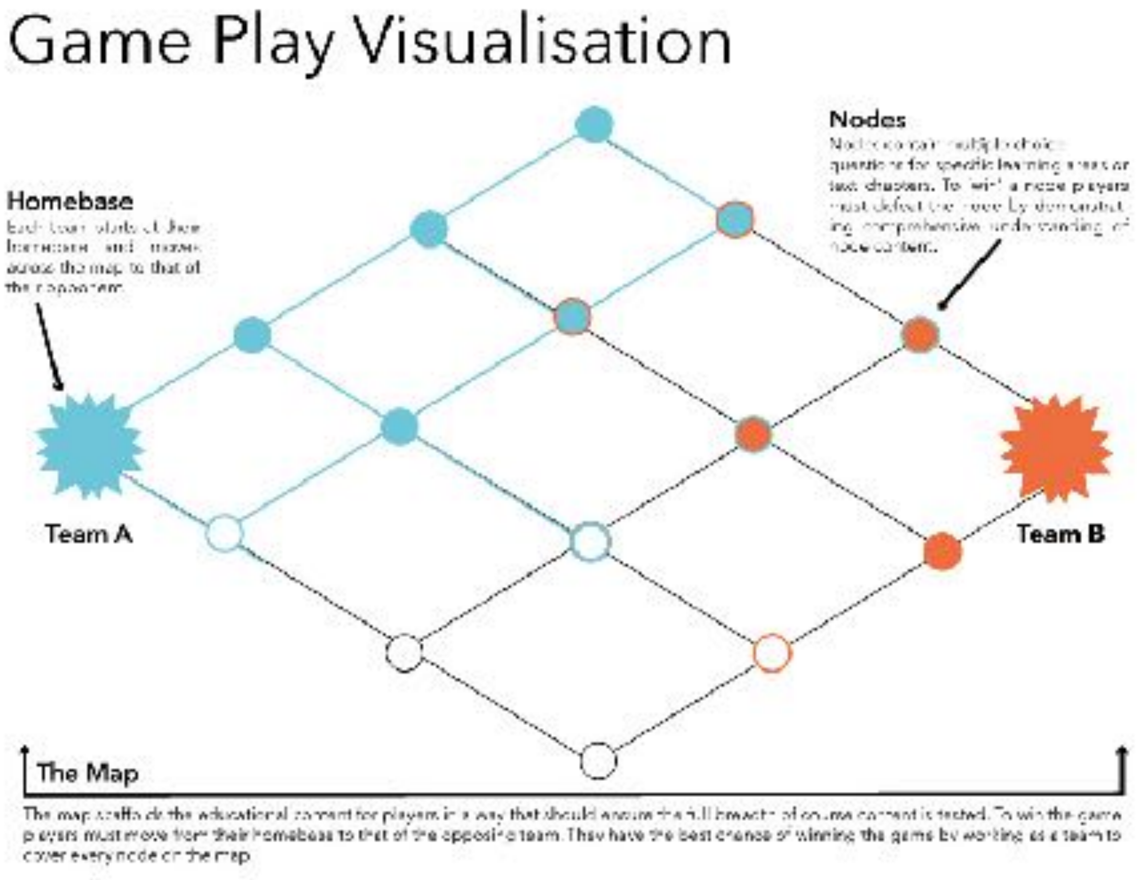


Figure 5.1: They Know gameplay visualisation

Displays the key characteristics of a 'They Know' game map.

An individual node comprises a set of multiple-choice question cards relevant to the subject area. Each node on the map, excepting the two home bases, has a 'neutral' status at the beginning of the game. Players can gain influence over individual nodes by correctly answering a node's question cards. Each time a player answers a question card correctly a portion of the node's outline turns blue. *Refer to Figure 5.2 for a screenshot showing how the They Know platform visually reinforces a team's networks of influence on a game map.* When a player has answered a sufficient number of question cards correctly, the node turns completely blue. Thus, each player and their team members can influence the nodes. The map designer determines how many questions a player must answer correctly to gain complete influence over a node. Any nodes over which an opposing team has influence are represented by a red outline. Additionally, the level of influence that teams have over individual nodes can change throughout the game, as players from different teams interact with the nodes. If an opposing team controls a node, a player can challenge the influence that team has over the node as they would for a neutral node (i.e., by answering a set number of questions correctly). If the team that has influence over a node wishes to defend it from an attack by an opposing team member, a team member will generally need to stay near that node so that they can defend that node. This is one method by which the 'They Know' game encourages team members to coordinate their actions during play. The use of a strong cooperative strategy increases players' ability to maintain control of the nodes and thus win the game.

Each player can navigate to any node on the map and attempt answer that node's question cards; however, they can only acquire influence over nodes that their team has a direct line of control to. Thus, a team must control a network of nodes from their home base to a specific node before a player can attempt to gain influence over that node. The need for teams to maintain this continuous network of influence between nodes is another way in which the game seeks to encourage cooperation among team members. Team members have to work together to maintain their network of influence or, should they wish to do so, work together to disrupt an opposing team's network. Team members are not required to cooperate in this way; however, specific game mechanics were incorporated within the game to incentivise cooperative play among team members over individual play. For example, it is very difficult for a team to maintain a direct line of influence from its home base across a network of nodes to the opposing team's home base if the team does not work together.

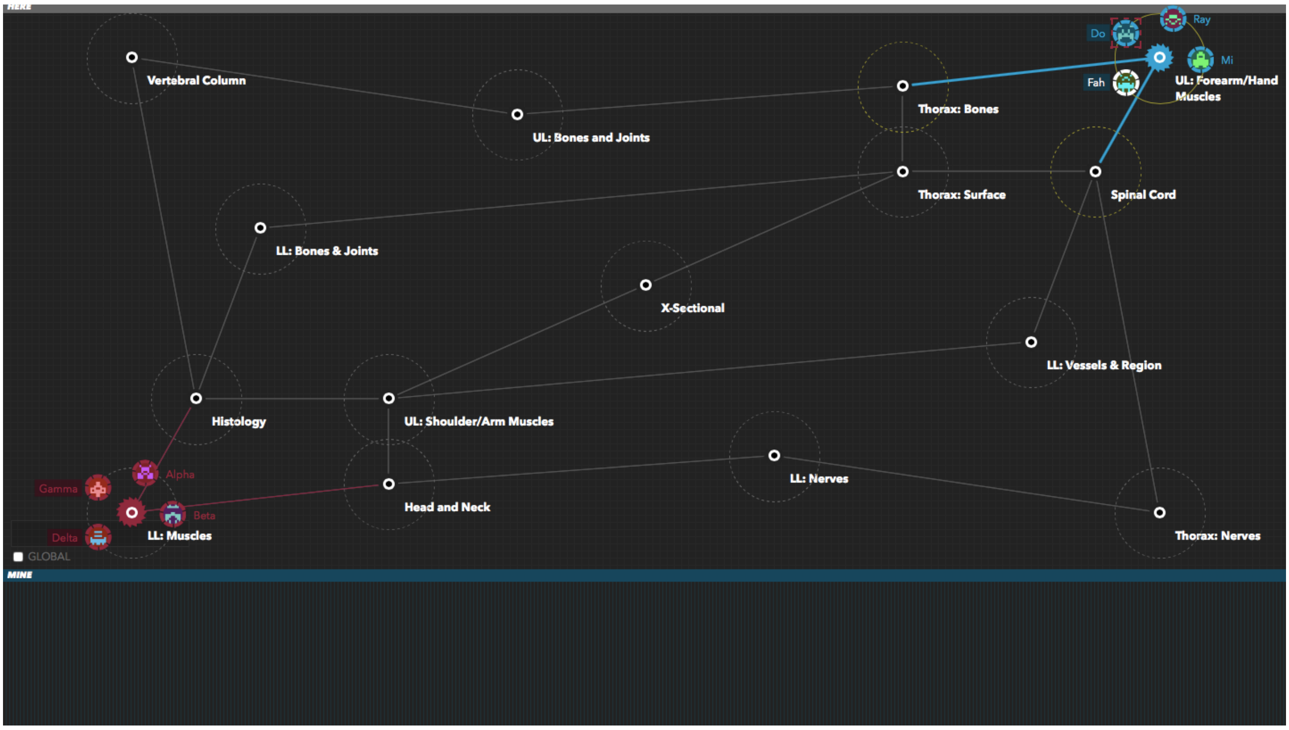


Figure 5.2: Screenshot of They Know: Anatomy

Screenshot showing how the They Know platform visually reinforces a team's networks of influence on a game map.

Question cards

Question cards are the central element of any 'They Know' game. *Refer to Figure 5.3 for a screenshot showing a question card in the game.* As stated above, question cards are initially housed within an individual subject node. A player can access question cards by clicking on the node they are on to request a question card. When a player clicks on the node a question from the node's repository is randomly drawn. Each time a player answers a question card correctly they gain some influence over the subject node. When a set number of question cards have been answered correctly the player will gain complete influence over the node for their team. Every time a player encounters a question card a copy of it is added to their avatar's card deck, regardless of whether the question has been answered correctly or incorrectly. They can see up to five random cards from their deck in their hand at any one time.

An individual question card has multiple features. The first and most obvious is the presence of a question. A question may be text-based or comprise an image and a number of answer options. There is no limit on the number of answer options, but in the context of the 'They Know: Anatomy' all question cards had between three and five answer options for players to choose from on each card. To select the answer the player thinks is correct they must type their selection. The platform uses the process of typing as a mechanic to reinforce the answer using kinaesthetic learning. Kinaesthetic learning is the process of using physical activities, such as typing, to support learning. A player receives immediate feedback as to whether their answer is correct or incorrectly. If a player answers correctly, the screen flashes green and if a player answers incorrectly, the screen flashes red and they lose health. To encourage players to draw on their team members' knowledge to identify the correct answer in the future, players are not told the correct answer if they answer incorrectly. A second feature of question cards is the timer. The timer adds an additional level of challenge to a question card. If a player does not type an answer within the time limit it will be registered as incorrect and they will lose 'health'.

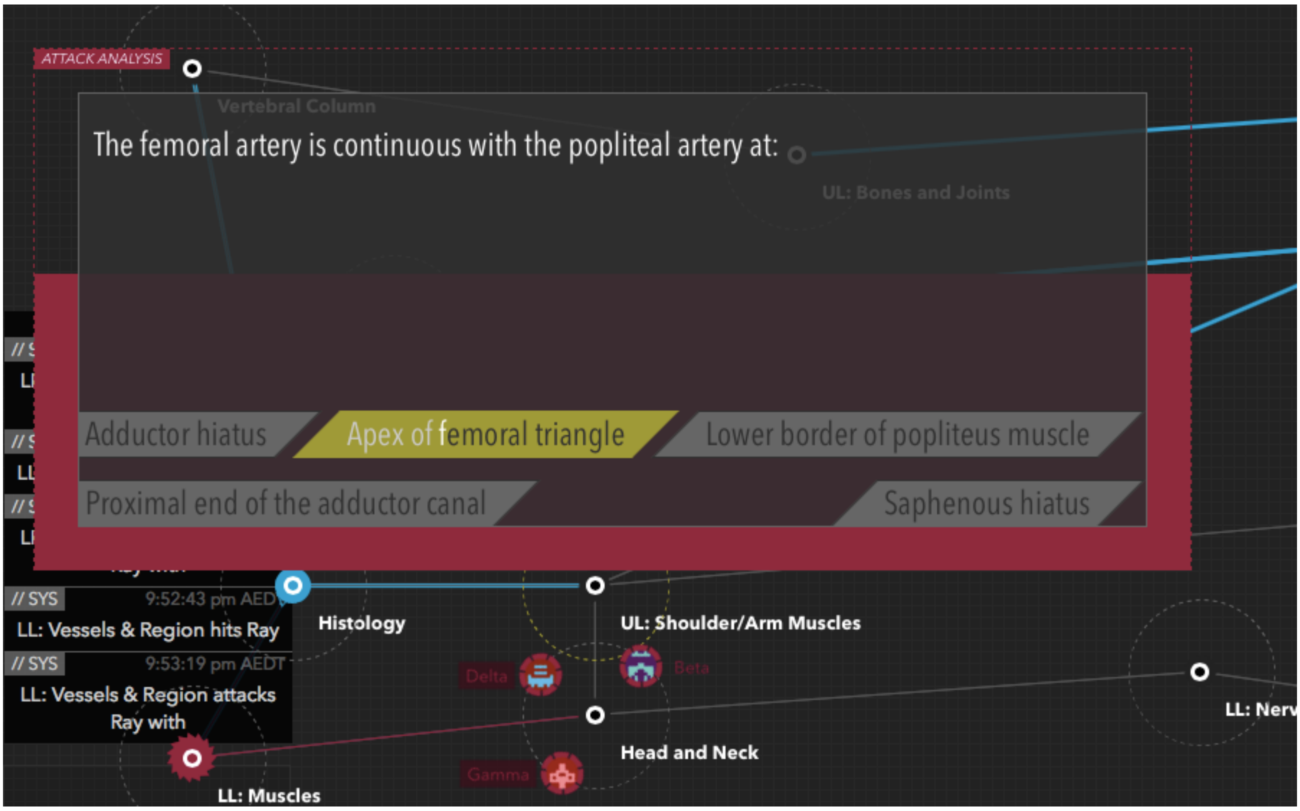


Figure 5.3: Screenshot of They Know: Anatomy

Screenshot showing a They Know question card.

Using cards as weapons

Each time a player encounters a question card a copy of it is added to their card deck. At the bottom of the screen the player can see a hand of cards taken from their card deck. *Refer to Figure 5.4 for a screenshot showing how the players screen looks when they have collected multiple game cards.* A player's hand consists of a random selection of up to five cards. The reason players collect these cards is so they can use them strategically to defend the nodes that their team has influence over from players on the opposing team. To use question cards from their hand as weapons, a player must be on the same node as an enemy player. Once on the same node, a player can click on the enemy player's avatar to select that player's avatar and then click on the card in their hand that they wish to use to attack the enemy player. The clicked upon card is then sent the to enemy player. If the enemy player answers the question incorrectly they lose 'health'. The enemy player also cannot answer questions stored in the node's repository if they are under attack from another player.

A player can also transfer their question cards to their team members. This has two benefits. First, it allows team members to share knowledge of questions on other nodes with each other. Second, it is the only way to restore 'health' to players once they sustained damage. The process of using question cards to help a team member is the same as the process used to attack an enemy player. Players on the same team who wish to share cards must go to the same node. Once there, they can click on each other's avatars and then select the card they wish to transfer. When cards are transferred between players on the same team, an incorrect answer does not reduce a player's 'health'; however, answering a question correctly does increase a player's 'health'. Figure 5.4 shows an example how cards are displayed to a player in a 'They Know' game, so that they can use them as weapons throughout the game. Weapon cards are displayed at the bottom of the screen.

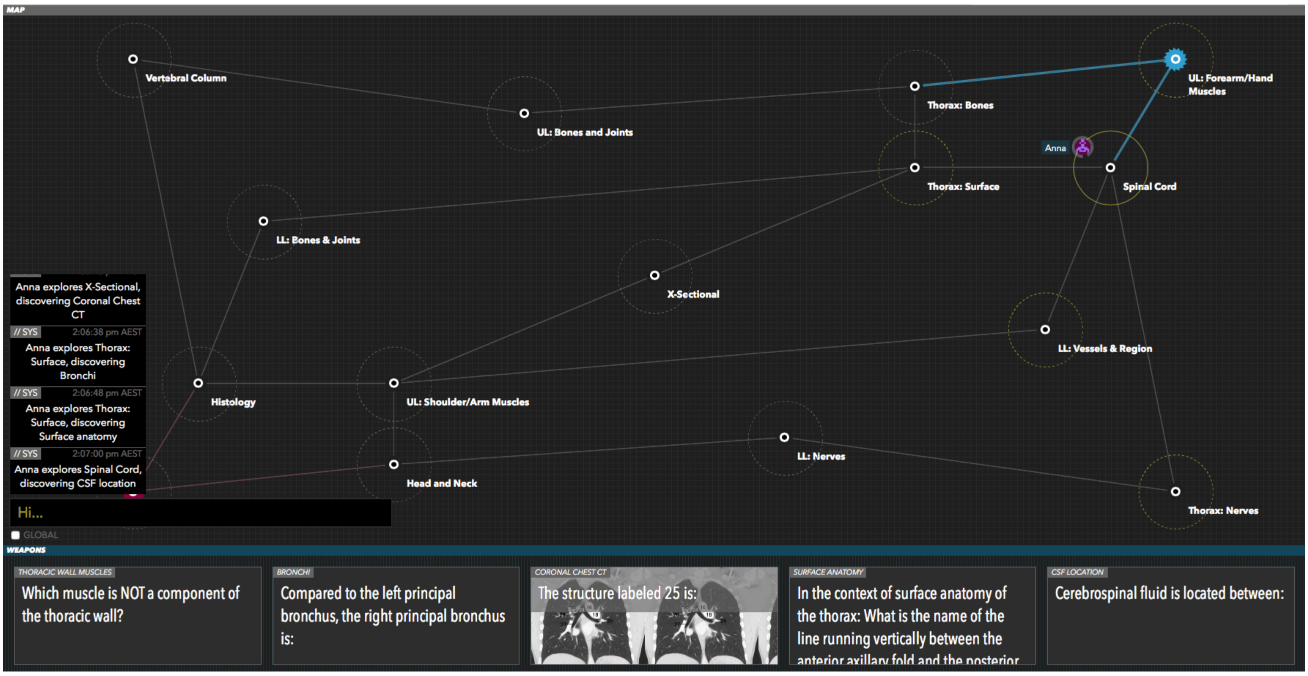


Figure 5.4: Screenshot of They Know: Anatomy

Screenshot showing how cards are displayed to a player in a 'They Know' game, so that they can use them as weapons throughout the game. Weapon cards are displayed at the bottom of the screen.

Aggressive nodes

When a player has gained complete influence over a node for their team, they may elect to continue to answer question cards. If a set number of additional questions are answered correctly, a second threshold for the node is passed and the 'aggressive' mode is activated. The map designer determines the additional number of question cards the player must answer correctly to increase the node threshold to aggressive. If a node has been activated as aggressive, players from the opposing team who navigate onto that node will be automatically attacked. Once a team has influence over a node and has activated the aggressive mode, no player needs to stay that node to defend it. Aggressive nodes are identifiable by their spiked (rather than smooth) outlines. *Refer to Figure 5.5 for to see how the design of nodes changes as their status transitions from neutral to aggressive.*

At the start of a game, only two nodes are aggressive by default: the two home bases. All of the other nodes have a neutral status. If more aggressive nodes are created on a game map, it becomes more difficult for an opposing team to gain a line of control across the game map and thus to win the game. Not only do aggressive nodes automatically attack players with cards, they also redeploy new cards at set intervals, regardless of whether or not the first question card has been answered. Thus, multiple question cards may be queued up, awaiting a player. This also increases the difficulty of the game.

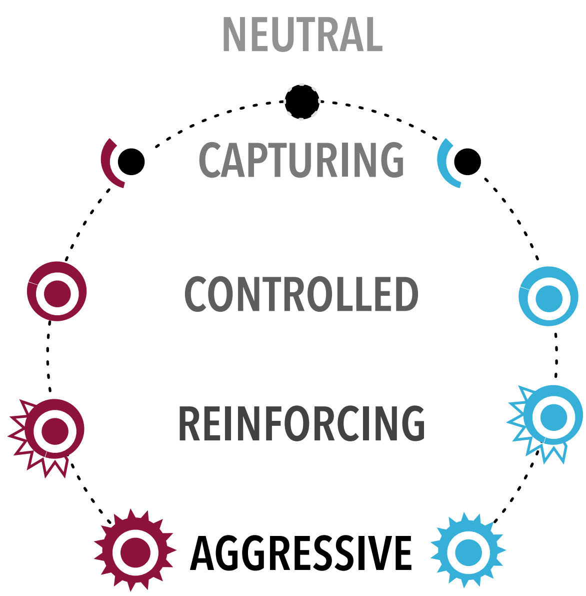


Figure 5.5: They Know: Anatomy node transitions

The visual cues used in a game to indicate the status of nodes as they transition from a neutral to aggressive.

Communicating with other players

'They Know' has an in-built chat system that allows players to communicate with one another during the game. Players can use this chat system to type messages to other members on their team. They can also elect to participate in a global chat that enables them to send messages to any player, regardless of their team by selecting a checkbox. Figure 5.4 displays an example image of a chat system in a 'They Know' game. The chat screen appears on the left-hand side of a player's screen.

Designing the game map for the 'They Know: Anatomy' game

At the end of the content development phase, the researcher was provided with excel files from a content matter expert. The files contained 245 questions across 15 subject nodes that aligned with the first year medical anatomy curricula. The questions were uploaded to the 'They Know: Anatomy' platform and node names (derived from the names of the excel files) were automatically generated. The researcher then reviewed the names of the subject matter nodes to ensure that they were correct. The researcher also reviewed each question card with images to embed the relevant images.

Once all of the question cards had been uploaded to the game platform, the researcher then designed the layout of the game map. A design map was created that comprised a network of subject nodes that encouraged cooperation among players on the same team and encouraged players to work strategically with their team members to take control of the opposing team's home base. The subject matter nodes were structured in a logically consistent manner, but were also connected to support multiple paths across the map for different players. Additionally, to encourage players to spread out across the map and explore as many nodes as possible and thus increase their exposure to the anatomy content, each path across the map was designed to have a similar number of nodes. To achieve this, nodes were distributed symmetrically between the two home bases across the design map and nodes had a similar number of questions near each home base. The subject areas for each home base were chosen because they had the same number of questions. Figure 5.2 (above) displays the layout of a 'They Know: Anatomy', Session A, game map.

The process of developing the first iteration of the 'They Know: Anatomy' map took approximately one month. Before developing a game layout, the researcher reviewed the game maps of commercial games in a genre similar to the 'They Know' game to gain insight into the creation of game maps. After reviewing map designs used in similar commercial games, the researcher used graph paper to sketch multiple possible layouts for the 'They Know: Anatomy' game. These sketches were used to predict how players might choose to traverse the game map and which paths may be more or less appealing to players. Once the researcher felt a well-balanced map had been designed, the paper sketches were transferred to the 'They Know' platform to create the first the 'They Know: Anatomy' game map.

In addition to laying out the game map, the platform required the researcher to set timers for the question cards. This feature affects how challenging players find a game. Thus, attempts were made to ensure that the timings set for the cards were appropriate. Specifically, the researcher attempted to answer the questions under multiple time constraints to ascertain which time limit provided sufficient time to read a question, consider the answers and select a response.

5.2.2 Evaluating the 'They Know: Anatomy' game

Study population and recruitment

The 'They Know: Anatomy' was designed to assist second year medical students revise anatomy questions that they had encountered during their first year of study. Thus, participants in this study comprised second year medical students enrolled in a medical degree at the University of Sydney. The researcher made a five-minute presentation to potential participants during their anatomy laboratory sessions in the second week of semester to promote participation in the study. This recruitment strategy ensured that every potential participant was aware of the study. After the presentation, an expression of interest sheet was distributed among the students who were asked to leave their contact details if they were interested in participating in the study. A follow-up email was then sent to all the students who left their contact details on the expression of interest sheet by the researcher.

Data collection before the intervention

To obtain background data about the participants, a link to an online survey was emailed to all of the students who expressed an interest in participating in the study. This survey included a mix of a five point Likert rating and open response questions that sought to elicit information on the digital game experience of the potential participants (see the appendix for a list of the questions asked in this survey). The survey also asked questions about participants' study habits of the and how often they undertook revision both individually and in groups. Any student who completed the online survey became eligible to participate in a 'They Know: Anatomy' session.

The structure of 'They Know: Anatomy' sessions

A 'They Know: Anatomy' session comprised two or more matches at spaced intervals. A match was designed to be no more than one hour. The matches were held at least 24 hours apart to allow participants time to undertake revision between the matches if they so wished.

A match of the 'They Know: Anatomy' game involved eight students, who were divided into two teams of four. Players remained in the same team for the entire session. The sessions were conduced in computer laboratories located on the University of Sydney campus. Players on the same team were co-situated in the same computer laboratory and attended the same session as their team members. In a majority of the matches , members of the opposing teams were situated in separate computer laboratories. Team members could only communicate via the in-built chat system that formed part of the 'They Know: Anatomy' platform.

Data collection during the intervention

During each session, a video camera filmed the two teams to capture player-player interactions within teams and also player-computer interactions. A session coordinator was also present to provide technical support and take field notes. At the end of each match, participants were asked to complete a paper-based six point Likert rating survey in which they provided ratings of the match. The survey asked participants to rank their experiences during the match across five domains: challenge, competition, engagement, enjoyment and replay likelihood. The scale ran from one to six (where six represented the most positive response and one the least positive response).

Data collection after the intervention

Within four weeks of completing the game session, participants were asked to participate in semi-structured interviews. These interviews explored participants' experiences with the 'They Know: Anatomy' game and their perceptions of the affects that the game had on their knowledge. The interview was unstructured; however, a schema was used to ensure consistency across the interviews. The audio recordings of each interview were transcribed, de-identified and thematically reviewed. *Refer to Table 5.1 for an overview of measures in the 'They Know: Anatomy' intervention.*

Table 5.1: Measures used in 'They Know: Anatomy' intervention.

Table 5.1: An overview of the measures used in the 'They Know: Anatomy' intervention and the timing of data collection			
Measures	**Pre Intervention**	**Intervention**	**Post Intervention**
Baseline Survey	X		
Observations		X	
Six Point Likert Ranking		X	
Platform Metrics		X	
Semi-structured Interviews			X

Human research ethics approval

The University of Sydney's Human Research and Ethics Committee granted permission for the study to be conducted.

5.3 The 'Qstream: Cancer Cup Challenge' intervention

As stated above, this chapter describes the development and evaluation of two games. The second game, 'Qstream: Cancer Cup Challenge', is considered in this section. The online 'Qstream: Cancer Cup Challenge' platform was chosen to deliver the training, as it had been shown to increase learner' knowledge recall and change their behaviours [57, 235]. This platform incorporates game mechanics to engage players and increase the likelihood that they will complete the online course. The game mechanics supported by the platform include a points allocation system that allows players to be rewarded for correct answers and a leader board that shows players how they rank against other players and teams. Additionally, the platform enables training to be delivered to participants who are geographically dispersed (a key requirement for recruiting participants to participate in the intervention). The 'Qstream: Cancer Cup Challenge' platform was chosen as it provides a different type digital game-based learning and health education experience to that provided by the 'They Know: Anatomy' platform. Further, the use of 'Qstream: Cancer Cup Challenge' platform also enabled this study to explore how health professionals (as opposed to health professionals in training) use health digital game-based learning.

The 'Qstream: Cancer Cup Challenge' game was developed to engage early career medical oncologists in quality improvement training related to identifying and responding to adverse events. Health professionals were selected to participate in this study for a number of reasons. First, early career doctors have particularly high levels of patient contact [236]. Thus, patient care is more likely to improve if such professionals are given training on how to identify and handle adverse events. Early career doctors are also often inexperienced, particularly in specialist areas, such as oncology, as evidenced by phenomena, such as the July Effect (a phenomenon that refers to increases in the incidences of adverse events that occurs when early career doctors begin their training) [237]. Early career doctors also have very busy schedules and often have little time to undertake necessary skills training. Thus, the online delivery of a program is likely to make the program more accessible to early career doctors. Further, it is often difficult for early career doctors to meet geographically, as they are often disbursed across organisations or, even if they work in the same organisation, work different shifts.

5.3.1 How the 'Qstream: Cancer Cup Challenge' platform works

Learners' accounts

To interact with the 'Qstream: Cancer Cup Challenge' platform, each learner has to set up a personal account that they can then use to enrol in individual courses. Each account is linked to each learner's profile and includes a variety of information, such as text-based biographical information, a list of any courses in which the learner is enrolled, a image of the learner, details as to the number of times that learner's profile has been used and the date the learner first became a member of the site. This information is not publicly available; however, any individual with a 'Qstream: Cancer Cup Challenge' account, who is logged in to account, can view another learner's profile.

A learner's account also stores a range of analytical data (e.g., information about the learner's interactions during a course, information on any courses in which the learner is enrolled, information about the number of times a learner answered questions incorrectly and details on the learner's progression through a course and whether the course has been completed). A learner's account also records the points (if any) that a learner has been awarded for completing courses or answering questions correctly.

'Qstream: Cancer Cup Challenge' questions

Each of the 'Qstream: Cancer Cup Challenge' multiple-choice questions comprised a question and a series of answer options. One or more of the answers presented in the series could be correct. The question field may be text-, image- or video-based. The order of the answer options can appear in random order or in an order chosen by the course developer. The questions also have an explanation section that may include text, image and video input. Finally, 'Qstream: Cancer Cup Challenge' questions also feature optional tags that allow course developers to indicate the relevant topic area for each question.

To answer a question, a learner must click on the option that they believe is correct. A cross or a tick is then displayed to indicate the correct and incorrect answers and the answer that the learner gave is highlighted. The learner also receives feedback as to the number of people who responded to that question and which percentage of that number responded correctly to each option. Further, if the course designer has chosen to include further explanations, the learner also receives feedback as to what answer they should have chosen with a detailed explanation as to why. Learners can leave comments on individual questions and review the program as a whole. *Refer to Figure 5.6 for a screenshot showing a* *question from the Qstream: Cancer Cup Challenge, before the learner selects their answer.*

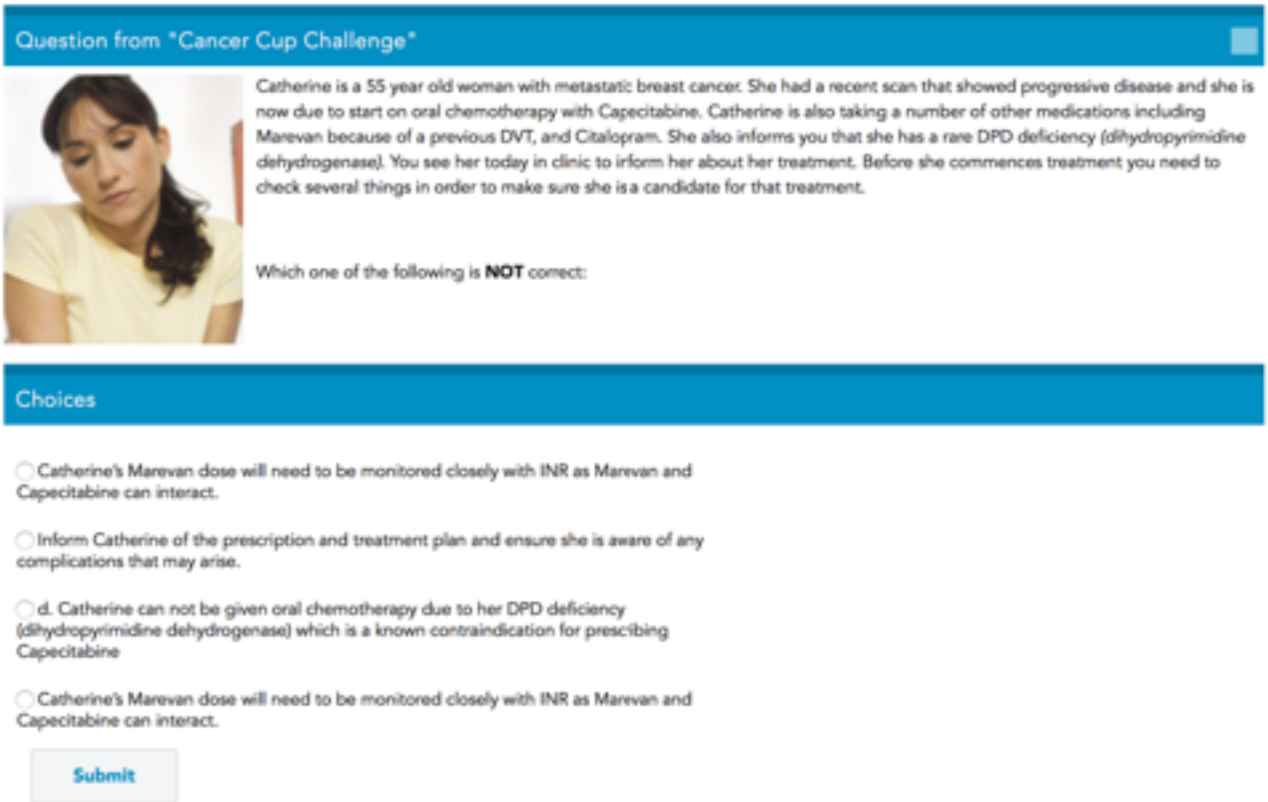


Figure 5.6: Screenshot of the Qstream: Cancer Cup Challenge

Screenshot showing a question from the Qstream: Cancer Cup Challenge.

Delivering questions to participants

The 'Qstream: Cancer Cup Challenge' platform delivers each question to learners multiple times at spaced intervals in a reinforcing pattern over a set number of weeks. Questions are delivered in this pattern until a learner answers them a certain number of times correctly. The designer of the individual 'Qstream: Cancer Cup Challenge' course determines the number times the multiple-choice questions will be repeated, the spacing of the questions and whether one or multiple answers will be correct. The individual course designer also determines the spacing and repeating of questions. *Refer to Figure 5.7 for a screenshot showing the spacing of the Qstream: Cancer Cup Challenge.*

Figure 5.7: Screenshot of the Qstream: Cancer Cup Challenge

Screenshot showing Qstream: Cancer Cup Challenge spacing interface.

The 'Qstream: Cancer Cup Challenge' platform uses gamification to engage learners and maximise the likelihood that each learner will complete the online course. It allows learners to compete as both individuals and team members and review their progress on de-identified leader boards [238]. The platform awards each learner points based on a predetermined algorithm that assesses individual's achievements. For example, each learner is awarded points for answering a question correctly, but additional points are also awarded to the first learner to answer that question correctly. Learners cannot lose points. The platform displays an individual leader board that shows how many points each learner has been awarded and their team. The leader board can display learners' scores in an identified or de-identified manner, depending on the preferences of the person setting up the 'Qstream: Cancer Cup Challenge' program. *Refer to Figure 5.8 for a screenshot of the leaderboards in the Qstream: Cancer Cup Challenge.*

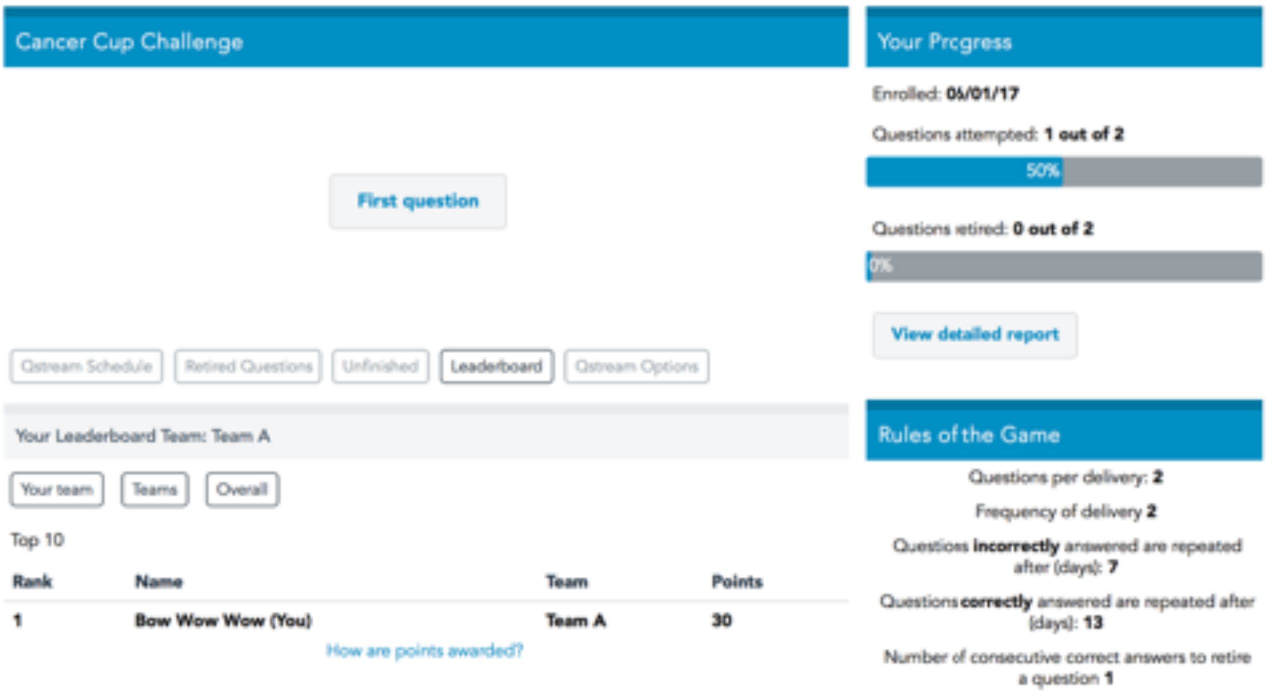


Figure 5.8: Screenshot of the Qstream: Cancer Cup Challenge

Screenshot showing the Qstream: Cancer Cup Challenge leaderboard.

Developing the adverse events content

The ‘Qstream: Cancer Cup Challenge’ was designed to deliver professional development training to early career doctors specialising in oncology in a hospital setting. To do this, the system delivers questions to learners’ on the identification and management of adverse events that significantly affect the quality of life of patients with cancer. To develop appropriate content for the course, a team of experts were engaged to act as an ‘Advisory Committee’. The Advisory Committee comprised senior medical oncologists, quality improvement staff members, educational designers, research fellows and most importantly, early career medical oncologists who understood the needs and expectations of the end users. This Advisory Committee also oversaw the development of the key learning objectives that would underpin the ‘Qstream: Cancer Cup Challenge and be used to build each of the questions.

The adverse events content was developed over a period of four months. The Advisory Committee members liaised primarily via email; however, face-to-face meetings were held periodically. The researcher managed the coordination of the case development process and aspects of the case review. At the conclusion of the content development phase, the final questions were provided to the researcher to input into the 'Qstream: Cancer Cup Challenge' platform.

Designing a digital game-based learning intervention

Following consultation with the Advisory Committee, it was decided that an international competition could be highly engaging for early career doctors and ensure that the key learning elements of the program were disseminated broadly. The Advisory Committee selected three countries across which the competition would be run: Australia, Denmark and USA. These countries were chosen because members of the advisory committee had worked with cancer centres in these countries. The researcher worked with the Advisory Committee to design a team-based game that would engage participants across the three countries. The researcher was guided by the Advisory Committee, which played a central role in informing the design of the challenge. The Advisory Committee comprised individuals who had a high level of experience in developing quality improvement training, including the Head of Safety and Quality at Dana Farber Hospital in the USA and the Director of Cancer Services for Western Sydney in Australia. Additionally, the Advisory Committee also comprised representative early career doctors from Denmark, Australia and the USA.

After considering the capabilities of the 'Qstream: Cancer Cup Challenge' platform, it was decided that the learners would be allocated to teams based on their nationalities. Each learner would be awarded points for participating in the program using the 'Qstream: Cancer Cup Challenge's' scoring algorithm. *Refer to Figure 5.9 for a screenshot showing how the Qstream platform allocates points for answering a question.* The scores of individual learners would then be aggregated to determine team scores. The team with the highest score at the end of the four weeks would be the winner.

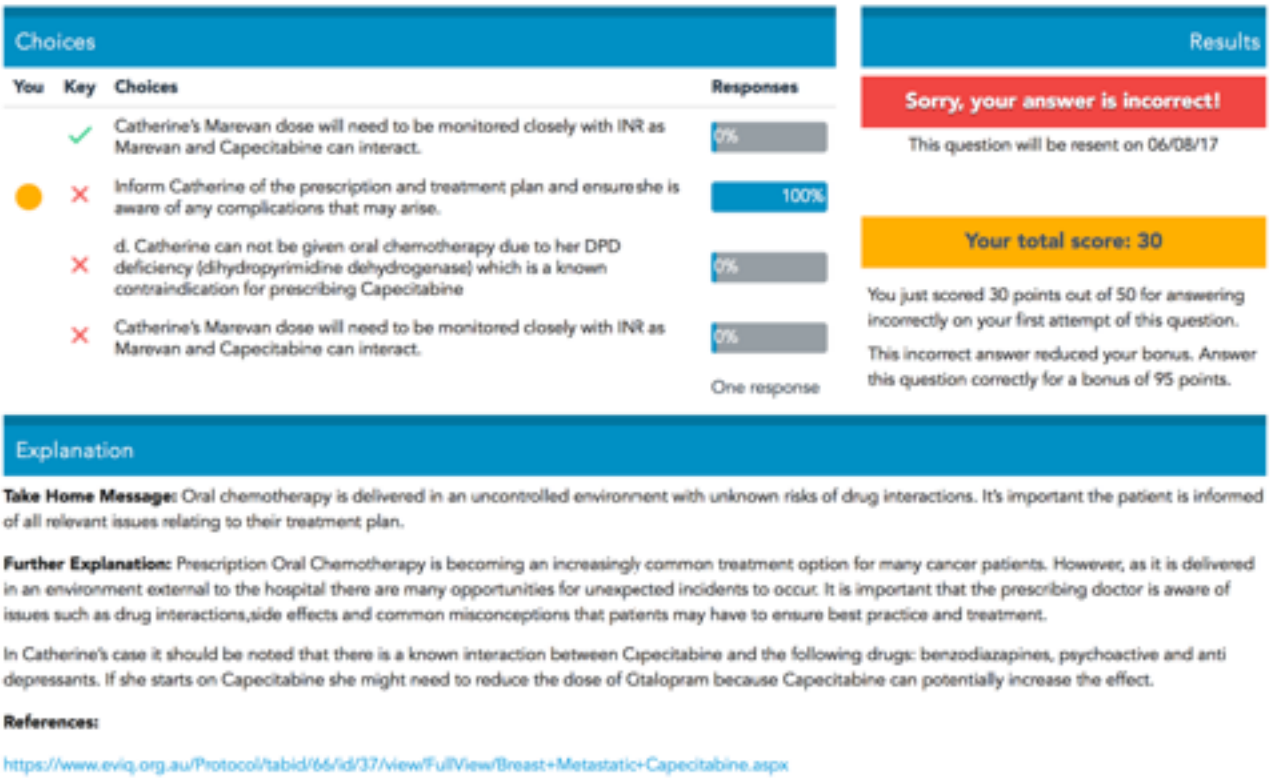


Figure 5.9: Screenshot of the Qstream: Cancer Cup Challenge

Screenshot showing the feedback and point allocation after a participant answers a Qstream: Cancer Cup Challenge question.

The researcher also designed other aspects of the 'Qstream: Cancer Cup Challenge' platform to increase the level of engagement of individual learners with the course. First, to reduce the time learners' needed to commit each day to work through the program, a limit was set as to the number of questions that learners would be emailed at any one time. Second, to ensure that all learners had one week to complete the first repeat of the questions, the spaced intervals that would elapse between each bundle of questions sent out were decided. The bundled structure of questions ensured that players who did not have time to complete questions on the day upon which they were released did not feel unfairly penalised for responding more slowly than other players.

5.3.2 Evaluating The 'Qstream: Cancer Cup Challenge' intervention

Study population and recruitment

As stated above, the 'Qstream: Cancer Cup Challenge' game was designed to deliver adverse events training to early career (Postgraduate Year (PGY) 2–5) doctors undertaking specialist training in oncology. Early career doctors who met these criteria were recruited across hospitals in the three countries targeted by the intervention (i.e., Australia, Denmark and the USA). To recruit participants, emails were sent to a list of potential participants, whose contact details had been supplied by

Advisory Committee members. A promotional flyer was first emailed to all potential participants, notifying them that the program was available. A week later, a follow-up email was sent that included a link that redirected participants to the web page through which they could enrol in the online program.

Structure of the 'Qstream: Cancer Cup challenge' intervention

The 'Qstream: Cancer Cup Challenge' was designed to run over four weeks. Once enrolled in the program, learners were assigned to teams based on their nationalities. As part of the ethics approval for this intervention, it was required that the learners be de-identified. Consequently, each learner was also assigned an alias. It was also thought that de-identifying learners would ensure confidentiality and discourage unfriendly competition. Players on the same team had access to the email details of each of their team members so that they could interact online. An online forum was set up to support the program. A commenting system was also set up on the 'Qstream: Cancer Cup Challenge' platform to allow players to interact with their team members and players on opposing teams.

Once learners had enrolled in the course, they were emailed cases that could be completed on a personal computer, tablet or smartphone application. The cases were sent to learners in the following spaced manner:

- Each learner received an email every two days that contained at least two cases.

- If the learner answered a case incorrectly, it was resent five days later.

- Once a learner answered a case correctly it was retired.

- The course was completed once all of the questions had been retired.

Additionally, once a week, the researcher emailed the leader board results to learners to keep them updated on the progress of their team and other teams. Learners were also sent their individual scores to allow them to track their progress over the course of the program. At the end of the four-week period, a small prize (i.e., a trophy engraved with each team member's name) was awarded to the team with the most points.

Data collection during the intervention

The 'Qstream: Cancer Cup Challenge' platform collects a range of metrics on registered participants, including information on their progress through the course, the number of questions that they have answered correctly and their level of engagement with the program. The researcher exported a report of this data at the end of each week over the course of ‘the Qstream: Cancer Cup Challenge’ to record how each individual player progressed.

Data collection after the intervention

At the conclusion of the ‘Qstream: Cancer Cup Challenge’ intervention, the learners were emailed a link to and asked to complete an anonymous online survey. The survey comprised five point Likert rankings and open choice questions and sought to obtain as much information as possible about learners’ experiences of the game. A follow-up email was sent to learners’ one week later, reminding them to complete the online survey. No further emails were sent to encourage learners to complete the online survey.

To explore players’ experiences during ‘Qstream: Cancer Cup Challenge’ in more depth, semi-structured interviews were also conducted with the learners. An email inviting the learner to participate in semi-structured interviews was sent out to all learners within four weeks of the game’s completion. Interviews were conducted in person or over the phone and took from 10 to 20 minutes. An interview guide was used to ensure a consistent structure was used in all interviews. *Refer to Table 5.2 for an overview of measures in the ‘Qstream: Cancer Cup Challenge’ intervention.*

Table 5.2: Measures used in the 'Qstream: Cancer Cup Challenge'

Table 5.2: An overview of the measures used in the 'Qstream: Cancer Cup Challenge' intervention and the timing of data collection			
Measures	**Pre Intervention**	**Intervention**	**Post Intervention**
Platform Metrics		X	
Online Survey			X
Semi-structured Interviews			X

Human research ethics approval

The Western Sydney Local Health District Human Research and Ethics Committee granted permission for this study to be conducted. The project was also reviewed by the Institutional Review Board for Protection of Human Subjects in Research (IRB) approval in the USA.

5.4 Chapter summary

This chapter outlined how two serious game platforms (i.e., 'They Know' and 'Qstream') were used to develop team-based games for medical students and early career oncologists who were working in a clinical setting. These platforms were used to build two games. The 'They Know: Anatomy' platform was designed for second year medical students. The

‘Qstream: Cancer Cup Challenge’ was designed for early career medical oncologists. These platforms were largely selected for their ability to support team-based serious games. There is currently a significant gap in the health literature in relation to the use of serious games to support cooperation and collaboration in the short and long term. In addition to providing descriptions of these two games, this chapter also described why each platform was selected for the study, how each platforms works, the process adopted to develop content for each game, how each game was implemented in each specific context and how each game was evaluated. In the next chapter, the results of the implementation and evaluations of the ‘They Know: Anatomy’ platform are presented.

'They Know: Anatomy'

Chapter 6

This chapter presents the results for the 'They Know: Anatomy' intervention that was conducted in 2014 and 2015. It begins by providing an overview of the structure of the intervention. It then describes the process used to develop the program, the recruitment approach adopted and how the program was delivered. Finally, this chapter sets out the findings related to the program, including observations, the results of the post-program evaluation surveys and comments made by participants in interviews. It also explores participants' engagement with the 'They Know: Anatomy' intervention and outlines their perceptions of the effects of the learning and revision approaches adopted by the study.

6.1 The structure of the 'They Know: Anatomy' sessions

The 'They Know: Anatomy' intervention comprised three sessions with separate groups of participants: the March 2014 session (Session A), the May 2014 session (Session B) and the August 2015 session (Session C). Three sessions were conducted to gain insights into how participants interacted with the game platform and other players. Each session of the

‘They Know: Anatomy’ intervention comprised two or more matches (at spaced intervals). A one-hour limit was set for the duration of the matches to minimise the time commitment required by participants. It was anticipated that the matches would run for approximately half an hour and that a one-hour time slot would be sufficient to conduct a single match. There was an interval of 24 to 48 hours between each match. The matches were spaced apart to provide participants with time to revise anatomy content (either individually or with their team members) between the matches so that they improve their performance in subsequent matches.

A ‘They Know’ type game can support any number of participants in each team. However, in this study, each team was limited to a maximum of four players on each team. Eight participants, who were divided into two even teams of four, participated in each session. The teams remained the same across each of the three sessions; however, a unique cohort of players participated in Session A, Session B and Session C.

6.1.1 Participants’ backgrounds

An anonymous online survey was used to gain background information about the participants, including information on their experience with digital games and their existing anatomy revision techniques. The survey did not collect demographic data (e.g., information about participants’ gender); however this information was only collected from the participants who played the digital game at one of the sessions. A link to the online survey was emailed to all of the students who expressed an interest in the study in March 2014 (n = 54) and in March 2015 (n = 20). The survey comprised 24 questions, 15 of which required participants to respond to Likert scales and nine of which required free-text responses. There were no mandatory questions in the survey. Consequently, the number of responses to each question varied. Participants' responses were aggregated across the two cohorts, as the years studied were consecutive (i.e., 2014 and 2015). There was a high level of heterogeneity among the medical program students from 2014 to 2015.

6.1.2 Participants' previous experience with digital games

The survey comprised six questions on participants' previous experience with games (both digital and non-digital). Of the six questions, four used Likert scales. Participants were asked to rate how often they played digital games on a dedicated console (e.g., Xbox, Playstation 3 (PS3) or Wii), on a handheld gaming device (e.g., PlayStation Vita or Nintendo DS handheld video game system) on a smartphone and on a personal computer or a Macintosh (Mac) computer. Participants' responses indicated that playing digital games on a dedicated console (e.g., Xbox, PS3, Wii) was relatively uncommon. Indeed, over 90% of the participants reported that they never or only occasionally played digital games on such devices. Participants' also indicated that they rarely played handheld consoles (e.g., PlayStation Vita or Nintendo DS). Indeed, over 80% of participants indicated that they never or only occasionally played games on handheld consoles. Interestingly, 35% of the participants indicated they played games on smartphones at least once a week and often did so daily. Finally, the survey responses revealed that the majority of participants only played digital games on Macs or personal computers infrequently. Playing digital games on Macs or personal computers was uncommon; however, the participants who did use these devices to play digital games, indicated that they played frequently and often daily. Similar to the participants who played digital games on Macs or personal computer, the participants who played non-digital games played those games frequently, often daily or multiple times a week. *Refer to Table 6.1 for details of participants survey responses regarding experience with commercial digital games.*

Table 6.1: They Know survey responses

Table 6.1: Survey respondents experience playing digital games on various types of consoles.				
	2014 (n = 35)	***2014 (%)***	***2015 (n = 11)***	***2015 (%)***
Previous experience playing digital games on a Mac or personal computer				
Never	12/35	34%	2	18%
Occasionally	9/35	26%	4	36%
1–2 days per week	6/35	17%	3	27%
3–5 days per week	4/35	11%	1	9%

1–3 hours a day	3/35	9%	1	9%
3+ hours a day	1/35	3%	0	0%
Previous experience playing digital games on smartphones				
Never	11	31%	2	18%
Occasionally	13	37%	4	36%
1–2 days per week	4	11%	3	27%
3–5 days per week	3	9%	1	9%
1–3 hours a day	4	11%	1	9%
3+ hours a day	0	0%	0	0%
Previous experience playing digital games on a dedicated console (e.g. Xbox, PS3 or Wii)				
Never	13	37%	8	73%
Occasionally	20	57%	3	27%
1–2 days per week	2	6%	0	0%
3–5 days per week	0	0%	0	0%
1–3 hours a day	0	0%	0	0%
3+ hours a day	0	0%	0	0%
Previous experience playing digital games on handheld consoles				
Never	25	71%	0	0%
Occasionally	5	14%	1	9%
1–2 days per week	3	9%	0	0%
3–5 days per week	2	6%	0	0%
1–3 hours a day	0	0%	0	0%
3+ hours a day	0	0%	0	0%
Previous experience playing non-digital games (e.g., board games and card games)				

Never	3	9%	0	0%
Occasionally	26	74%	9	82%
1–2 days per week	6	17%	2	18%
3–5 days per week	0	0%	0	0%
1–3 hours a day	0	0%	0	0%
3+ hours a day	0	0%	0	0%

A free-text question asked participants to detail the types of digital games that they had experience playing. Participants could indicate the multiple games or genres that they played frequently. If a participant listed more than one game, only the first game listed was used in the genre analysis. In total, 41 participants responded to this question; however, eight indicated they did not play commercial digital games frequently enough to have a strong preference for any game. The responses of participants who indicated that they did not play digital games were removed from the analysis. Consequently, only 33 free-text responses were used to determine the genres of games that second year medical students played the most frequently.

Participants listed between one and 10 games; however, the majority of participants listed only one game or, if they listed more than one game, all the games listed were from the same genre. Ten participants (i.e., 24%) indicated that they played casual games, such as Puzzle, Card and Trivia games frequently. The types of games played by this group of participants included smartphone games (e.g., *Bubble Shooter*) and casual games on personal computers (e.g., *Tetris* or *Spider Solitaire*). Three participants (i.e. 7%) stated that they played digital games from the Simulator genre. Five participants (i.e., 12%) stated that they played digital games from the Role Playing genre. One participant stated that they liked playing multiplayer games, regardless of the genre. Another participant stated that they liked playing games of the First Person Shooter genre and another participant that that liked Action Adventure games. Finally, eight participants (i.e., 20%) indicated that they played games in the Strategy genre, including Real Time Strategy and Multiplayer Online Battle Arena games.

6.1.3 Participants' attitudes towards digital games

Participants were asked two questions in relation to their attitudes towards digital games in the online survey. One question used a Likert rating response and the other a free-text response. The Likert question asked participants to rank four types of activities (i.e. competitive solitary, competitive team-based, non-competitive solitary and non-competitive team-based activities) using a scale (where one indicated a strong negative attitude and five indicated a strongly positive attitude). There were 45 responses to this question.

Over 70% of the participants who responded indicated that they liked competitive solitary activities and competitive team activities and over 80% indicated that they liked non-competitive solitary activities. These activities could either be digital or non-digital. In response to a question asking them to rank non-competitive team activities, 85% of participants indicated that they liked such activities. *Refer to Table 6.2 for details of participants preferences regarding solitary and cooperative game-play experiences.*

Table 6.2: They Know survey responses

Table 6.2: Survey respondents preferences in relation to four categories of recreational activities (i.e., competitive solitary, competitive team-based, non-competitive solitary and non-competitive team-based activities).				
Competitive solitary activities				
	2014 (n=35)	2014 %	2015 (n=11)	2015%
Hate	1	2%	1	9%
Dislike	7	20%	2	18%
Like	15	43%	6	55%
Love	12	34%	2	18%
Competitive team based activities				
Hate	1	3%	0	0%
Dislike	8	23%	3	27%
Like	13	37%	6	55%
Love	13	37%	2	18%
Non-competitive solitary activities				
Hate	0	0%	0	7300%
Dislike	6	17%	0	2700%
Like	22	63%	9	82%

Love	7	20%	2	18%
Non-competitive team activities				
Hate	0	0%	0	0%
Dislike	6	17%	1	9%
Like	18	51%	7	64%
Love	11	31%	3	27%

A free-text survey question asked participants to describe what they liked or disliked about digital games. Sixty free-text comments where provided, 41 from participants in the 2014 cohort and 19 from participants in the 2015 cohort. Of these, the positive aspects about the recreational nature of video games were mentioned 31 comments. In seven comments (i.e., 23%), digital games were cited as providing a form of relaxation and entertainment. In six comments (i.e., 19%), interactivity, immersion and a variety a positive traits of commercial digital games were listed. In five comments (i.e., 16%), competition was recognised as a positive attribute of digital games. Digital games were described as an enjoyable way of interacting with friends or as an outlet for competitive urges. In two comments (i.e., 6%), participants stated that they liked the medium, as it enabled them to pass time and have fun in an undemanding environment. In two other comments (i.e., 6%), participants stated that they liked that digital games enabled them to sharpen their reflexes and develop the skills necessary to win the game. One participant described being able to play digital games at your own pace as positive. Another participant commented that the cost of games was low for a high entertainment value. One participant indicated that they liked the mental stimulation offered by digital games and another reported that they liked the problem-solving and world-building aspects of games. Finally, one participant stated that they liked solving in-game puzzles, such as secret levels.

Twenty-six comments included references to the aspects of games that the participants disliked. Of these comments, being a waste of time or not having any time to play games due to a heavy study load represented participants' dominant dislikes and were mentioned in 11 comments (i.e., 42% of the comments). In four comments (i.e., 15%), participants stated that they disliked staring at a screen due to eyestrain, social isolation or because studying already required that they spend a lot of time before a screen. In three comments (i.e., 12%) participants stated that they disliked the inactivity related to playing video games and the antisocial nature of staring at a screen. Two participants disliked the fact there were no tangible benefits to playing games. One participant indicated that they had a hardware limitation, as a high end computer was needed to play games. Finally, one participant stated they found digital games difficult to access and navigate and one participant cited a dislike for the repetitive nature of tasks in some games.

In three comments, the positive traits of many digital games were also perceived as having negative aspects that were largely related to the immersive nature of the medium. These participants stated that they found digital games so engaging that they lost track of time when playing them, but also indicated that they often felt frustrated at the amount of time they had wasted after the stopped playing. One participant referred to this as the 'addictive' element of digital games.

In relation to participants' attitudes towards digital games, a preference was shown for non-competitive over competitive activities. Participants perceived solitary competitive and team competitive activities as being highly enjoyable. Overall, participants commented more on the positive (than the negative) attributes of digital games. Digital games were viewed positively as a form of entertainment and as a tool for relaxation. Further, the competitive aspect of digital games was seen as appealing, especially as a means for structuring socialisation. Finally, participants expressed an interest in using digital games to learn new skills or sharpen their reflexes.

6.1.4 Participants' approaches to revision

In the baseline survey, data were also collected on how participants revised in studying for their degree. The participants were first asked about the frequency with which they engaged in solitary study and the methods they used. They were then asked about their views towards group revision. Forty-four participants responded to questions in relation to the frequency with which they engaged in solitary study. A majority of the participants (i.e., 32 or 73%) stated they studied alone daily. Ten participants (i.e., 23%) indicated they studied alone weekly. Two participants (i.e., 5%) indicated that they studied alone monthly and two other participants (i.e., 5%) indicated they only studied alone when the examination period was approaching.

When asked about their study methods the most popular study tools used by participants were the readings recommended for the course (40 or 91% of participants indicated that they used the readings to study). The second most popular study method was the use of Wikis, such as Wikipedia (28 or 64% of participants reported that they used the Wikis). Flash cards were used by 20 (i.e., 45%) of participants, journals by 16 (i.e., 36%), phone application by 13 (i.e., 30%) and blogs by three participants (i.e., 7%).

The survey then asked participants a similar set of two questions about their cooperative study habits and methods. Forty-five participants responded to the questions about group study sessions. A majority of the participants (i.e., 21 or 47%) indicated they studied with their peers weekly, 11 (i.e., 24%) indicated that they studied with their peers rarely, six (i.e., 13%) stated they studied with their peers as examinations approached and five (i.e., 11%) stated they studied with their peers monthly. One participant (i.e., 2%) indicated that they never studied with their peers. No participant stated that they studied collaboratively with their peers on a daily basis.

Forty-four responses were collected on group study methods. Each of the participants who responded (i.e., 100% of participants) indicated that they undertook their revision activities face-to-face. However, four participants (i.e., 9%) indicated that they also used email correspondence and four (i.e., 9%) stated they used Google groups to engage in group study. One participant stated they used video conferencing tools, such as Skype, to engage in group study.

6.2 Session A (March 2014)

The first session (Session A) of the 'They Know: Anatomy' intervention was conducted in late March 2014. An email was sent to all second year medical students who had expressed an interest in participating in the study, inviting them to sign up to the March session. This session comprised three one-hour matches of 'They Know: Anatomy', spaced over a period of least three days. It was anticipated that participation at each attendance would take approximately one hour, as participants were required to set themselves up in a laboratory, play a match for approximately half an hour and then complete a post-match evaluation.

Session A was attended by eight participants, who were divided into two teams of four. Each team comprised three male participants and one female participant. The matches were spaced and repeated at a specified interval to increase the likelihood that players on the same team would cooperate. It was anticipated that the first match would provide players with an opportunity to familiarise themselves with the rules of play and the game system. It was also anticipated that team interaction would increase in the second match as the players became better acquainted. Finally, it was anticipated the optimal level of team cooperation would be exhibited in the third match, as by this stage, participants would be familiar with the rules of the game, how to navigate the game and would have had two opportunities to get to know their team members. It was further anticipated that this combination of factors would enable team members to collaborate effectively and that team members would be able to use their combined anatomy knowledge to improve the gameplay strategy adopted to win the game.

All of the matches for Session A were conducted in two computer laboratories at the University of Sydney's Camperdown campus. Both laboratories were equipped with iMac desktop computers. Players were given access to their own iMac computers in the laboratory. The iMacs were connected to the university's internet infrastructure and run on the web browser Chrome. This enabled participants to access the digital game as it was played online. Team members on one team shared one computer laboratory and team members of the opposing team shared another computer laboratory. In the game, players were able to move as individuals and could control their own player avatars by using a computer mouse to interact with the nodes and access the multiple-choice questions. However, to effectively cross the game map, team members had to work cooperatively and communicate verbally to coordinate their movements and to achieve their common goal of capturing the opposing team's base.

6.2.1 Session A, Match 1

Before Match 1 commenced, data collected from the 2014 baseline survey was reviewed to gain insights into participants' levels of digital game experience. Upon reviewing this data, it became evident that the participants had very little experience playing commercial digital games and almost no experience playing commercial digital games from the Strategy genre (the most similar genre to the genre of the 'They Know: Anatomy' game). Participants were given a five-minute presentation before Match 1 began to introduce them to the game. The presentation was given to the eight participants as a single group. It covered basic rules of play and demonstrated how to move around the game map and access question cards. Participants were given the opportunity to ask questions at the end of the presentation; however, no questions were asked at the end of the presentation.

At the conclusion of the presentation, the participants were sent to whichever of the two rooms their team had been allocated. Each room was supervised by a session coordinator, who was available to provide support if there were any technical issues with the computers or connecting to the game. The participants were asked to draw on the skills and knowledge of their team members if they had questions about how to play the game or needed answers to anatomy and histology questions.

Participants had five minutes in the computer laboratories to talk with their team members while the computers were being logged into the game. They were advised that the session might run for one hour, but that the game would end when one team won and thus may not take a full hour. The anticipated time frame for the first match was based on the time it takes to complete matches of commercial team-based Strategy games and the length of time it had taken to complete tests of the 'They Know' platform with non-specific subject matter content. At the start of the match, participants engaged in some interactions with their team members; however, most participants were silent and focused on navigating around the game map to familiarise themselves with how to navigate their avatar to different subject nodes. As the match progressed, participants were more likely to interact with their team members; however, many of the interactions were social or arose when participants sought clarification on how to interact with the game.

At the end of the one-hour period allotted to Session A, the match had not finished. The session coordinators prompted participants to end the session, noting that a draw could be called, but the participants indicated that they wished to continue playing until a team had won. There were discussions between the session coordinators and the participants of both teams, but the participants were adamant that they wished to continue playing. Consequently, the session coordinators decided to continue the match until a team won. However, after another hour elapsed with no winner, the participants decided to end the session due to other commitments. The participants were disappointed that there was no clear winner and some participants indicated that they would have liked to keep playing, but ultimately left the match with their team members.

At the conclusion of the Match 1, participants were asked to complete a survey to rate various aspects of the game. According to responses to the Likert ratings, participants enjoyed positive experiences in the first match. Indeed, the majority of participants selected ratings of five or a six across all domains of the evaluation survey. One of the five domains, engagement, received a 100% positive rating by participants. Challenge and competitiveness also received very positive ratings from participants (87.5% of participants ranked these domains positively). Enjoyment and a desire to play the game were also ranked positively by 75% of participants. *Refer to Table 6.3 for the aggregated participant responses to the six point Likert ranking for Session A, Match 1.*

Table 6.3: They Know Session A, Match 1 survey responses

Table 6.3: Participants' responses to the Likert **scales** for **Match** 1 of **Session A (n** = 8).						
	1	**2**	**3**	**4**	**5**	**6**
Challenge				12.5%	12.5%	75%

Competitiveness				12.5%		87.5%
Engagement					37.5%	62.5%
Enjoyment				25%	12.5%	62.5%
Desire to replay			12.5%	12.5%	25%	50%

An impromptu discussion also occurred between the participants and the session coordinators at the conclusion of Match 1. During this discussion, participants stated that they felt dissatisfied that neither team had won and noted that the desire to obtain a clear outcome was a significant driver to continue playing the game once the first hour had elapsed. Additionally, the participants stated that due to the difficulty of the questions, it had been difficult for either team to take control of the nodes on the map for a sufficient period to maintain a line of control to the opposing team's home base. When asked to explain the source of the difficulty, the participants identified a combination of factors. First, they felt that while the questions related to content that they were required to know by the end of their first year of study, the wording and content of the questions was significantly more difficult than what they would encounter in any test. Some of the participants were of the view that the subject matter of the game represented anatomy and histology knowledge that they should have at the start of the second year of the medical program. Second, due to the difficulty of the questions, participants noted that they needed additional time to consider which answer was correct and that the time limits set to answer the cards were often too short to allow for this to occur. Participants also expressed interest in using their own questions to populate a future 'They Know: Anatomy' map. They stated that the faculty expected medical students to add questions to a central repository for shared revision and that these questions could potentially be used in future games. All of the participants indicated that they felt engaged with the game and a majority stated that they were excited to return for the next session in three days.

6.2.2 Redesigns based on Match 1 feedback

Participants responded positively to Match 1, but it was evident that some changes needed to be made to ensure that the participants continued to engage with the game in Match 2. The most significant change was the introduction of a time limit for individual matches to prevent matches from running indefinitely. A time limit was set to act as a safeguard in the event that neither team was able to take control of the opposing team's home base. A time limit was set to ensure that the game would end by a set time. If this occurred, a winner would then be determined using an algorithm designed to determine which team controlled the most nodes and had answered the most questions correctly across all the nodes. The incorporation of the timer represented a potentially significant change to the educational effects of the game, as it altered the game's dynamic. Thus, focus of the game became not only about response speed, but also about the accuracy of the participants' responses.

Additionally, a review was conducted of the game's anatomy and histology questions to correct some minor issues that had been identified by participants during Match 1. These mostly comprised fixing links to image files that had not appeared correctly on question cards; however, in some cases, it also included rewording the questions slightly to shorten the reading time.

6.2.3 Session A, Match 2

All of the participants who participated in Match 1 returned for Match 2. They were divided into the same two teams and sent to two separate computer laboratories to play the game. Before the commencement of Match 2, the participants were advised of the changes that had been made to the game following Match 1. This included notifying them that a match time limit of 40 minutes had set for the completion of the match. They were also advised that if the game ended because of the time limit (and not because one team had gained control over the other team's home base), a winner would be determined based on which team had answered the most questions correctly and controlled the most nodes.

As with the previous match, the participants had five minutes before the match to talk with their team members while the coordinators finalised the set-up of the game. The session ran smoothly and when player discussion occurred, it was observed to focus more on optimal strategies for covering the game map rather than the rules of the game and helping others learn to play. However, a lot of inter-team chatter also occurred that was unrelated to the anatomy and histology content of the game or to gameplay strategy.

The match concluded after 40 minutes. Thus, the game finished not because one team had gained control of another team's home base, but because the time had expired. Unlike the previous match, there was little post-match discussion. Some participants remarked on the new timer mechanic, noting that it was 'nice' to have a winner, but that it was not as satisfying as winning would have been if an opponent's base had been overtaken.

Participants were again asked to complete a survey for Match 2. The Likert scales were the same as those used following the end of Match 1. One participant left the match without completing an evaluation; thus, only seven responses were collected. As with Match 1, engagement was ranked positively by 100% of participants. The same rating was also given to the competitiveness domain. Both challenge and desire to replay received a positive rating from a majority of participants (i.e., 86% and 71.5%, respectively). Enjoyment received the lowest rating in Match 2, with only 57% of participants rating it positively. *Refer to Table 6.4 for the aggregated participant responses to the six point Likert ranking for Session A, Match 2.*

Table 6.4: They Know Session A, Match 2 survey responses

Table 6.4: Participants' responses to the Likert scales for Match 2 of Session A (n = 7).						
	1	**2**	**3**	**4**	**5**	**6**
Challenge				14%	29%	57%
Competitiveness					43%	57%
Engagement					57%	43%
Enjoyment				43%	28.5%	28.5%
Desire to replay				28.5%	43%	28.5%

6.2.4 Redesigns based on Match 2 feedback

It was evident that the participants had grasped how to play the game by the conclusion of Match 2. Within their teams, the participants had also encountered almost all of the 240 anatomy and histology questions across the game map. However, the participants were still failing to collaborate with one another during the game sessions to discuss anatomy subject matter.

After a review of the literature on how players collaborate when playing team-based digital games, the computer laboratory set-up was modified. The set-up of the final match was similar to that of a Local Area Network

(LAN) gameplay session. A LAN refers to a type of digital game environment in which players are situated together and connected to each other's computers via a shared network. In LAN environments, players from the same and opposing teams are situated in the same location and are not separated from one another. In Match 3, participants from both teams were situated in the same computer laboratory. Each team sat together, but could easily talk across the room to players on the opposing team should they so wish. This set-up is was similar to how small group activities are often conducted in classrooms.

6.2.5 Session A, Match 3

Two participants (one from each team) failed to attend Match 3 of Session A. Consequently, Match 3 proceeded with two teams of three rather than two teams of four. The session coordinators observed that the co-situated teams displayed an increased level of interaction in response to the changed gameplay environment. However, no significant changes in interactions were observed between individual team members. Notably, there were numerous interactions among members of the two teams, including friendly hazing. The post-match discussion suggested the participants preferred this format to having the teams separated, as it increased the sense of competition between the teams.

The participants were also asked to complete the same Likert scales for Match 3 as they had completed for the previous Matches 1 and 2. Only four participants completed the evaluation. Thus, only these responses could be analysed. These participants ranked four of the domains (i.e., challenge, competitiveness, enjoyment and a desire to replay) extremely positively. One domain (i.e., engagement) was ranked positively by 75% of participants, but 25% of participants gave a relatively neutral response. One participant left the following unsolicited comment at the bottom of the evaluation form: *'Game is fun and good for learning. It would be great for us to be able to input anatomy content because there is a lot of anatomy content'. Refer to Table 6.4 for the aggregated participant responses to the six point Likert ranking for Session A, Match 3.*

Table 6.4: They Know Session A, Match 3 survey responses

Table 6.4: Participants' responses to the Likert scales for Match 3 of Session A (n = 4).						
	1	**2**	**3**	**4**	**5**	**6**
Challenge					75%	25%
Competitiveness					25%	75%
Engagement				25%	25%	50%
Enjoyment					75%	25%
Desire to replay					75%	25%

6.3 Session A evaluations

To gain further insights into participants' experiences of the 'They Know: Anatomy' intervention, all of the participants involved in the March 2014 session were invited to participate in semi-structured phone interviews. Each interview took from 15 to 30 minutes and required participants to reflect on their experiences across all three Session A matches. The interviews comprised questions on players' experience of other educational games, how challenging they found learning anatomy and histology and included specific questions about their personal experiences with the 'They Know: Anatomy' game in terms of both educational effect and inter-team cooperation.

The semi-structured interviews were conducted within one month of the completion of Session A. Thus, all of the interviews were concluded by May 2014. Participants had some time to reflect upon their experiences between the final gameplay session and the interview. All of the eight participants who participated in Session A agreed to be interviewed about their experiences.

Before Session A, information had been obtained in the anonymised online survey about the gameplay experiences of the medical students who had expressed interest in the study. However, as the survey data collected were anonymous, no specific knowledge about the commercial digital game experience of session participants was available. To address this issue, all of the participants who agreed to be interviewed were asked to answer a question about their level of experience with commercial digital games. An analysis of the Session A interview data showed that Session A participants had an unexpectedly high level of commercial digital gameplay experience. Indeed, 50% of the participants identified as frequent digital game players and 50% described themselves as multiple times a week players who sometimes played for four or more hours a day or infrequent or non-players. In relation to participants' experience with educational games, exposure was relatively low. Only three participants (i.e., 37.5%) had any specific experience with educational games. Further, of the participants who indicated that they had specific experience with educational games, each stated they had played these games in primary school and thus had no recent experience with the genre.

The data from the interview transcripts were divided into two main categories:

1. Participants' perceptions of their engagement with the 'They Know: Anatomy' game.

2. Participants' perceptions of the 'They Know: Anatomy' game as a tool for supporting learning and revision.

Within these two categories, multiple subcategories were identified. Details of the findings across each of the categories and subcategories are outlined below.

6.3.1. Participants' perceptions of their engagement with the 'They Know: Anatomy' game

The results of the Session A interviews reflected the comments participants made on engagement during the unstructured discussions following each match. Unlike the Likert ratings, which only provided data on whether the players found the game engaging, interviewees' responses in the semi-structured interviews provided valuable insights into why or why not participants found playing the 'They Know: Anatomy' game engaging. Interviewees' responses in relation to how they engaged with the 'They Know: Anatomy' game were grouped into engagement subcategories and are discussed in further below.

Competition between teams

Most of the interviewees referred to the competition between the two teams in recounting their experiences. Of the eight interviewees, six made comments in relation to how inter-team competition was a central engagement mechanic of the game platform. Each of the six interviewees who discussed the effects of competition on player engagement made positive comments. Three of the interviewees gave brief remarks, affirming that the competition was fun; however these comments provided very little insight into why the competition was engaging. One interviewee stated:

> *'I just liked the competitive aspect to it because most games … most learning games don't throw in like a one team versus another kind of aspect to it. So, I like the competitive aspect where you basically have to learn more because you know you're in a team.'*

The other three interviewees provided more information about their responses to the competition. Each of the three interviewees had different perceptions on the competitive nature of the game and why it was positive. One interviewee noted that interacting across the teams was particularly entertaining, as they could use the in-game chat to 'smack talk' their opponents and thus effectively use in-game chat to reinforce the superiority of their team over their opponent's team. Another interviewee particularly liked the way that the competition played a significant role in forging bonds among team members. None of the team members were close friends outside of the context of the study, but this participant found that the desire to beat the opposing team was a particularly strong vehicle for encouraging team cooperation. Thus, sharing a goal (i.e., to win) encouraged individuals to work together in a way that other activities failed to do. One interviewee stated:

'I liked how it was competitive. I liked that it was cooperative as well, there were other people playing … I'd say it's fun because it's cooperative and competitive'.

The final interviewee stated more engaging tools were needed to teach subjects to learners who have difficulty connecting with content. This interviewee particularly liked the escapism they experienced while playing the game, stating:

'It was the competition that was fun … I almost forgot I was playing an anatomy game, it was more of a competition'.

Cooperation among team members

An analysis of the interview data from Session A revealed that interviewees perceived a crossover between engaging with the competitive and cooperative aspects of the game. However, interview responses suggested while these elements were interwoven, players normally engaged more strongly with one or another of these elements. In the interviews, a total of five interviewees specifically mentioned the effects that cooperation within their team had on their level of engagement with the game. One interviewee stated:

'I think the whole team aspect of it and the competitive part I guess. You know you were trying to beat the other people, but you were

> *also trying to get the questions right as well. The teamwork was pretty fun.'*

Another interviewee echoed this sentiment, stating:

> *'I think that was a good thing [the cooperation]. It helped us to work together and it sort of forces that, you know, that cooperative spirit'.*

One interviewee stated that they thought that teamwork made the game fun. However, numerous other interviewees noted that while cooperation among team members was engaging, it also affected their learning experiences. One interviewee particularly enjoyed the verbal interactions (i.e., the ability to ask questions and shout advice and directions back and forth) with their team members. This response was interesting, as it suggests that this player would not have engaged with their team members as effectively if they had not been co-situated during the game.

Another interviewee raised an unexpected, but interesting aspect of the cooperative game element, suggesting that having to cooperate to reach a common goal was challenging, but served to engage players with the game during the matches. This interviewee also suggested that this aspect was relatively unexpected and noted that when they had been told that they would have to play an educational digital game, they had not expected to have to work in teams, but that the team approach was more engaging than a solitary approach. This interviewee stated:

> *'I don't know if it would have been as exciting as just a solo kind of game. I think the point where you kind of work together and like you can send questions to your friends that you know the answer to and you can help them out … it's pretty fun.'*

Some interviewees referred to their experience of discussing and sharing the multiple-choice questions with their team members. Two interviewees stated that they enjoyed sharing questions with their team members and helping their team members to answer questions. Having a common goal was also referred to as a rewarding experience that brought team members together. One interviewee noted that they enjoyed being able to look over at their team members' screens to see how they were progressing and helping if needed. This again suggests that being co-situated with team members had a significant effect on participants' sense of cooperation and in the creation of a shared team identity. One interviewee expressed similar sentiments, noting that working as a team to share anatomy knowledge was not only fun, but created a sense of personal fulfilment. This interviewee stated:

> *'Where we didn't know certain questions, and we'd consult with each other, that came up spontaneously, and it was quite fun. The*

sharing of knowledge. You know, when someone helps you to clarify content, I thought that was quite fulfilling.'

One aspect of cooperation that was identified as having a particular effect on the educational experience of the digital game was the ability to share knowledge and questions with team members. The process of discussing the questions with team members acted as a pathway to internalising the correct answers. Additionally, game elements, such as the question timers, served as catalysts for discussions within teams, as they create a sense of urgency and a need to work out the correct responses as quickly as possible. One interviewee stated:

'It was more like talking to each other, helping each other with answers. Like each person would do each section and then kind of help each other ... it was good because I didn't think about the learning it was more about the helping each other. Just to win we had to do a lot of work together and it just kind of happened. I don't think we were consciously trying to do teamwork, it just kind of happened in the process of doing what the system was designed to do.'

Finally, one interviewee suggested a unique way in which cooperation in the 'They Know: Anatomy' game affected their educational experience. This interviewee observed that, as time went on, they felt stronger ties and obligations to their team members. Consequently, they were driven to cover more territory, in an attempt to answer more questions, and search their memory for answers and internalise the correct answers more rigorously, as they were aware that their team members were relying on their knowledge to win the game.

6.3.2 Participants' perceptions of the 'They Know: Anatomy' game as a tool for supporting learning and revision

During the semi-structured interview, process interviewees were asked to reflect on how the 'They Know: Anatomy' game affected their knowledge of anatomy and histology. This line of questioning sought to gain insights into whether interviewees were of the view that the digital game had affected their learning and revision approaches or viewed it merely as a fun experience. Additionally, these questions created an opportunity to collect data on any of the educational outcomes that the participants perceived the game as having that may not have been anticipated. During the interviews, all of the interviewees stated that the experience of playing the 'They Know: Anatomy' game affected their knowledge of anatomy and histology content and their confidence in their knowledge. Responses varied among interviewees, but the information gained provided insightful insights for future study sessions.

Digital games as tools for revision

Some interviewees discussed how they would use the 'They Know: Anatomy' game for revision if it were a tool available to them. Some interviewees were of the view that their current strategies for revising anatomy and histology could be enhanced if the game were used to complement their book revision. One interviewee was of the view that the game would be a beneficial tool for breaking up long periods of book study, as book revision can become draining and learners' can reach a point of knowledge saturation. This interviewee noted that a digital game could allow the knowledge obtained during a book revision session to be reviewed in a more relaxing and varied manner than that used in other approaches.

Another interviewee suggested that the framing of the game was quite confrontational to learners when an incorrect answers were given and thus it very effectively tested knowledge confidence. Another interviewee took a slightly different view, stating that they were particularly drawn to the aspects of the game at which they did well, as it increased their confidence as to the areas of anatomy and histology that they knew well.

Further, two other interviewees noted that the game acted to probe the peripheries of their knowledge. One interviewee stated that playing the game helped them to identify the aspects of anatomy that they did not know as well as they thought they did, stating:

'There was a lot of aspects of anatomy that I realised I wasn't clear about and those questions were good. I think it helped. The gaming [sic] motivated me to learn fast, and the fact that there was problem-solving helped me to learn.'

One interviewee thought that the 'They Know: Anatomy' game would be particularly beneficial as a revision tool, if it aligned directly to the curriculum. This interviewee observed that it would be possible to adapt the content to match any curriculum and thus ensure valuable course alignment. The interviewee stated:

'I do definitely think it's beneficial. I love games that are, sort of, serve the dual purpose of getting you to play them and also teaching you stuff. And I think that if this became a huge thing if it was in the curriculum as a resource to use, that would be a fantastic idea. I can definitely see myself using it in the future and just not even just to study, but just to play, just for the competitive aspect of it.'

Finally, one interviewee suggested that the digital game was a useful way of breaking up revision sessions or studying subject matter at times that were hard to concentrate, stating:

'As for this kind of game, it's more for when, I guess, sometimes when you feel that you can't concentrate and then it's [the game]

something that makes it fun and makes it, it doesn't feel like it's draining and you can do it in your leisure time. I think it's a good … it's a good, kind of procrastination but still productive kind of thing.'

The level of challenge of the game

Two interviewees stated that the level of challenge they experienced while playing the digital game directly affected their learning; however, very little detail was provided as to how the level of challenge of the game generated this effect. One interviewee noted that the level of challenge of the digital game prevented players from losing interest. Continuing to play the game ensured that players were exposed to an increasing number of anatomy and histology questions, thus maximising the likelihood of any educational impact. This is particularly important when considering the issue of learner engagement with anatomy content (see discussion above).

One interviewee was of the view that the game was very effective at reinforcing the information that was covered in the map, but that the map could not cover everything that medical students needed to know about anatomy and histology unless it was enormous and that a large map would make the game incredibly challenging and could reduce players' engagement with the game. Another interviewee noted that during the final match, the problem of coverage could be resolved by allowing users to create their own maps or multiple maps to cover additional content.

Finally, two interviewees discussed the role of the map as an educational tool and how it encouraged them to attempt to master all the nodes. This topic was particularly interesting because it illustrates the blurry line between enjoyment and education in serious games. Both of these interviewees were of the view that this aspect of the platform affected their desire to cover more nodes and answer more questions, partly because they enjoyed seeing their progress as they conquered nodes. One interviewee described the relationship between enjoyment and education in the game, stating:

> *'[The] conquering of nodes was quite fun, where you could explore and then try and answer questions and then have a sense of mastery over a number of questions'.*

Repetition and delivery of subject matter

Two interviewees found that the repetition of questions was particularly effective in reinforcing their anatomy and histology knowledge. One of these interviewees noted that as a result of the multiple repetitions, they could still easily remember the answers to some questions during the interview (i.e., one month after they had played the game).

The final two interviewees both discussed different aspects of the multiple-choice questions and which of these aspects they found particularly effective. On interviewee found the varied format of the multiple-choice questions engaging and noted that the questions with images were particularly effective. This interviewee also liked that the format of the questions reinforced whether or not they had acquired that knowledge, as they had to know the correct answers to the questions. Similarly, another interviewee also noted that the digital game highlighted what a player did and did not know was, but attributed this not to the variety of the multiple-choice questions, but to the use of the question timer. This interviewee was of the view that the urgency created by the timer required players to assess their confidence in their knowledge in a way in which a non-gamified multiple-choice quiz could not.

Supporting different learning styles

Four interviewees noted that different individuals have different learning styles. They all expressed the view that the primary goal of the game was to ensure that participants learn as much of the curriculum as possible, but that to do this the tools needed to be engaging for all learners and thus different tools may be needed to meet the different needs of learners. One interviewee further observed that a very rigid approach was adopted to teach anatomy and believed that there would be great resistance to the adoption of new tools and technologies. This interviewee stated:

"If you ask anyone who's studied to do things before the advent of computers they'll tell you, of course, there's no need, all you need is labs and textbooks, but I think that it's certainly beneficial. I think that lots of people take lots and lots of different avenues to learning anatomy. I know that between myself and my peers, just on an individual level, almost everyone approaches learning anatomy differently and some people would really, really benefit from a game because they don't like to be presented with a model and just memorise things."

6.4 Redesigns between Sessions A and B

Following an analysis of the data collected during Session A, two major changes were made before Session B. First, a modification was made to the way in which participants received instructions on how to play the digital game. Strategy games have quite complex mechanics. Consequently, a large amount of information needs to be conveyed to participants at the start of each session. Conveying such information can be challenging, but is not unique to the Strategy genre; rather, it is common across all video game genres.

The ability of video games to dynamically teach players how to use the game itself while still engaging them in the world has been the subject of significant research in the digital game literature. In Session A, participants received a tutorial on how to play the 'They Know: Anatomy' game and a brief oral presentation. However, presenting the information in this manner meant that the participants could not refer to it again during the game if they were unsure of how certain elements worked. To address this issue, an interactive tutorial was developed for Session B. Second, the number of matches in a session was reduced from three to two. This decision was made because the inclusion of a third match did not significantly increase the levels of interaction between participants on the same team, as had been anticipated when a three-match structure was selected.

6.5 Session B (August 2014)

The second session (Session B) of the 'They Know: Anatomy' intervention was conducted in August 2014. Session B was the final session of 2014, as sessions could not be conducted any later in the year because there was a risk that they would clash with participants' end of year examinations. As with Session A, Session B participants were chosen from a cohort of 35 second year medical students who had been recruited in February 2014. Anyone who had participated in Session A of the study was removed from the recruitment pool.

As per the procedure adopted for Session A, eight participants were recruited for Session B. The participants were emailed the information about when each of the two Session B matches would be conducted. This email also stated that each match would take approximately one hour. Six male and two female participants were recruited for Session B. As occurred in Session A, the participants were allocated to two teams of four that comprised three male and one female participants.

In Session A, the participants had been given a five-minute presentation that included an overview of the rules of play and instructions on how to control the avatars. This design had been selected, as it had been anticipated that the participants would spend a significant amount of the first match familiarising themselves with the gameplay specifics as a team by exploring the game map and engaging in team discussions. However, while this did occur, it was not as prolific as anticipated. Additionally, during the interview process, a number of the Session A participants noted that they struggled to grasp the rules of play during the first match and felt that they benefited more from the educational experience provided in the second match, as they were less focused on learning how to play the game.

As stated above, an interactive pre-game tutorial was developed for Session B to make it quicker and easier for participants to learn to play 'They Know: Anatomy'. The pre-game tutorial was accessible via each participant's computer and set up for use so that each participant could begin immediately upon entering the computer laboratory. The tutorial ran a modified version of the digital game that progressively introduced participants to elements of the game. When the participants first began the tutorial, they saw a black screen with only their avatar in the middle and were prompted to click anywhere. As they clicked, elements of the game, such as subject nodes and questions cards, were revealed. The tutorial was designed to ensure that the participants would be familiar with all key aspects of playing the game upon completing the tutorial, regardless of their level of experience with commercial digital games. It was anticipated most of the participants would need approximately five minutes to complete the tutorial (i.e., the time allowed was equivalent to the time it took to deliver the oral presentation in Session A). However, Session B participants could continue to access the tutorial on their individual computers during the matches. Thus, Session B participants could return to the tutorial during the game at any point to refresh their understanding of the rules.

The second major change to Session B was a reduction in the number of matches from three to two. Session A had implemented a three-match design to maximise cooperation between team members. As stated above, it had been anticipated that Match 1 would enable participants to learn the rules of play, Match 2 would increase team interactions and Match 3 would showcase a combination of team interactions and participants' gameplay knowledge. However, a review of the field notes and video recordings of Session A revealed that three matches did not increase the level of cooperation among participants by the final match as originally anticipated. Match 2 was the most interactive Session A match and no increases in team cooperation was observed in the third match. Consequently, only two matches were conducted in Session B.

The data from Session A, suggested that modifying the anatomy and histology content of the game for Session B could be beneficial; however, this change was not implemented to ensure consistency. The game timer element that had been implemented in Match 2 of Session A was implemented in the Session B matches.

6.5.1 Session B, Match 1

To introduce the digital game to the participants, an interactive online tutorial introducing key aspects of gameplay was made available at the start of the match. This approach was notably different to the procedure used in Session A. In Session A, participants had been briefed outside of the computer laboratories before the Match and given five minutes to discuss the game in the laboratories. In Session B, the participants were able to work through the tutorial at their own pace and were free to interact with their team members and answer their team members' questions.

Upon the completion of the tutorial, a waiting screen automatically loaded. The waiting screen provided no information about the game map. Thus, the participants who completed the tutorial quickly gained no advantage over those who required more time. The participants were unable to view the 'They Know: Anatomy' map until the match started. The match was coded to start automatically when the last of the eight participants had completed the tutorial. Some participants finished the tutorial quickly. This may be because they were more experienced with digital games. Conversely others need significantly more time to complete the tutorial. At this point, a 40-minute timer for the match began to run and each participant was able to begin exploring the map. As stated above, the participants could revisit the tutorial during the game, but the game could not be paused to do so.

The participants in this match interacted less with their team members than the participants had in Match 1, Session A. Initial interactions between team members were low; however, as the match progressed, some discussions between players on the same team occurred. Some of the conversations were directed towards the subject matter of the multiple-choice questions, but participants also asked their team members questions about elements of the game and also engaged in non-subject matter related discussions. The match concluded after 40 minutes when the timer ran out (i.e., no team's home base was overtaken). The in-built algorithm was used to determine the winner.

As occurred in the Session A matches, there was a brief unstructured discussion between the session coordinators and the session participants at the end of Match 1, Session B. The sentiments expressed by the participants were similar to those expressed by Session A participants, particularly in relation to the challenging nature of the anatomy and histology questions. The participants were of the view that the questions covered information they would be expected to know in their examinations, but also felt that no examination questions would ever be as difficult as the questions asked in the game.

The participants also discussed how 'game lag' affected their experiences of the 'They Know: Anatomy' game. In digital games, game lag refers to the phenomenon that arises when the internet connection is slow or unreliable. In this instance, game lag was caused by the university internet dropping out during the match. This had not occurred during Session A. However, in Session B, participants experienced delays when trying to respond to questions in Match 1. The game lag issue caused participants to feel frustrated. During the post-match discussion, all of the participants indicated that these technological issues had reduced their enjoyment of the game. However, as they noted in the post-match evaluation comments, they nonetheless liked the concept of the game. Despite the challenges created by the content and the technological issues related to the internet connection, most of the participants indicated that they found the gameplay experience engaging and rewarding. They also stated that they enjoyed working in teams, something they had not expected to do. All of the participants expressed excitement for the second match.

In addition to the impromptu post-match discussions, the same Likert scales used in Session A were administered at the end of each Session B match. The evaluation responses were analysed after the match and aggregated to obtain an overview of how the participants perceived their experience with the digital game. All of the participants were asked to complete the Likert scales, but only seven did so. Participants' responses to the Likert scales for Match 1, Session B were broader than those provided by Session A participants. Some participants left specific comments on their evaluation sheets, stating that they had given lower ratings for enjoyment and engagement due to the technical issues related the computer lag. Two participants left the following comments on their Likert rating sheets: *'Low enjoyment due to lag, idea of the game is fun' and 'Just needs to be less lag and it will be really fun. Will be back on Wednesday!'.*

Challenge was the most highly ranked domain with 86% of participants indicating that their experience was challenging. The other domains were given negative and neutral ratings. Based on the comments left on the evaluation sheets, these negative and neutral ratings appear to be attributable to the game lag issue. Engagement received a 58% positive rating, followed by competitiveness and desire to replay, which were both ranked positively by 57% of participants. The enjoyment domain was only ranked positively by 14% of the Match 1, Session B participants. *Refer to Table 6.6 for the aggregated participant responses to the six point Likert ranking for Session B, Match 1.*

Table 6.6: They Know Session B, Match 1 survey responses

Table 6.6 Participants' responses to the Likert scales for Match 1 of Session B (n = 7).						
	1	2	3	4	5	6
Challenge			14%		86%	
Competitiveness		14%		29%	43%	14%
Engagement		29%	14%		29%	29%
Enjoyment	14%	29%	14%	29%	14%	
Desire to replay	14%	14%	14%		43%	14%

6.5.2 Redesigns based on Match 1 feedback

No modifications were made to the game design following Match 1 of Session B nor were any modifications made to the gameplay environment. However, a temporary private network was set-up in the computer laboratory for Match 2 of Session B to ensure that the game lag issues that had affected Match 1 did not reoccur.

6.5.3 Session B, Match 2

Match 2 of Session B was conducted three days after Match 1. All of the participants who had participated in Match 1 of Session B returned for Match 2 of Session B. Participants were allocated to the same teams as they had been in for Match 1. Unlike in Match 1, no time was allocated for participants to complete the tutorial in Match 2. Instead, participants were given five minutes in the computer laboratories before the commencement of the match to situate themselves and reconnect with their team members.

During the match, the participants interacted with each other more than they had during Match 1; however, much of the conversation between team members did not relate to the anatomy and histology subject matter. Most of the participants commented on how much more smoothly the game was running and observed that they were not having any issues responding to the questions as a result of a game lag. As with Match 1, Match 2 concluded when the timer ran out after 40 minutes. The in-built algorithm was once again used to determine a winner. As with previous matches, the participants expressed disappointment that the victorious team had to be determined by the algorithm, noting that such a victory felt less definitive and that they could not see a direct link between their actions in the game and how the winner was determined. The algorithm the game used to allocate a winner was explained to the participants, but the participants continued to be of the view that it would be more 'clear cut' if the victory had been determined by an opposing team's home base being overtaken.

At the conclusion of the match, the participants were asked to complete the same Likert scales that they had completed following Match 1. As with Match 1, only seven of the eight participants completed the evaluations. The results of the Match 2 evaluations were much more consistent with the results of the Session A evaluations. Overall, the participants indicated they had very positive experiences with 'They Know: Anatomy' game once the technical issues had been resolved. The gameplay experience was ranked positively across all of the five domains used in the Likert scales. Indeed, the participants gave every domain a positive rating of 100%. Thus, the Session B participants engaged much more with the game than did the Session A participants. *Refer to Table 6.7 for the aggregated participant responses to the six point Likert ranking for Session B, Match 2.*

Table 6.7: They Know Session B, Match 2 survey responses

Table 6.7 Participants' responses to the Likert scales for Match 2 of Session B (n = 7).						
	1	**2**	**3**	**4**	**5**	**6**
Challenge					100%	
Competitiveness					57%	43%
Engagement					71%	19%
Enjoyment					100%	
Desire to replay					71%	19%

Unlike in previous matches, only a small amount of post-match discussion took place. The discussion that did occur related to the game lag issue. Notably, the participants commented that addressing the game lag issue had resulted in a much more enjoyable gameplay experience.

6.6 Session B evaluations

As occurred in Session A, semi-structured interviews were conducted after Session B to evaluate participants' experiences. The interviews were carried out within four weeks of Session B ending (i.e., the majority of interviews were conducted in late August; however, a few interviews were conducted in the first week of September).

All of the Session B participants were emailed an invitation to participate in a 15 to 30 minute phone interview about their experiences. Of the eight Session B participants, six agreed to participate in semi-structured interviews. A similar format to that adopted for the Session A interviews was adopted for the Session B interviews. The interview questions sought to explore how participants engaged with the platform, interacted with their peers and perceived the educational impact of the experience. The themes that emerged from the Session A interviews were also incorporated into the Session B interviews to obtain additional data.

Similar to the Session A interviewees, the Session B interviewees were asked about their previous experiences with digital games, particularly educational games, at the start of the interview. There was a relatively even division between frequent video game players and non-players (43% of participants self-identified as belonging to these two groups). One interviewee indicated that they had played video games semiregularly before beginning their degree, but no longer had any time to play video games. In relation to their experiences with educational digital games, four of the interviewees stated that they gained some experience of educational digital games at primary school and high school. The interviewees had mostly played serious educational games that had been designed to teach typing; however, the participants also referred to a spelling game and an unnamed mathematics game. The remaining three interviewees had no previous experience with educational games.

As with the Session A interviews, the Session B interviews were audio recorded. The audio recordings were then transcribed, de-identified and analysed. A correlation was found between the responses of Session A and Session B interviewees. As with Session A, interviewees' comments were divided into two main categories:

1. Participants' perceptions of their engagement with the 'They Know: Anatomy' game.

2. Participants' perception of the 'They Know: Anatomy' game as a tool for supporting learning and revision.

Within those two categories, multiple subcategories were also identified, including increases in engagement due to competition between opposing teams, increases in engagement due to inter-team interactions, using cooperation teamwork to support learning and using digital games to support revision.

6.6.1 Participants' perceptions of their engagement with the 'They Know: Anatomy' game

Session B interviewees expressed similar ideas about the 'They Know: Anatomy' game and their engagement with the game to those expressed by Session A interviewees. The discussion on participants' perceptions of their engagement with the 'They Know: Anatomy' game has been divided into two subcategories: competition between teams and cooperation among team members.

Competition between teams

Only three interviewees commented on cross-team competition and how it increased their engagement with the game. One interviewee noted the enjoyed the interactions caused by the competition, citing this as one of the most enjoyable aspects of the digital game. The other two interviewees echoed the sentiments that Session A interviewees had expressed about competition. They noted that the competition was fun and particularly unique in this type of educational game. One interviewee stated that the competition motivated them to continue and stay focused on their end goal of winning. This interviewee stated:

'It was fun; it was definitely engaging once you started playing because of the competition you kind of wanted to keep going at it which was good'.

Cooperation among team members

A number of Session B interviewees described cooperation among team members as a central component of the 'They Know: Anatomy' game. Four interviewees discussed this aspect of the game in some detail; however, their comments largely reflected those expressed by Session A by interviewees. Two of the interviews stated that they enjoyed the inter-team cooperation because it was fun and fulfilling, but did not describe how they cooperated with their team members. Another interviewee provided more detail on their interactions with team members and how it engaged them with the game. Similar to the other two interviewees, this interviewee described the cooperation as fun and rewarding and referred to it as the most fun aspect of the game. They also noted that they liked having the option of talking with teammates when they were unsure of an answer, as this increased how invested they felt in their team.

One interviewee raised an aspect of the inter-team cooperation that had not been raised by Session A interviewees: the game interface. This interviewee liked that they could see the movements of all their team members on the game map, stating that this increased their sense of connection with team activities. The interviewee responded:

'What else did I like about it? … that I could see what everyone was doing at the same time'.

Another interviewee noted that they spoke aloud a lot when answering questions and wondered, upon reflection, if their behaviour had been distracting to their team members, but noted that it was not something that they had considered at the time. Notably, none of the other interviewees commented on another player talking aloud during the matches. The same interviewee noted that having teammates to help them answer questions was especially rewarding, as they valued the accomplishment that they shared by finding the correct answer together. The interviewee stated:

'There was one or two people on my team who were helpful, whenever I had a question that I didn't know the answer to I would say it. And I found that I think I was the only person on my team who was vocalising when I didn't know something and maybe my teammates found that annoying umm … I don't know, but when people helped me out, that was really good.'

Interestingly, only one interviewee raised the issue of team members having different areas of expertise playing digital games and also in their knowledge of the subject matter, noting that while they liked having assistance answering questions, some team members were less knowledgeable than others and thus most interactions occurred between the team members who were more knowledgeable.

The final interviewee discussed how inter-team cooperation affected the strategic approach adopted by their team to conquer the map. This interviewee was of the view that the team developed a sense of who was ‘good’ at what by discussing answers to specific questions with team members or asking team members for help during the game. This information was then used to spread the team across the map strategically to ensure optimal coverage. This interviewee also noted that this strategy was very spontaneous and continued to evolve throughout the match, creating a unique experience and requiring team members to adapt to the changing conditions. The interviewee stated:

> *‘The gameplay was very fast so there was no consensus or set consensus of how to approach the game as a team, but I think it was more like this is the collaboration was more on an ad hoc basis.’*

6.1.2 Participants’ perceptions of the ‘They Know: Anatomy’ game as a tool for supporting learning and revision

During the semi-structured interviews the, interviewees were asked to reflect on how the ‘They Know: Anatomy’ game affected their knowledge of anatomy and histology. The question was asked to gain an understanding of whether or not participants were of the view that the digital game had affected their approach to learning and revision. The themes that emerged from the Session B interviews reflected those that emerged from the Session A interviews. The same two themes were identified in both the Session A and Session B interviews: cooperation among team members and the use of digital fames as revision tools.

Digital games as tools for revision

Session B interviewees spent a significant amount of time discussing how they thought the 'They Know: Anatomy' game could be used as an effective revision tool. Of the seven interviewees, four discussed this theme in detail. The majority of interviewees who discussed this element of the gameplay experience viewed the 'They Know: Anatomy' game as a beneficial tool for revision, noting that it highlighted the limits of their subject matter knowledge. Further, in addition to reinforcing the areas that they knew well, the interviewees stated that the digital game also helped them to identify knowledge that they had lost over time (sometimes in areas that they thought they knew well). One interviewee noted:

> *'I learned what I knew. It was good showing me what I had mastered fairly well and what I really needed to revise based on my speed in answering questions'.*

One interviewee thought the map layout with subject matter nodes effectively assisted learners to identify their knowledge strengths and deficits. This interviewee noted that the nodes made it easier for them to recall weak areas of knowledge, as they could recall the layout of the nodes and the areas of the maps with which they struggled rather than having to remember one or two questions they answered incorrectly. They also noted that they could use this knowledge to target revision areas in the future. The interviewee stated:

> *'I think it helped me identify some areas that I was really weak in. Because I've only got a limited amount of time until the answer because it tells me straight away whether I'm right or wrong. It helped me sort of know, 'Oh, ok, well, I'm consistently getting [the] cross-sectional anatomy node wrong, and I keep dying so maybe I need to brush up on my cross-sectional anatomy'. Whereas if I was doing the histology node, I could just go through that because I knew most of the answers there. I thought I was actually better at cross-sectional anatomy…I feel like it did help me figure out where I was at.'*

Three interviewees also discussed the structured quiz format and how it was a powerful tool for revision because it quickly tested the effects of any other revision activities they had undertaken. Another interviewee noted that quizzes were effective as a knowledge reinforcement tool before examination and that the added pressure of the timer mechanic in the 'They Know: Anatomy' game was particularly beneficial.

Thus, interviewees' feedback about the digital game was mostly positive; however, some interviewees expressed concerns about the platform. One interviewee thought the digital game was limited due to the lack of feedback given to the multiple-choice questions. They liked the structure, but felt feedback needed be incorporated to make the digital game a truly effective revision tool. This interviewee stated:

> *'This game is more structured like a quiz. So, in my opinion in order to learn you need to have some feedback mechanism. So, there was no feedback as to whether the question you got was right or wrong. I think that could be incorporated again if there was a feedback mechanism [about] where you went wrong so you can learn.'*

Finally, interviewees discussed the pressure created by the timer, observing that it was unique because it altered the tone of the revision session. The use of timers to test knowledge increased the importance of answering correctly and triggered the recall process. One interviewee was of the view that the pressure created by the timer assisted participants to quickly identify the subject content that they did and did not know. This interviewee stated:

> *'We don't really have that many tools out there where there's a timed aspect to it … I mean [there are] a lot of little pictures or things like that online where you can do the quizzes, but there's no time aspect to it, which kind of takes the pressure off. So, [the game]*

was an interesting method where [sic] I could test that I either knew it really well or I didn't figure it out in time.'

The level of challenge of the game

During the Session B interviews, three interviewees expressed the view that the multiple-choice question timers acted as a barrier to learning. These interviewees were concerned that the timer placed pressure on participants and that it did not allow participants adequate time to reflect upon the correct answers. This did not compromise their enjoyment of the game; however, these interviewees were of the view that adjusting the timer would not negatively affect participants' engagement and could increase the educational impact of the game. One interviewee commented:

'By the time you read the question and figure out you need help and then ask someone else, it's sorry, your 10 seconds is done kind of thing'.

The second interviewee was of the view that the timers were a challenge in the context of the session, but felt that more experienced players may not have experienced any such issues. This interviewee stated:

'We really didn't have time to interact because of how quick everything was going. I think it would've been more helpful to have

more time to answer questions; it would be 'Hey, guys, what is the answer or what did you guys think?', have time to pause for a second, do our game plan and then go back. I am guessing over time, you would play it a few times so you would kind of know ... I guess because we were so fresh, that would've been helpful.'

6.7 Redesigns between Session B and Session C

Session C of the 'They Know: Anatomy' intervention was conducted in 2015. Consequently, a new cohort of second year medical students had to be recruited to participate in the session. The game map was redesigned prior to Session C based on observations of how participants in the previous sessions had crossed the map. The question cards used in the 2015 iteration of the 'They Know: Anatomy' intervention were the same as those used in 2014 sessions; however, the layout of the subject nodes was altered. The game map was designed to be more compact and to make it easier for participants to win the game by taking control of the opposing team's base. It was thought that making the number of subject nodes in the map network smaller would make it easier for teams of four to cross the map within the time limit.

A new game orientation process was also developed for Session C, as the two previous iterations had failed to successfully introduce the game to the participants. The tutorial used for Session A provided players with an efficient overview of the digital game rules and allowed them to ask questions; however, the use of an oral presentation meant that participants had nothing to refer to during the session if they were unable to remember how certain aspects of the digital game worked. The tutorial designed for Session B attempted to overcome this issue by allowing players to continue to access the tutorial during the gameplay session; however, this tutorial could not be adapted for players who had different levels of experience with commercial games. Thus, while some players found the Session B tutorial very helpful, others had little use for it and had to wait to start the match until the slower players had finished the tutorial.

The game orientation was also revised because the 2015 participant cohort appeared to have a very low level of experience with digital games and it was anticipated that they would require further support to familiarise themselves with the game elements. Thus, in place of an interactive tutorial or oral presentation, the Session C participants each received a 10-page game manual that set out both basic rules and more complex aspects of the game. This manual also included screenshots of the game to enable participants to see the map layout before they logged into the game. Before playing the first match, each team was given 10 minutes to review the manual and discuss a strategy for crossing the game map to win the game. The participants remained in possession of the game manual for the duration of the match and could refer to it as they wished during the match.

An additional modification was also made to the gameplay environment for Session C. The 2014 interviewees had commented on the effects that inter-team competition had on their engagement and educational experience. A review of the observational data collected during the 2014 sessions (from field notes and video recordings) revealed that Session A and Session B participants had engaged in long periods of solitary play. To address this issue, a modified match structure was adopted. In addition to the pre-game discussion, a 15-minute post-match briefing was also incorporated into the match. In the post-match debriefing, players were required to participate in a guided reflection activity with their team members to explore how their team had fared in the game, assess their knowledge strengths and weaknesses and consider new strategies for approaching the next match. At the conclusion of the first match, participants were asked to move away from their computers to participate in the debriefing session. Each team was given a short set of instructions by the match coordinator to guide the discussion, but were also encouraged to discuss the match autonomously. Team discussions focused on individuals' performances, as participants' identified their strengths and weaknesses. Participants were also encouraged to make observations about their team members' abilities. Finally, they were asked to consider strategies (e.g., any revision they needed to undertake to strengthen their team's knowledge) for Match 2.

6.8 Session C (May 2015)

The final session of the 'They Know: Anatomy' intervention was conducted in May 2015. Following the 2015 recruitment activities, 20 students (compared to 54 in 2014) expressed interest in participating in the study. Despite less students expressing interest in 2015, there was nonetheless a sufficient number of students to conduct Session C of the 'They Know: Anatomy' intervention.

Eight participants, who were divided into two even teams of four, participated in Session C. Each team comprised three female and one male participants. Conversely, each of the 2014 sessions comprised six male and two female participants. The participants undertook the matches in two computer laboratories at the University of Sydney's Camperdown campus. Players on the same team were co-situated in the same computer laboratory; however, the two teams were situated in separate computer laboratories from one another. When the two teams were co-situated in the same lab in the previous Session it had increased interaction. However, this interaction was not focused on the subject matter, and so a decision was made to return to using two different computer labs for the different teams. The laboratories were equipped with iMac desktop computers. Each player was given access to an iMac computer in the laboratory that was connected to the university's internet infrastructure and able run the web browser, Chrome.

The session comprised two matches, held three days apart (i.e., the same structure was adopted as that used in Session B of 2014). Each match took approximately one hour, allowing time for the pre-match discussion and post-match evaluations. Participants were emailed information about when each match for Session C would be held and were then able to self-select to participate.

6.8.1 Session C, Match 1

Participants had approximately 10 minutes to review the game manual and discuss a strategy with their team members as they waited for the computers to be logged into the digital games. As occurred in the previous sessions, participants were quiet for the first five to 10 minutes of the game. They appeared to use that time to familiarise themselves with how to navigate the game and to apply what they had read in the game manual to playing the game. As the game progressed, discussion among the participants increased.

Observations of the match showed that a clear division emerged between the team members identified as content or strategy experts and those identified as novices. Numerous interactions occurred when 'weaker' participants sought advice from 'stronger' team members or when 'stronger' participants asked other team members if they wanted or needed assistance. The modifications to the match structure appeared to increase interactions among team members. Additionally, as the match progressed, interactions among team members relevant to reviewing anatomy and histology subject matter also appeared to increase. Interactions among team members appeared more focused on subject matter; however, the modification to the game map layout did not make it easier for participants to cross the game map any faster. Once again, the algorithm had to be used to determine the winning team when the time limit expired and not because a team had gained control of an opposing team's base.

Following the match, the participants were guided to engage in the post-match debriefing. Discussion during the debriefing sessions for both teams focused on the mechanics of the game and what participants did and did not like. Participants also sought to clarify numerous misconceptions about navigating the map and taking control of nodes. Numerous participants referred to the computers in the laboratory, noting that they were very slow.The session coordinators observed that participants focused on what members of the opposing teams did or did not know rather than what their team members did or did not know.

Before leaving the computer laboratories, participants were asked to complete the same Likert scales used in Sessions A and B. All eight participants completed the post-match evaluations. An analysis of the responses showed a significant amount of variation between the experiences of Session C participants in 2015 and the experiences of

Sessions A and B participants in 2014. Notably, none of the Session C participants ranked the domain of enjoyment positively; rather, a majority of participants (i.e., 87.5%) gave that domain a neutral rating. This may be because the Session C participants' lower level of digital game literacy created a steeper learning curve in Match 1 and thus lowered their enjoyment. Responses to the other four domains were fairly consistent to those given in the 2014 sessions. Both challenge and competitiveness received the highest positive ratings (87.5%), followed by engagement (75%) and finally desire to replay (62%). *Refer to Table 6.8 for the aggregated participant responses to the six point Likert ranking for Session C, Match 1.*

Table 6.8: They Know Session C, Match 1 survey responses

Table 6.8 Participants' responses to the Likert scales for Match 1 of Session C (n = 8).						
	1	**2**	**3**	**4**	**5**	**6**
Challenge				12.5%	62.5%	25%
Competitiveness				12.5%	62.5%	25%
Engagement				25%	62.5%	12.5%
Enjoyment		12.5%	50%	37.5%		
Desire to replay	12.5%	12.5%	12.5%		37.5%	25%

6.8.2 Redesigns based on Match 1 feedback

No changes were made to the environment set-up, game rules or content between Matches 1 and 2 of Session C. All of the participants returned and played on the same teams in Match 2 as they had for Match 1. Participants also attended the same computer laboratories (i.e., players in the same team were once again co-situated). However, the participant of one team failed to attend. Thus, a team of three had to play against a team of four. The team of four players had an advantage over the team of three players in competing for the win condition.

6.8.3 Session C, Match 2

Match 2 was conducted three days after Match 1. Again, one hour was allocated for the completion of the match. Participants had 10 minutes at the start of the match to discuss their strategies for the match and share any new knowledge that they had acquired between the matches if they had opted to engage in inter-match anatomy and histology revision. It was anticipated that the game would run for the same time as it had in Match 1. No structured debriefing was conducted following the match.

During Match 2, there were noticeably more interactions among the team members from the start of and throughout the match. Some non-subject matter related discussion did take place; however, much of the inter-team discussions focused on answering the anatomy and histology questions. Additionally, one team had established a team leader who helped guide the team's strategy during the game and offered advice on which players should go to which subject nodes on the map.

At the conclusion of the match, brief discussions took place between the participants and the session coordinators. The participants stated that they had enjoyed Match 2 more than Match 1. A number of participants also indicated that they would like to have access to the game at home so that they could play it with their friends or in their study groups.

The participants were again asked to complete the five domain Likert scales used in the previous 'They Know: Anatomy' matches. All seven participants completed the scale. Consistent with the end-of-match discussions, the Likert ratings revealed a significant change in positive ratings for the domain of enjoyment from 0% to 58%. Challenge was once again rated highly at 100%, followed by competitiveness and engagement (71% and 71%, respectively). Desire to replay received a positive rating of 57%. *Refer to Table 6.8 for the aggregated participant responses to the six point Likert ranking for Session C, Match 2.*

Table 6.9: They Know Session B, Match 2 survey responses

Table 6.9 Participants' responses to the Likert scales for Match 2 of Session C (n = 7).						
	1	**2**	**3**	**4**	**5**	**6**
Challenge					100%	
Competitiveness				29%	71%	
Engagement				29%	57%	14%
Enjoyment			14%	29%	29%	29%
Desire to replay			29%	14%	14%	43%

6.9 Session C evaluations

Semi-structured interviews, similar to those used in Sessions A and B, were conducted following Session C to evaluate participants' experiences As occurred in Sessions A and B, the interviews were conducted within four weeks of Session C ending (i.e., the interviews were completed by the first week of June 2015). Unlike the interviews for Sessions A and B, the Session C interviews were conducted face-to-face and lasted longer (30–60 minutes depending upon participants' availability). Session C participants were emailed and asked to participate in interviews. Of the eight Session C participants, seven agreed to participate in the semi-structured interviews. This included the participant who had only attended one of the two matches.

As occurred in Sessions A and B interviews, the interviewees were asked about their previous experiences with digital games, particularly educational games, at the start of the interview. The responses of Session C interviewees were surprisingly different to those of Sessions A and B interviewees. Of the seven interviewees, only one identified as an experienced and frequent video game player. An even number of the interviewees had either no experience with video games (n = 3) or rarely played video games/considered their experience minimal (n = 3). Of the three participants who considered themselves inexperienced video game players, their definitions of video game experience differed significantly. One interviewee said they were a former serious video game player, but had stopped playing digital games as the activity took up too much time. Another interviewee said they only played 'easy' digital games and thus did not consider themselves experienced, but was familiar with what digital games involved from observing serious players. Finally, one interviewee said they were not really experienced, but did spend a lot of time playing mobile games on their smartphone.

The responses of Session C interviewees about their exposure to educational games also differed to the responses of Sessions A and B interviewees. Only one interviewee stated they had no experience with educational games. One interviewee stated that they currently played an educational game to revise content for their degree. The majority of interviewees stated that they had gained some exposure to educational games during school, mostly in primary school, but noted that the games they had played were not very memorable or impactful.

The data from the interview transcripts were divided into six categories:

1. Participants' perceptions of their engagement with the 'They Know: Anatomy' game.

2. Participants' perceptions of the 'They Know: Anatomy' game as a tool for supporting learning and revision.

3. Participants' perceptions on which elements of multiplayer games foster cooperation.

4. Participants' perceptions on the effects of the post-game debriefings.

5. Participants' perceptions on reducing social isolation in large cohorts.

6. Participants' perceptions on engaging end users as game designers.

Multiple subcategories were also identified within the six categories, including increases in engagement due to competition between opposing teams, increases in engagement due to inter-team interactions, using cooperation and teamwork to support learning and using digital games to support leaning and revision.

6.9.1 Participants' perceptions of their engagement with the 'They Know: Anatomy' game

As with the Session B interviews, the Session C interviews focused less on participants' engagement and more on the educational effects of the game. However, a number of interviewees did refer to their engagement with and enjoyment of the digital game. These comments largely reflected those made by the 2014 interviewees and no novel insights were gained.

Competition between teams

Six interviewees discussed how cross-team competition affected their engagement with the 'They Know: Anatomy' game during Session C. Most of the interviewees were of the view that the competitive aspect of the game ultimately created an engaging experience. However, some interviewees were of the view that while the competition was engaging, it was also stressful.

Two interviewees noted that there were very few opportunities to be competitive when the stakes are low in tertiary education. Consequently, they were surprised at how engaging the experience had been and how it motivated them to work harder to recall the correct answers to certain questions. One interviewee concluded that they liked the competition in the game because their team won and it was fun and engaging. This interviewee stated:

> *'It [the competition] was good. I have a skewed view of winning both the sessions. My team won, so I think it [the competition] is brilliant because I just won'.*

The interviewees also discussed the effect that the competition had on their commitment to their team. Overall, they felt that the competitive aspect of the game positively affected their recall of information. They also noted that they felt invested in their teams and thus put more effort into recalling latent anatomy knowledge. As one interviewee stated:

> *'I feel like because you felt like the stakes were a bit higher, I felt a little more motivated to dig deep and try and recall the answer. I liked that. It was kind of fun; it gave it more of a raison d'être, why am I doing this.'*

Two interviewees raised issues around the complexity of the competition and how it created both an engaging and negative experience. These interviewees were of the view that there was a fine line between positive and negative competition. They noted that the competition in the 'They Know: Anatomy' game was fun, but that could change if the specific implementations of the game changed. One interviewee expressed concern that a team with one or two very competitive players could negatively affect the experience of others, stating:

> *'I feel like if I had really competitive people in my team who were disappointed in my performance because it was bringing the team down then, I would've really resented it. I didn't feel like that, so I didn't mind the competitive stuff was there.'*

Another interview described the competition as motivating and stressful, stating:

> *'It [the competition] was good and bad. It was fun to be competitive and, at the same time, it was stressful. It was hard to think about what I was doing versus, 'Oh my god, I have to get this right'. It's exciting when I got them right and a little frustrating when I didn't know what I was doing. But overall the competitiveness makes it a little bit addictive, of course, as a medical student, everyone is kind of competitive.'*

Cooperation among team members

The role of team dynamics in engaging participants was not the subject of extensive discussion among Session C interviewees. Only one interviewee referred to it, stating:

> *'I enjoy teamwork. I liked the aspect of working on the same thing with a group of people and being on the same side. I enjoyed it'.*

6.9.2 Participants' perceptions of the 'They Know: Anatomy' game as a tool for supporting learning and revision

The Session C interviewees talked extensively about the role of digital games in supporting and guiding their revision. The discussions covered a wide range of topics, but were particularly focused on the role of the 'They Know: Anatomy' game in reactivating latent or inactive knowledge. The interviewees also discussed how digital games could assist them to target areas for revision, considered ideas about flexibility in learning and identified the traits that make digital games valuable revision tools.

Reactivating latent knowledge

Session A and B interviewees referred to the ability of the 'They Know: Anatomy' game to reactivate latent knowledge. Consequently, it was unsurprising when Session C interviewees mentioned this again. However, the Session C interviewees discussed the complex range of mechanics that made the 'They Know: Anatomy' game particularly adept at bringing dormant and forgotten knowledge back to the forefront of their minds.

Some interviewees stated that the 'They Know: Anatomy' game provided a useful way of reviewing a large amount of content that they had not encountered for over a year. They further noted that the structure of the game itself (i.e., the map layout of subject matter nodes and sets of questions) provided clear overview of anatomy as a subject and enabled them to better understand the scope of the subject. One interviewee said it was humbling to see the year's anatomy and histology subject matter laid out across the map and that it reinforced the necessity of revising and engaging in continued study to retain their understandings of important information.

Multiple interviewees echoed the idea that the map layout of the game was useful in identifying gaps in their understanding of anatomy and histology. Some interviewees were surprised at the areas in which they had strong knowledge and stated that they would not have realised this if they had not played the game. Most of the interviewees described the digital game as a useful tool for identifying weaknesses in their knowledge. A number of interviewees provided specific examples of topic areas covered in the game with which they surprised themselves by their poor performance. One interviewee stated:

> *'It was useful. It was thrown in my face that I had gaps in my knowledge when I was doing the multiple-choice questions ... this is a new way to do that'.*

The interviewees also mentioned the ability of digital games to reinforce and refresh knowledge, One interviewee noted that the digital game was particularly good at reinforcing information that students would need to be able to recall automatically on the spot in the future, as opposed to information that required deeper contemplation or review.

Targeting areas for revision

The interviewees noted that the digital game assisted them to refine and target what revision they would need to undertake for anatomy and histology revision. These insights also allowed them to tailor their approaches to revision based on their strengths and weaknesses. One component of this was the ability of the game to be played quickly and repeatedly without becoming boring. Thus, it could be used before or after study sessions to target future revision.

The interviewees were also of the view that the 'replayability' of the game would support and encourage students to engage in inter-match revisions of anatomy and histology content to maximise the likelihood that they would win future matches. A number of interviewees noted that they did a small amount of revision between Matches 1 and 2 of Session C. These interviewees stated that in a real-world context, playing the game might encourage students to engage in more revision between matches than what had been undertaken for the present study. The interviewee stated:

> *'I thought about it [doing revision between matches], but I didn't look anything up. I think if I knew that it was not just research, but part of the curriculum or an ongoing competition I would definitely go away and look up the things I didn't know and study for it, but I didn't on this occasion.'*

Finally, some interviewees discussed the value of the digital game in assisting students to prioritise which areas of anatomy and histology to revise. Playing the digital game provided participants with a clear overview of the subject nodes on the map at which they were strong and weak. The interviewees were of the view they could use this information to make more informed decisions about what areas to revise and prioritise. The interviewees found the final analytics screen that appeared at the end of the game to be particularly beneficial in supporting this process, as it mapped their progress over the game and compared it to the other players.

Learning in periods of downtime

A few interviewees raised whether the 'They Know: Anatomy' game could be used to support short revision sessions. The interviewees described the intense nature of textbook revision and noted that a digital game would be particularly useful to breakup such sessions. This concept was similar to the idea of 'productive procrastination' identified by Session A interviewees; however, the Session C interviewees expanded upon this theme. One interviewee described having time to study anatomy as a luxury and thought that the competitive nature of the game would motivate and encourage students to revise, but noted that other factors could affect whether students used the game to revise. This interviewee stated:

'I am competitive and would've liked to study [between game matches], but I had other obligations. It is a luxury to do anatomy study and because a lot of the anatomy that was tested was first year and [because] that's not tested in our upcoming exam, it was not wise to do so.'

Interviewees were of the view that the minimal time commitment required to play a game on a platform increased the likelihood that they would engage in a quick revision session in between other study sessions. One interviewee stated:

'It's kind of a fun thing to do not during cramming time because I could do it in the between phase … I have kind of already studied, and now it's time to go over it, have fun and see if I can get anything else. I would use this in between [other study] I have already learned and I would kind of review and if the team can hash it out a little bit.'

Finally, interviewees discussed how the game could be used to quickly identify which areas they needed to revise and which areas they did not need to revise. One interviewee stated:

'It would be really nice to know what areas you don't need to study as much on because you do understand it and what you need to work on. I don't feel like I have a system at the moment that helps

me differentiate between the two ... I liked that aspect of the game. Being able to quickly see I was quite strong on head and neck, but my histology was awful, it would help redirect my learning.'

The inherent traits of digital games

A small number of interviewees mentioned that there were inherent traits of digital games that made them appealing for revision, including the risk–reward systems used in many digital games. One interviewee noted that the 'They Know: Anatomy' game used the balance of risk and reward to affect players' experiences and to make the process of learning fun and engaging. This interviewee stated:

'I was really chuffed when I knew something. That was really a nice feeling. I was quite frustrated when I didn't know something'.

Another interviewee referred to the ability replay digital games and viewed this aspect of the 'They Know: Anatomy' game as particularly appealing, noting that replaying the game also increased participants' exposure to subject matter.

The level of challenge of the game

Two interviewees raised the educational value of a challenge, noting that the challenge made the game particularly enjoyable and played an important role in reinforcing their knowledge deficits. Another interviewee stated that they found the content itself to be quite challenging and that while this was confronting, it had motivated them to learn more.

Repetition of subject matter

Four interviewees referred to the digital game's repetition mechanic and its educational effect. These interviewees noted that the repetition of questions helped to reinforce their knowledge, making it easier to recall later. One interviewee described feeling frustrated when they got an answer wrong more than once, stating:

> *'Yes, repetition helped retain information about what was answered wrong and answered right the second time. It was frustrating to get the answer wrong twice'.*

6.9.3 Participants' perceptions on which elements of multiplayer games foster cooperation

Session C interviewees discussed the role of inter-team cooperation in supporting collaborative learning during the game matches. The role of strategy to connect a team and its ability to encourage shared decision-making were considered particularly important elements for supporting cooperative learning. A small number of interviewees mentioned other inter-team cooperation elements that affected their learning experiences, including the effect of team structure and its role as a support system and the effect of team members working towards a common goal.

Developing a team strategy

The interviewees discussed the process of developing a strategy as a team in detail. Many interviewees cited it as a novel experience, noting that they had not undertaken learning activities or played similar games previously. The majority of interviewees noted that they were able to work with their team members to develop and reflect upon their gameplay strategies during the pre- and post-game discussions. During these discussions, team members discussed their perceived strengths and weakness in anatomy and histology knowledge and how they could use that information to decide how best to cross the map in future games.

One interviewee expressed concern that the approach for developing a gameplay strategy could have both negative and positive effects on learning, as at times it limited knowledge acquisition. This interviewee stated:

> *'The one problem I think was our strategy. We stuck to what we already knew overall, so we didn't venture out and try to learn new things by going to spots we weren't very comfortable with'.*

Other interviewees held different perspectives as to whether their team strategies encouraged them to avoid hard subject matter nodes or nodes in which they had less confident. One interviewee noted that they intentionally went to areas that they perceived as hard to ensure that weaker team members did not feel pressured to gain control of those territories. Another interviewee noted that a team strategy had been developed to maximise the learning of each person on the team, so that they would be less vulnerable if they were attacked with questions in weak areas by the opposing team.

Finally, two interviewees noted that inter-team discussion was viewed as a component of the team's strategy. Team members were encouraged to ask questions if they were having difficulties, seek help from other team members and ask for assistance in defending the home base from an enemy team member to ensure the team crossed the map quickly and efficiently.

Shared decision-making

Session C interviewees talked extensively about the process of shared decision-making in the game. The interviewees described working as a team to make decisions about strategies or how to answer individual questions to be a surprisingly rewarding experience. Additionally, as they came to know their team member's strengths and weaknesses of the subject matter, the process helped team members feel closer to one another and that they had more in common with their team members.

The interviewees liked that the game enabled them to make shared decisions with other team members, but overall felt that the discussion of questions among team members was not common and more shared decisions were made about strategies for winning the game rather than to reinforce learning. Some interviewees noted team discussion should be incorporated into the game to increase cooperation among team members. One interviewee suggested that players should have to read out questions to one another and reach a team consensus before inputting any answer. Another interviewee suggested that it would be useful to have one player be the coordinator of the team, but not as a controlling avatar, to help other players and provide advice on how to move across the map.

Finally, one interviewee noted that they felt a very strong desire to work with and help their team members during the game session, but expressed surprised at how often the group answered questions incorrectly. This also revealed that rather than having different gaps in knowledge, the participants shared a number of gaps in knowledge.

Working towards a common goal

The interviewees expressed mixed opinions about the value of shared decision-making; however, all of the interviewees found that having a common goal created a positive experience. They liked that the 'They Know: Anatomy' game allowed players to work through content autonomously while still being linked to the success or failure of other players.

The interviewees suggested that working towards a common goal during the game had a significant effect on their learning. Interviewees noted that they felt compelled to work harder to recall information and answer questions correctly on multiple occasions, as they did not wish to let their team members down. One interviewee also noted that the process of working towards a shared goal was quite novel and fun, stating:

> *'It was very novel, quite nice. I enjoy teamwork, so I like the aspect of working on the same thing with a group of people and being on the same side. I enjoyed it'.*

Team structure and a support system

Interviewees did not talk about team structure at great length. However, those that did discuss the team structure and support system noted that they valued the support system provided by the team structure of the 'They Know: Anatomy' game. The interviewees noted that the structure had numerous advantages, including knowing that there was a support system and that they could rely on team members when necessary.

Some interviewees discussed how the structure of teams affected the enjoyment of the game. One interviewee was of the view that the game could be used to encourage cooperation among stronger and weaker students and that teams should comprise participants whose skills and strengths varied. The interviewee stated:

> *'I think that the learning will happen best in this game where you have strong people in a team with weak people'.*

6.9.4 Participants' perceptions on the effects of the post-game debriefings

In Session C, a new element was introduced to the gameplay experience to increase team cooperation (i.e., 20-minute post-match debriefings were held). The interviewees were asked to reflect upon these debriefings and talk about how they found their interactions with teammates during the debriefing.

Peer feedback

The interviewees used some of the debriefings to obtain their peers' feedback and described this as a useful experience. They noted that after playing the game, they had some idea of the areas in which team members had or lacked knowledge and that this was discussed in the debriefings. The debriefings were also used to discuss approaches to exploring the game map that could be used in the future. One interviewee stated:

> *'It was good because then I could hear everyone's feedback and think "Yeah, that's right, I didn't think about that". It was a good debrief'.*

One interviewee noted that the participants discussed the different strategies players used to interact with the game map. This led to a discussion about what worked and what did not work. Another interviewee noted that the debriefings provided them with insights into the various approaches adopted by different participants.

Two interviewees noted that they discussed how the other team played and used the debriefing to examine how members on the opposing team moved and their strengths and weaknesses. In one debriefing, the participants focused on the movements of particularly strong players and considered how they could avoid getting in the paths of these players in the future.

Generally, the peer feedback revealed that the debriefings increased the confidence that teams had in their approaches. Interviewees stated that by the end of the debriefing, they had articulated a clear plan of how they would win the next map.

Clarifying the rules

The debriefings were also used to clarify game rules. Due to the range of experience that participants had with digital games, not everyone was certain about the different game features at the end of Match 1. Some participants used the debriefings to share what they had learned about the game rules. Interviewees also said that they had discussed what they would do in the next match if certain problems were encountered. One Interviewee stated:

> *'It turned out some of the people in the team hadn't understood the rules in the game. Some people didn't understand about sending questions to other people. I hadn't understood that you had to be in the centre of the node to get questions. I think we mostly just went over the rules of the game that we missed… it was useful to prepare for the second match.'*

Applications of the 'They Know: Anatomy' game

The interviewees noted that they had briefly discussed how the 'They Know: Anatomy' game could be used outside a study context. The interviewees discussed their desire to find new tools to combat the boredom of revision and noted that digital games could address this issue. The interviewees also considered whether the game could be used in anatomy laboratories as students were settling or whether a two-hour block of time studying could be broken up by a 20-minute game. The interviewees were of the view that the game would provide a pleasant break from monotonous routines while still allowing them to use their time productively.

6.9.5 Participants' perceptions on reducing social isolation in large cohorts

A number of Session C interviewees were of the view that the 'They Know: Anatomy' game experience reduced their social isolation. These interviewees observed that there was a large number of medical students enrolled in the program and noted that interactions among students were only minimal. The interviewees also discussed the highly competitive environment in which they were in as students and noted that this reduced the likelihood of students interacting.

Bonding

The primary value of the 'They Know: Anatomy' game in reducing social isolation related to its ability to encourage participants to bond as a result of the team structure. The interviewees described how incorporating the game into the curriculum could encourage more widespread social interaction across the course. One interviewee stated:

> *'I feel like there is [sic] so many people in the class I see every day and run into them all the time and I have no idea what their names are, and they have no idea what my name is. It seems silly when I spent seven hours with you in a room yesterday. Any opportunity we have with a new group even for a day, I feel like that opens up communication.'*

One interviewee also contrasted the experience of the small game to that of a larger program, stating:

> *'It was kind of like a bonding experience in a way. It's different to a big program where you don't know anybody and they were in my year and I had never met them and it was nice to meet new people.'*

Another interviewee discussed the possible advantages of using the game in problem-based learning or clinical groups. In such circumstances, students are assigned to groups randomly and often do not engage with group members other than to meet the minimum requirements. A structured team-based activity, such as the 'They Know: Anatomy' game, could be used to encourage bonding among group members assigned. The interviewee stated:

> *'If it was [sic] structured in a way that kind of said it's Clinical Group A and Clinical Group B [are competing]. Yeah, I think that would be better… I feel like when you have a group that you've already got and then you're forced to work together on something against some other group, it doesn't make you hate the other group, but it bonds your current group. I just think it would be nice. You could do it on a bigger scale, you could do it across clinical schools.'*

Conversely, another interviewee suggested students' reactions to such an activity might be mixed. This interviewee stated that while many students might like such an activity, a significant number would resent being asked to participate in a game-based activity. The interviewee stated:

> *'Being forced to play a game, I think there would be a lot of backlash. I think half the group would be great and excited and half the group would be "Why do I need to do this? This is not for me"'.*

A low pressure environment

Several interviewees stated that they found the experience of engaging in friendly competition with their peers interesting. They noted that the game provided them with unique insights into the strengths and weaknesses of their peers that they would not otherwise have gained. In the context of the game, the interviewees noted that they were less hesitant to share information about the areas that they were struggling to learn. The game also allowed participants to see that other students were experiencing problems and that they were not alone in finding certain areas challenging.

Structuring groups and courses

A number of interviewees were of the view that 'They Know: Anatomy' game provided an opportunity to structure study and clinical groups. One interviewee suggested that playing the game earlier in the year might help students to identify others in the course with complementary strengths and weaknesses, which in turn could help students to form stronger study groups. One interviewee noted that the game could also be used as an accessible team-based tool for students who did not feel they had a group of friends with whom they could form a study group because such students could play with random teams using the game system.

Another interviewee thought it would be interesting to use the game to run cross-clinical group competitions. They were of the view that this experience could strengthen bonds among members of clinical groups without negative feelings being developed towards opposing groups. The interviewee stated:

> *'[I] feel like when you have a group that you've already got and then you're forced to work together on something against some other group it doesn't make you hate the other group, but it bonds your current group. I just think it would be nice. You could do it on a bigger scale, you could do two clinical schools that have it.'*

Another interviewee thought that the game could be used to structure curricula. If a session was played earlier in the year, a course coordinator could ascertain the spread of knowledge across the cohort and then use this information to tailor the curriculum to the needs of students.

6.9.6 Participants' perceptions on engaging end users as game designers

The Session C interviewees were eager to discuss the potential of User Generated Content (UGC) in relation to the 'They Know: Anatomy' game and how UGC would affect their educational experiences. The discussions included suggestions as to how the system could be modified to create both user-generated questions and user-designed game maps.

Developing questions

Most of the interviewees wished to discuss the questions that had been developed for the 'They Know: Anatomy' game and how these questions could be improved in the future. Similar to the Sessions A and B interviewees, the Session C interviewees were of the view that the questions were quite difficult. However, the interviewees appreciated that the course coordinators had developed the resources to ensure that the content aligned with knowledge that they needed to acquire

The interviewees expressed a range of opinions in relation to UGC. Overall, the interviewees expressed some concerns about the quality of questions developed by students. One interviewee stated:

> *'I'm a bit sceptical of letting the students build them because we had a similar program called Med Bank where students get to write their own questions. It's really bad. Really, the questions are very irrelevant. They're just really silly things like, 'In what year was blah, blah legalized'—it doesn't really matter. I would be worried about that. Most people don't know what is an important concept of anatomy and what is a really minute thing that no one would actually care about. If it was something set by anatomy demonstrators or whatever then I think that would be good.'*

Several interviewees thought that UGC could have a potentially positive effect on the game, but that guidelines would need to be implemented on how to write the questions and what type of content was suitable for inclusion. One interviewee thought a peer review process whereby questions were anonymously rated might work. Another interviewee noted that UGC might cause individuals to 'show off' by writing impossibly difficult questions and were unsure about whether such behaviours could be avoided.

Map design

The interviewees were very positive about the possibility of designing their own game maps using expert developed questions. Generally, the interviewees were of the view that students would benefit if they could design game maps that set out information in a way that was useful to each individual. One interviewee stated:

> *'Yeah, I would be optimistic about something like that [designing a map using faculty built multiple choice questions so the map had a structure consistent to knowledge of player]'. Another interviewee suggested that the maps could be randomly designed, stating: 'Maybe the map should be randomly generated for each episode of the game and the team starting place switched'.*

6.7 Chapter summary

This chapter presented findings on the 'They Know: Anatomy' intervention conducted in 2014 and 2015. Additionally, it provided an overview of the three sessions of the 'They Know: Anatomy' intervention that were undertaken and described how the data collected during sessions were analysed and used to inform the implementation of subsequent sessions. Finally, it set out findings on participants' experiences of the sessions and explored participants' perceptions of how multiplayer games could be used in the future. The next chapter presents the results of the implementation and evaluations of the 'Qstream: Cancer Cup Challenge' intervention.

'Qstream: Cancer Cup Challenge'

Chapter 7

> *This chapter presents the results of the 'Qstream: Cancer Cup Challenge' intervention that was conducted in the final quarter of 2014. It begins by providing an overview of the structure of the intervention. It then describes the process used to develop the program, the recruitment approach adopted and how the program was delivered. Finally, this chapter sets out the findings related to the program, including the results of the post-program evaluation surveys and comments made by participants in interviews. It also explores participants' engagement with the 'Qstream: Cancer Cup Challenge' intervention and outlines their perceptions of the effects of the learning and revision approaches adopted by the study.*

7.1 The structure of the 'Qstream: Cancer Cup Challenge' session

The 'Qstream: Cancer Cup Challenge' intervention, comprising a single iteration of the program, was conducted in the final quarter of 2014. The intervention was informed by a larger program that sought to develop oncology specific training for health professionals in Western Sydney, Australia. Before the ‘Qstream: Cancer Cup Challenge’ game was designed for this study, an online ‘Qstream’ program (i.e., the Guideline Program) was used disseminate the latest clinical guidelines on genetic assessment and testing for women with particular types of cancer to clinicians in Western Sydney. The Guideline Program used the same platform as the ‘Qstream: Cancer Cup Challenge, but did not use gamification. The Guideline Program was developed by an experienced team of clinicians and educational designers (including the author of the present study) and was led by a research fellow who designed the program’s evaluation methodology.

Twenty-nine health professionals were recruited to participate in the Guideline Program; however, only 18 (i.e., 62%) completed the program. The majority of these participants agreed that the Guideline Program assisted them to update their subject matter area knowledge. Despite being well received, the Guideline Program did not have a 100% completion rate. Subsequently, a decision was made to develop an online program for oncology health professionals in Western Sydney, Australia. This new online education program, which would become the ‘Qstream: Cancer Cup Challenge’, provided the researcher with an opportunity to incorporate gamification features into the ‘Qstream’ platform and investigate how these features affected health professionals’ completion and engagement rates.

The ‘Qstream: Cancer Cup Challenge’ intervention was conducted over four weeks. Once participants were enrolled in the program, they were assigned to teams based on their nationalities. In accordance with the ethics approval requirement for the study, participants were assigned aliases. It was also anticipated that the assignment of aliases would ensure confidentiality and discourage unfriendly competition.

Under a ‘Qstream’ platform, any number of participants can enrol in a single program. Efforts were made to recruit a comparable number of junior doctors from the three participating countries to reduce any perception that a team with more members would have an advantage over other teams. Unlike in the ‘They Know: Anatomy’ intervention in which participants had to participate synchronously and were co-situated, participants of the ‘Qstream: Cancer Cup Challenge’ were able to participate online asynchronously and they were dispersed from their team members and players on opposing teams.

7.2 The Intervention

Participants of the ‘Qstream: Cancer Cup Challenge’ intervention were allocated to teams to encourage cooperation between the dispersed group of learners. Upon answering a question, participants were presented with a de-identified league table that displayed information about their and their peers' performances. Participants were also sent periodic emails of the teams' scores.

Of the 50 medical oncology trainees invited to participate in the intervention across the three sites (Australia, Denmark and the USA), 35 oncology trainees registered to participate in the program. Thirty-one (i.e., 89%) participants completed all the questions in the intervention. In relation to the Australian team, 11 of the 12 participants (i.e., 92%) completed the questions. In relation to the Danish team, all of the 11 participants (i.e., 100%) completed the questions. Finally, in relation to the USA team, 10 of 12 participants (i.e., 83%) completed the questions. Overall, 35 participants answered at least one question (i.e., 70% of those who were invited to participate in the program and 100% of those who accepted the invitation and were subsequently enrolled in the program) and 31 participants competed the game (i.e., 62% of those who were invited to participate in the program and 89% of those who accepted the invitation and were subsequently enrolled in the program).

Of the 35 participants, 16 (46%) were male, 15 (43%) were female and four (11%) did not indicate their gender. The Australian team comprised six males (50%), four females (33%) and two (17%) participants who did not indicate their gender. The Danish team comprised four males (36%), six females (55%) and one (9%) participant who did not indicate their gender. Finally, the USA team comprised six males (50%), five females (42%) and one (8%) participant who did not indicate their gender.

7.3 Post-program evaluations

At the conclusion of the intervention, all of the participants were asked to complete a brief online survey. In response to this request, 17 participants completed the online survey. Participants were asked to answer a range of questions on the content and structure of the game in which they were directed to use a scale of one to five (where one represented the lowest level agreement and five represented the highest level of agreement).

To obtain further insights into participants' perceptions of their experiences of the 'Qstream: Cancer Cup Challenge' intervention, the participants were also invited to participate in semi-structured phone interviews. The interviews lasted approximately 15 minutes. In the interviews, participants were asked to reflect upon their experiences of the online program, their previous experiences with online training programs and the perceived impact of the program on their ability to identify and manage adverse events. The interviews were conducted within four weeks of the intervention concluding. Fourteen participants volunteered to participate in the semi-structured interviews about the 'Qstream: Cancer Cup Challenge' intervention. At least one interview was conducted with a junior doctor from each participating country.

The data from the interview transcripts were divided into two main categories:

1. Participants' perceptions of their engagement with the 'Qstream: Cancer Cup Challenge' game.

2. Participants' perceptions of the 'Qstream: Cancer Cup Challenge' game as a tool for supporting learning and revision.

Within these two categories, multiple subcategories were identified. Details of the findings across each of the categories and subcategories are outlined below.

7.3.1 Participants perceptions' of their engagement with the 'Qstream: Cancer Cup Challenge' game

An analysis of participants' responses to the post-program survey provided insights into participants' perceptions of their levels of engagement with the 'Qstream: Cancer Cup Challenge' intervention. Aggregations of participants' responses to the Likert scales indicated that the early career doctors who participated in the intervention experienced high levels of engagement with the program. Indeed, 82% of the participants agreed that the 'Qstream: Cancer Cup Challenge' intervention was engaging. In addition to using Likert ratings, participants were also given the opportunity to leave free-text comments about the strengths and weaknesses of the game and invited to make general remarks about the game.

Participants left 32 free-text comments about the game (some participants left more than one comment). Of the 32 comments, 21 described the experience as positive. The reasons given as to why the participants enjoyed the course included that they enjoyed receiving expert feedback after each question, the individual competition aspect of the course and the flexibility and manageability of the game format. One participant indicated they appreciated that the questions covered scenarios that were not commonly considered in clinical education and training programs. The primary issue that participants raised in relation to program was the level of difficulty of the content. Many participants stated that the questions were not sufficiently challenging. Further, the participants indicated that they would have preferred the questions to be focused on one tumour type rather than spread across a range of areas early career medical oncologists need to be informed about.

Competition between the teams and individual competition

A number of interviewees discussed the competition that arose between the teams and individual competition. Participants' responses varied widely in relation to the effects of the game's competition mechanic. Three interviewees stated competition acted was a direct source of motivation during the intervention and increased their motivation to complete the program. One interviewee noted:

'I was competing against someone else. I liked that, since it is a motivation'.

Two other interviewees expressed uncertainty about the effects of the competition. Both stated that they enjoyed the competitive aspect of the intervention, but believed that they would have completed the game in any event. Additionally, one of these two interviewees stated that they were quite surprised at how effective the competition was, but were unsure if it was the primary factor that motivated them to complete the program. This interviewee further stated they only realised how effective the scoring system was when they saw their rank on the leader board dropping because they had answered questions incorrectly. The interviewee noted that they were surprised at how much competition increased when participants saw that they were answering questions incorrectly.

The interviewees also stated that they engaged more in the individual competition (which they could track by the leader boards) than they did in the team competition (which they could track by the aggregated point system). Similarly, the data from the online survey showed that participants engaged more in the individual competition than they did in the team competition. The interviewees described the individual leader board as particularly engaging, noting that they enjoyed seeing their scores progress up the leader board. Seeing their progression not only engaged participants who wished to win the challenge, but also engaged participants because it enabled them to compare their knowledge to that of their peers. Thus, the competition was not only about winning, as it also allowed participants to ascertain their international rankings. However, one interviewee observed that the addition of player biographies would have been strengthened the program, as it would have provided participants with a sense of whether they should have reached the same levels as other participants.

A number of interviewees discussed the effect of de-identification on competition, noting that it was difficult to engage in the competition when they did not know whom they were competing against. However, these interviewees also expressed the view that the identification of participants would cause issues. As one interviewee stated:

> *'De-identification made it harder to engage in the competition, but without it, the competition could have been negative because you end up with in your face type of competition, which is probably what you would like to avoid with that (de-identification).'*

Seven interviewees noted that competition did not act as a primary source of motivation to complete the program. These interviewees noted that while the competition did not create a barrier to their engagement, it also did not affect their desire to complete the course. One interviewee added that they could not engage in the competition, as there was no real prize. The winning team of the 'Qstream: Cancer Cup Challenge' was awarded a trophy; however, the interviewee was of the view that that prize provided no direct benefits to participants. The interviewee noted that they had taken part in other competitions in which prizes (e.g., pizza parties) were awarded and that these competitions had been more engaging.

Cooperation within teams

In the online survey, participants were asked to rank the extent to which the inter-team cooperation motivated them to continue participating in the 'Qstream: Cancer Cup Challenge' intervention. The data analysis revealed that the participants enjoyed this aspect of the game less than they enjoyed the individual competition aspect of the game. Indeed, only 47% of the participants who responded to the survey indicated that they enjoyed the team-based aspect of the course.

The interviewees expanded upon the data derived from the online survey, noting that the team cooperation aspect of the game was not as engaging as the individual competition aspect of the game. Of the 14 interviewees, seven discussed how inter-team cooperation affected their experiences of the intervention and 12 stated that cooperation within their teams did not significantly affect their engagement with the game. Conversely, two of the interviewees stated that they engaged strongly with the team competition aspect of the game and that earning points for their team was a significant motivator and encouraged them to engage with the course. Both of these interviewees were of the view that being part of a team added a sense of excitement and variety to what could have otherwise been a dry quality improvement activity. As one interviewee stated:

> *'Even though we didn't know exactly who was on our team, it was still a good motivation to provide a little bit of excitement to the thing rather than just turning it into another exercise we had to do. I think that was certainly a good motivation to complete at least the next case. I quite enjoyed that.'*

A few interviewees noted that they enjoyed the team cooperation aspect of the game; however, generally, the interviewees described this aspect of the game as 'non-impactful' and a few interviewees had no awareness of this aspect at all. One interviewee stated that team cooperation could be a valuable and engaging element of a program, but that it had not been so in the intervention. Another interviewee noted that the team competition could have been made more engaging, if participants had to solve the cases cooperatively as teams rather than by working individually to contribute to shared scores. Another interviewee noted that the implementation of a team approach could be used to connect doctors who were the only specialists at their hospitals with peers from other hospitals.

The main criticism raised against team cooperation echoed the sentiment that participants had expressed about competition: that is, that the participants had insufficient information about the players on their teams. Three interviewees discussed this issue in detail, noting that team cooperation could have been improved if participants had been granted access to biographical or other information about their team members before the intervention began. One interviewee added that not understanding the algorithm by which points were awarded to individuals and teams prevented them from engaging with their team to compete against the other two teams, stating:

> *'In terms of Australia versus Denmark versus America was a bit difficult. I wasn't sure how many people were competing from the other teams. It's about the amount of points you're getting directly rather than the proportional average mark of each group. It's difficult to know how many people are answering the questions to determine what that mark means from a competitive aspect of it.'*

Four interviewees discussed the effects of inter-team cooperation on learning outcomes. Three interviewees were particularly positive about the effects of the team mechanics on their educational experience throughout the program. One interviewee enjoyed the way in which the game displayed their team members' answers to questions after they had entered a response, noting that peer feedback increased their confidence in their answers. This interviewee also enjoyed seeing the progress of their peers. The interviewee thought that this type of learning differed to more typical revision processes (e.g., reading books or attending lectures) and thought delivering revision tools that were different from traditional methods, but still effective was an important area to address.

Another interviewee noted that it was rewarding to know that improving their knowledge and answering questions correctly supported the progress of their team. However, another interviewee felt less positive about the team aspect of the program and was of the view that both the inter-team cooperation and the competition aspects of the game reduced its educational impact. This interviewee was also of the view that the emails sent detailing team scores and encouraging the teams to work together were distracting and increased the likelihood that participants would ignore the cases referred to in the emails.

7.3.2 Participants' perceptions of the 'Qstream: Cancer Cup Challenge' intervention as a tool for supporting learning and revision

Exploring participants' perceptions of the educational effects of the 'Qstream: Cancer Cup Challenge' intervention represented a central component of the interview process. An analysis of the semi-structured interview data revealed that the participants' were aware of the educational benefits of the game. Further, the participants viewed the platform as a valuable revision tool that could be easily integrated into their busy schedules. The specific factors that the interviewees identified as supporting learning and revision were grouped into subcategories and are explored further below.

Digital games as tools for revision

During the interviews, most of the discussions on the educational impact of the 'Qstream: Cancer Cup Challenge' intervention focused on its effectiveness as a revision tool. Of the 14 interviewees, nine interviewees discussed this issue; however, two interviewees only referred to it very briefly, noting that they thought the program effectively reinforced knowledge and could be used to address gaps in the broader educational program. The interviewees discussed the merits of the program as a revision tool. A number of the interviewees were of the view that the experience was particularly beneficial, as the platform made it easy to answer questions in short, quick bursts and was adaptable to professional schedules. Additionally, a large number of interviewees noted that the program was useful at reactivating dormant knowledge.

The interviewees consistently referred to the accessibility of the program and how it maximised educational impact. Each of the four interviewees who discussed this aspect noted that delivering questions in small bundles (rather than all at the same time) was extremely beneficial, as the method of delivery ensured that the participants were not bombarded with information, did not experience 'information overload' and did not feel overwhelmed at the thought of completing the program. Notably, one interviewee made positive comments about the short amount of time it took to complete the program each day, noting that this allowed them to answer questions when they had a break between patients or when commuting to and from work.

In relation to the effectiveness of the 'Qstream: Cancer Cup Challenge' intervention in reactivating dormant knowledge, one interviewee stated:

> *'It sort of reminded me of things I would've encountered previously. It was a good refresher in those areas. Things like drug interaction, it was good to remind me to always think about that as an issue. Rather than being new information, the benefit of the course was the stimulus for thinking about those issues where otherwise I would not have.'*

Other interviewees observed that participating in the program helped them to solidify information of which they were aware, but were not confident. As doctors in training, their exposure to certain important clinical scenarios they had to know how to manage may have occurred several years earlier making it challenging to recall how to handle them. One interviewee was of the view that that the program was useful, as it brought to the forefront situations that might have been covered at the start of their training, but that did not come up often or that they had not thought of recently. Another interviewee noted that they appreciated the ability of the program to change the way in which they thought about certain situations. This interviewee noted that the program highlighted the need to change certain approaches to situations that had become ingrained overtime or approaches that did not represent best practices.

Repetition of subject matter

Some interviewees discussed the effects of repetition on educational outcomes in relation to the 'Qstream: Cancer Cup Challenge' intervention. Three interviewees referred specifically to this game mechanic. The interviewees liked that reminder emails were sent out during the game and noted that you could not forget to participate in the intervention, as email reminders continued to be sent out until a question was answered. One interviewee also liked that participants had to repeat a question until they responded correctly, as it ensured that they could not ignore something that they did not know.

Subject matter difficulty

The interviewees referred the content of the 'Qstream: Cancer Cup Challenge' intervention as a notable limitation. Overall, the participants were of the view that the content was too easy. Numerous interviewees referred to the content being two easy. Additionally, there was a perception that participants from different countries were at different points in their training and that consequently, it was difficult to develop an international competition that comprised cases that were challenging for everyone. However, some interviewees noted that they answered some questions that they thought they knew well incorrectly and that they had found this confronting.

7.4 Chapter summary

This chapter presented findings on the 'Qstream: Cancer Cup Challenge' intervention that was conducted in the final quarter of 2014. This chapter also explored the attitudes of junior doctors (from three different countries) towards gamification being used to augment an online program on adverse events management. Findings were presented about participants' perceptions of their engagement with the intervention and their perceptions of the potential effects that such a tool could have on their learning and revision approaches. This chapter represents the last chapter of Part 2 of this dissertation. The next chapter represents the final part of this dissertation. In the next chapter, the results of both the interventions conducted for this study are synthesised with the literature and the study's key findings are discussed.

Implementing digital game-based learning in health education

Chapter 8

This chapter considers the results of the study conducted for this dissertation and the literature review undertaken to explore the role of digital game-based learning in health education. Three major themes are explored: 1 - Creating immersive experiences for learners using digital games, 2 - Fostering cooperative learning using multiplayer digital games and gamification platforms and 3 - Designing digital game-based learning environments to support adult learners. The chapter also considers the processes used in multiplayer digital games to support cooperative learning, learners' perceptions of the effects of such processes and the elements of digital games that support cooperative learning. Finally, this chapter discussing findings relating to the use of co-design to enable learners involvement on the development of content and game layout in digital game-based learning environments. The findings of this research are analysed in relation to previous relevant findings on cooperative learning, online learning and digital game-based learning. Due to the exploratory nature of this research, it was necessary to introduce some new literature is introduced in this chapter to further contextualise the study's findings.

8.1 Creating immersive experiences for learners using digital games

The ability of digital games to engage learners is well established; however, gaps remain in the literature as to how precisely digital games motivate learners to interact with subject matter and little is known about the elements of gameplay that affect learner interaction with the game [111]. Additionally, very little is known about how digital games can be used to motivate adult learners, such as health professionals and trainees in ongoing training and professional development. Further research is required to investigate adult learners' attitudes towards the use of digital games in education and obtain information about their experiences with commercial digital games.

The results of the present study extended understandings about adult learners and the extent to which they have been exposed to commercial digital games. Further, this study represents a significant piece of investigative research on the use of digital game-based learning in health education. One objective of this research was to identify the level of exposure medical students have to and their attitudes towards commercial digital games. Second year medical students who participated in the 'They Know: Anatomy' intervention were asked to reflect on their past exposures to commercial digital games to assess how common digital game use was among the group participants. The results of the survey revealed that playing digital games was relatively rare for these second year medical students. The participants were slightly more likely to play digital games on smartphone devices than on consoles or personal computers because they were able to access mobile games during short periods of 'downtime' or between other tasks. Notably, the participants who stated that they predominantly played games on their smartphones were less likely than people who played PC of console games to consider themselves digital game players. Similarly, past research has shown that smartphone game players do not generally consider themselves regular game players or game players at all [239].

Even the participants that played digital games on their computers or consoles were likely to play casual games, such as Puzzle, Card or Trivia games. Many participants felt that digital games had positive attributes; however, some participants expressed concern about the amount of time required to play digital games recreationally, citing issues related to balancing the time required to play games and the time required to study. Additionally, some participants expressed concerned about the amount of time they already spent looking at computer screens while studying and indicated that they had little desire to do so in their 'downtime' .

The participants in this dissertation study stated that their usage of commercial digital games was low; however, it should be noted that the sample size was small. Additionally, previous research into media use by tertiary students has revealed similar results. Specifically, research has shown that whilst some tertiary students are highly adept at using technology there is wide variation in their skills and a large portion do not use technology extensively or have skills limited to only a small number of technologies [240]. One survey of 2,588 first year university students found that tertiary students' use of both computer and console video games was diverse (e.g., some students played digital games daily and others almost never played digital games) [241]. Participants in the present study had a relatively low level of regular exposure to commercial digital games; however, they still showed a high level of engagement with the 'They Know: Anatomy' intervention. Participants' enthusiasm to play multiple matches with the serious digital game used in the intervention suggests that not being a regular digital game player is not a barrier to the use of digital games in educational settings.

The results of this study also extended the existing literature on the ability of digital games and gamification platforms to motivate learners. This study showed the value of digital game-based learning in engaging adult learners from two demographics (i.e., second year medical students in Australia and early career doctors specialising in oncology in Australia, Denmark and the USA). The results from the two interventions undertaken in this study showed that digital games and gamification platforms effectively motivated learners to revise subject matter that they typically find confronting or difficult to internalise.

In the 'They Know: Anatomy' intervention, participants played the game to revise with anatomy and histology subject matter. Previous research on anatomy has shown that it is a subject with which students often struggle to engage [231] and that the material can be difficult to retain, contains many new terms and requires significant memorisation [232]. The results of the 'They Know: Anatomy' intervention reinforced conclusions in the literature that many medical students find anatomy a challenging subject. Additionally, the findings showed that health students struggle to find the motivation to familiarise themselves with anatomy as a subject because of the complexity of the terminology and the vastness of the content. The results of the 'They Know: Anatomy' intervention also showed that digital games motivated participants to revise anatomy and histology content and supported individuals with different learning styles. Some participants were of the view that the faculty might resist adopting new approaches for teaching anatomy and histology, but that medical students could benefit from the use of digital games as a revision tool for these subjects.

Additionally, the findings of this research show that digital games and gamification motivates learners to re-familiarise themselves with subject matter that they had not encountered in a long time, but needed to understand to do their jobs effectively. The participants in the 'Qstream: Cancer Cup Challenge' intervention were hospital-based early career doctors undertaking specialist oncology training. The results of the 'Qstream: Cancer Cup Challenge' intervention indicated that participants perceived the identification and management of adverse events to be something that should be straightforward. However, numerous interviewees noted that they incorrectly answered questions that they thought they knew during the 'Qstream: Cancer Cup Challenge' intervention. Answering questions incorrectly when they thought they knew the correct answer was confronting to the participants and revealed to them that they had not internalised the subject matter as well as they believed. Participants in the 'They Know: Anatomy' intervention also described a similar experience when encountering anatomy and histology subject matter that they thought they knew well, but performed poorly on during the game. This process revealed to 'They Know: Anatomy' participants that they had anatomy and histology knowledge deficits of which they had not been aware. Finally, in the 'Qstream: Cancer Cup Challenge' intervention, the use of gamification helped motivate participants to continue with the program regardless of the level of confidence they had about their knowledge of how to handle adverse events. Further, it was noted that the gamification of the platform made it difficult to ignore questions and the delivery system for the content repeated questions until participants answered them correctly (i.e., participants could not defer answering to some time in the future).

The results of the present study also provided insights into the ways in which certain game genres motivate learners. It has been argued that game genre should be considered more carefully when using digital games for learning and that the identification of specific game genres that support certain learning processes would allow educators and educational designers to augment learning experiences more effectively [66]. Research has shown that certain genres of digital games do enhance online learning; however, more research is needed to expand understandings of the relationship between game genres and learning. This is particularly important in the area of health education, as no research appears to have been conducted on how digital game genres could be used to immerse learners in education and training. Further, it is often difficult to ascertain which genres of digital games have been researched in the area of health education, as the genre of the game being studied is rarely specified. In many instances, the descriptions of the digital games being researched are so insufficient it is impossible identify the genres from the descriptions.

Further, the results of this study make a significant contribution to the literature, as they evaluate two under explored genres (i.e., Strategy games and gamification). In relation to serious games for adult learners, the findings showed that a game genre needs to provide a gameplay experience that is sufficiently sophisticated to appeal to a wide variety of learners' needs and that offers an experience sufficiently enjoyable that players desire multiple encounters with the game. In both the 'Qstream: Cancer Cup Challenge' and 'They Know: Anatomy' interventions, there were variations in how and why players were motivated to player their respective games. The results showed that participants could be divided into two super groups depending on whether they were primarily interested in the subject matter of the game or whether they primarily wanted to experience the game as a form of entertainment. In the latter group, there was also a division caused by the multiplayer nature of the game, as some players were primarily motivated by competition and other players were primarily motivated by team interactions.

The results of this study reinforce some of the concepts explored in the literature in relation to the different motivations of game players (e.g., that there are four player styles that affect the equilibrium of and exist in commercial multiplayer games) [242]. It appears that in multiplayer games, adult learners' player styles affect motivation to participate in digital game-based learning. Further, these styles are distinct from those evident in commercial multiplayer games. Thus, to support the diversity of player styles, serious consideration must be given to the selection of game genres when deciding how to design and implement game-based learning for any demographic.

In addition to the broader findings on the value of using digital games that can support complex gameplay experiences, the findings of this study also revealed how specific game genres engage players. To date, the means by which specific game genres motivate players to interact with digital games has never been explored in the health education literature. In the first intervention (i.e., the 'They Know: Anatomy' intervention), a digital game platform for developing Strategy games was used. Strategy games have not been the focus of extensive research; however, due to the growing popularity of eSports that incorporate multiplayer strategy games, they have received attention from the commercial sector [105]. This study collected one of the first data sets on the use of Strategy games in health education.

The study focused on how Strategy games motivate players to interact individually with the game, and also other learners playing the game. Participants of the 'They Know: Anatomy' intervention discussed the ways in which the strategic nature of the game immersed them in the gameplay experience. They also discussed how the game incentivised them to work effectively with team members to maximise the likelihood of winning the game. The second intervention (i.e., the 'Qstream: Cancer Cup Challenge') used gamification to encourage health professionals to update their knowledge around the handling of adverse events. Research into the use gamification in health education is particularly valuable, as it has been predicted that the prevalence of gamification in this area will only increase in the future [243]. The findings of the second intervention suggested that health professionals are interested in the use of gamification in delivering training. However, using gamification in online training may be more complex than using serious digital games, as game mechanics must be identified that work well in a specific online environment and appeal to a specific group of learners.

The results of the present study also extended previous research on gamification that has suggested that many applications of gamification only take the most engaging mechanics of games (e.g., achievement points) and embed them in non-game environments [29]. Criticism has been directed at gamified learning environments for focusing too much on goals and not enough on encouraging playful encounters [28]. In the Qstream intervention learners indicated that commonly used mechanics such as leaderboards can be an effective motivator for ongoing interaction with an online course. However, in order to motivate some learners it may be necessary to use additional mechanics that are more suited to changing certain behaviours. This finding aligns with the literature, which suggests that identifying learner behaviours that need to be changed and then choosing elements of games that may affect these behaviors is a more effective way to implement gamification in online learning [30].

The 'Qstream: Cancer Cup Challenge' platform used in this study supported the use of gamification to augment online programs. The platform adopted numerous elements that particularly appealed to participants, including leader boards to show participants how they ranked against their peers and placed limits on the number of times a question could be answered correctly before it became inaccessible to learners. The findings of this study indicate that some participants found the leader board in the program extremely engaging, but others did not consider it a primary motivator for completing the program. The findings of this intervention suggested that careful consideration must be given to determine what mechanics should be embedded in online education programs for gamification to have maximise player motivation to complete the program.

The results of this study also revealed the central, but complex role that competition has in encouraging adult learners to participate in digital game-based learning. Limited research has been conducted on the role of competition in facilitating engagement with digital games in health education. To date, research on competition in digital games has only considered the attitudes of medical students [155, 196] and surgical trainees [186] towards competition in serious digital games. The results of this study provide further insights into the attitudes of health professionals and students towards the use of competitive serious digital games in education.

The medical students and early career doctors who participated in this study identified the competitive aspect of digital games as being highly motivating; however, there was variation between the groups in relation to whether the individual competition or the team-based competition was more engaging. The medical students were of the view that the competition between the two teams in the 'They Know: Anatomy' intervention provided a significant form of immersion during their gameplay experience and motivated them to continue playing. Conversely, the early career doctors who participated in the 'Qstream: Cancer Cup Challenge' intervention did not feel a strong connection to their team members and were thus less motivated to compete with the other teams in the program. However, it should be noted that the 'Qstream: Cancer Cup Challenge' participants were highly motivated to compete with individual players in the program and stated that seeing their name progress on the leader board as they overtook other players, was more motivating than seeing their teams' overall rankings improve. However, the desire to improve the teams overall ranking may have been stronger if team members where known to each other, such as if they were all on the same hospital ward. The early career doctors in the 'Qstream: Cancer Cup Challenge' intervention were motivated by individual competition; however, a significant number of these participants noted that the game acted as only a secondary (and not a primary) motivation to complete the program. These findings support previous research that competition in digital games often has no effect on motivating and engaging health professionals [186].

Finally, the interventions undertaken in this study identified the effects of multiplayer digital games in motivating learners to interact with their peers. Little research has been conducted on the use of multiplayer digital games in health education. In the literature review, only three studies were found that discussed the effects of multiplayer digital games on engaging health professionals and/or trainees in educational activities [155, 197, 199]. The results of this study show that multiplayer games have the capacity to motivate health professionals and trainees to enrol in and complete life long education, particularly in online and blended training environments.

8.2 Fostering cooperative learning using gamification and digital games

Cooperative learning has been shown to offer a range of benefits to learners [69]. However, the promotion of cooperation in adult learning represents a significant challenge for educators and educational designers. This has proven particularly problematic in the delivery of online education and training, which is frequently delivered asynchronously [244] and where encouraging interactions between learners is all too rarely given serious attention [58]. One distinctive element of multiplayer digital games is their ability to support cooperation and teamwork. Multiplayer digital games can provide tools for scaffolding interactions between learners in online learning. However, to date, little research has been conducted into the use of multiplayer games in online adult education, particularly in the area of health education.

Research has shown that cooperative learning can enhance students' academic performance [69]. Additionally, it has been shown that encouraging interactions between learners can create a sense of social belonging [245]. The results of the interventions used in this study reflect those detailed in the broader literature on cooperative learning (i.e., learners enjoy cooperating and cooperative learning can be beneficial for encouraging learners to interact with subject matter). The interventions in the present study showed that both medical students and early career doctors viewed playing a cooperative game as a novel and surprisingly rewarding experience. Further, the participants in both interventions indicated that they found that multiplayer digital game-based learning provided an effective method for revising subject matter content in both anatomy and histology and oncology quality improvement training. Both the team-based interventions helped participants reinforce the subject matter they knew well and helped them to quickly identify which topics they did not know as well as they thought. These findings reflect previous research on cooperative learning that has shown that the process of interacting with other learners in a group assists in the process of restructuring cognitive pathways to improve students' academic performance [71].

The results of this study also identified the value that multiplayer digital games and gamification have in encouraging interactions between students and professionals who may not normally have any reason to interact. The medical students who participated in the 'They Know: Anatomy' intervention noted that it was often difficult to get to know other students in their degree because of the number of students enrolled each year. They suggested that multiplayer games could be used to encourage interactions across clinical groups or medical programs in general and that this could have a positive effect on students. Similarly, the early career doctors who participated in the 'Qstream: Cancer Cup Challenge' intervention discussed how, as they became more specialised in their careers, they often became isolated from other doctors in the same specialities. Studies have shown that health professionals who practise in areas in which they do not have access to colleagues experience high levels of isolation and that this is a significant problem that can be challenging to overcome [246]. Implementing digital game-based learning in a way that made it easy for team members to cooperate with each other, regardless of their physical locations, could be a useful tool for early career doctors practising in rural or isolated areas. Overall, the findings of the two interventions showed that digital games have the potential to support interactions between learners who may not normally be willing or able to interact (e.g., learners in large cohorts or dispersed learners). Thus, the benefits of multiplayer digital games are not only limited to learning subject matter content, they also relate to broader applications in learning than knowledge acquisition.

The results of this study also addressed a gap in the research on how multiplayer digital games support interactivity and cooperation in learning. The study identified four overarching processes in multiplayer digital games that foster cooperation between participants:

1. Developing a team strategy to win the game.

2. Facilitating shared decision-making.

3. Working towards a shared goal.

4. Creating a sense of investment in a team.

These four processes affected learners' acquisition of knowledge in different ways. Further, the results of the two interventions identified elements within digital games and game-based learning environments that facilitate cooperation between players. The overarching processes through which multiplayer digital games support cooperation are discussed in the following sections.

8.2.1. Developing a team strategy to win the game

Developing a strategy to win a game is a core process within multiplayer digital games that fosters cooperation and teamwork; however, the ability of different game genres to support this process varies. In this study, the 'They Know: Anatomy' intervention used a game from the Strategy genre. Consequently, the game had strategic elements embedded throughout it that actively encouraged the players to develop a strategy to inform how their team approached the game. Conversely, the 'Qstream: Cancer Cup Challenge' intervention used gamification to augment an online program. Specifically, it used game mechanics to encourage players to participate in team-based competition. The game mechanics used in the 'Qstream: Cancer Cup Challenge' platform did not require participants to develop a team strategy to complete the program. Such game mechanics could be embedded into future iterations of the program to add a strategic element; however, they were not used in the

'Qstream: Cancer Cup Challenge' intervention in this study. Consequently, the data collected for the 'Qstream: Cancer Cup Challenge' intervention failed to provide any specific insights into the development of team strategies and the findings related to this element have been derived from the 'They Know: Anatomy' intervention. The incorporation of features into the 'Qstream: Cancer Cup Challenge' platform that enable teams to develop strategies to win the game could increase learner engagement and enhance the team aspect of the gamification platform.

The effects of developing team strategies on learning experiences

The results of the 'They Know: Anatomy' intervention indicated that the process of developing a team strategy was perceived as being beneficial to both teams and individual players. Developing a team strategy was viewed as advantageous, as it increased the likelihood that a team would be victorious. Participants stated that while team members worked together to develop strategies to win the game, due to the fast-paced nature of the game, participants had to develop strategies on an ad-hoc basis rather than in a structured way in advance. In relation to individual players, the process of developing a team strategy was seen as a valuable means of increasing a player's confidence in their anatomy and histology knowledge. Developing a team strategy also encouraged players to reflect on the strengths and weaknesses in the knowledge of their team members and opposing team players to determine how best to cross the game map. These findings supported previous research that has shown that the process of reflection increases learners' confidence in their skills and abilities [247]. Further, these findings support previous research that has shown that when playing commercial strategy games, ranking one's individual skills against the skills of other players has a positive effect on players' emotional states [9].

The results of the 'They Know: Anatomy' intervention contributed to the literature on reflective learning by demonstrating that personal reflection during gameplay increases learners' confidence. Additionally, the process of reflecting on any strengths and weaknesses in their personal knowledge enables individuals to identify which areas in a unit of study they need to target in future revision (i.e., that ranking one's individual skills against one's peers increases awareness of peer strengths and weaknesses). The results of the 'They Know: Anatomy' intervention also suggested that the same phenomenon that occurs in commercial strategy games (i.e., that ranking one's individual skills against one's peers increases one's emotional states) occurs when strategy games are used in an educational context and that this increased players' confidence in their subject matter knowledge. Finally, the process of developing a strategy to win the game incentivised players to reflect on the strengths and weaknesses in their personal and their peers' knowledge and also made it straightforward to undertake this type of reflection. This process may not occur outside the context of team-based games. The process of making ongoing evaluations of opponents when playing commercial digital games has been shown to be a specific consequence of the social competition that occurs in multiplayer games [9].

Game elements that support the development of a team strategy

The results of the 'They Know: Anatomy' intervention identified numerous elements within multiplayer digital games and gamification platforms that support the process of developing team strategies. In the 'They Know: Anatomy' intervention, the structure of the game map had a significant effect on participating players' game strategies, as winning the game was directly linked to the ability of teams to cross the map network effectively and take control of an opposing team's home base. To do this successfully, team members had to develop a strategy to coordinate their passages across the game map. By changing the layout of the game map, it was possible to modify the ways in which participants interacted with the subject matter. Using more subject matter nodes with fewer questions allowed the participants to identify the breadth of the content in the game; however, it also made it more difficult for participants to cross the map because there were more nodes to cover during the game. Consequently, there was less need to cooperate to take control of an individual node, and the time spent trying to take control of a node was less. Creating a game map with fewer subject matter nodes, but more questions within each node, encouraged participants to explore the subject matter in greater depth. Additionally, team members often completed the same nodes at the same time and were thus more likely to cooperate with one another. To date, no research has been conducted on the effects of changing aspects of strategy games to effect how learners interact with content. One study considered the use of algorithms to develop custom maps in team-based strategy games and player's perceptions about using game maps generated by them [248]. However, further research is needed to investigate what effects changing strategy game map layouts have on learners' interaction with subject matter content.

The use of short duration matches that are repeated at spaced intervals can also facilitate the development of team strategies among team members playing digital games and using gamification platforms. In the 'They Know: Anatomy' intervention, the duration of the game match was quite short (i.e., approximately 30 minutes) to encourage teams to play repeated matches at future points in time. By engaging in repeated matches, teams could formulate a strategy for approaching the map, evaluate the effectiveness of that strategy in relation to winning the game, engage with the subject matter and potentially alter the team strategy before subsequent matches. Additionally, having spaced intervals between the matches provided participants with opportunities to undertake subject matter revision to improve their chances of winning future matches. The use of digital games to encourage repeated encounters with subject matter not only encouraged revision, but also improved long-term knowledge retention. Research has shown that repeated periodic studying effectively ensures the long-term retention of knowledge [228].

Another game element that had a significant effect on the development of team strategies in the 'They Know: Anatomy' intervention was the use of a post-match debriefing. Debriefings enabled consensuses to be reached on which team member was strong and weak at certain subject nodes. Players could then use this information to decide how to progress across the map in subsequent matches. The incorporation of a debriefing session allowed participants to create links between their engagement with the game, the fun they had experienced and what they had learned. These results show that the use of post-game debriefings in education reinforced participants' learning and allowed learners to distinguish between the enjoyment of a gameplay experience and its educational value [201].

Debriefings have been used in other health education contexts; however, they have not been widely considered in the literature on implementing serious games in education. One study used a debriefing session in a game-based learning environment that sought to teach students how to design a medical practice [197]. The results showed that the debriefing sessions encouraged the exploration of ideas that emerged during the gameplay session and formalised learning outcomes. Similarly, the results of this study suggested that post-game debriefings create deeper learning experiences than those derived from just playing a digital game. A debriefing session was not used in the 'Qstream: Cancer Cup Challenge' intervention; however, had such a session been implemented, it may have increased the levels of cohesion among team members. The research on cooperative learning has shown that the use of structured activities, such as debriefings, effectively encourages group cohesion[69]. However, coordinating such a discussion in an asynchronous setting would have presented challenges that did not arise during the 'They Know: Anatomy' intervention debriefing. Thus, while debriefing sessions might increase interactivity in future implementations of the 'Qstream: Cancer Cup Challenge' intervention, consideration needs to be given to how such sessions can be embedded effectively.

8.2.2 Facilitating shared decision-making

The results of this study also showed that in addition to fostering cooperative learning, multiplayer digital games and gamification platforms also facilitate shared decision-making. In the 'They Know: Anatomy' intervention, participants could either make decisions autonomously or participate in shared decision-making. The game mechanics embedded in the platform were insufficient on their own to encourage a high level of shared decision-making. Consequently, a combination of game mechanics and other elements were used to facilitate this process. In the 'Qstream: Cancer Cup Challenge' intervention, no formal mechanisms in the platform facilitated shared decision-making. However, other elements could be used to facilitate shared decision-making between participants, if they participants incentivised to do so. For example, players could use online or face-to-face approaches to consult with their team members and reach a consensus on the correct response to a question before answering individually. This approach also increased the number of participants on a team who answered questions correctly.

The effects of shared decision-making on learning experiences

The results of the 'They Know: Anatomy' intervention showed that the process of shared decision-making by members of the same team affected players' individual learning experiences. Shared decision-making could take the form of reaching a consensus on which response was correct in respect to a question card or deciding whether a question card acquired while playing the game should be used to attack a player on an opposing team. Several participants were surprised at the effect that shared decision-making had on their learning experiences and their engagement with the game, especially its ability to increase the sense of reward they derived from playing the game.

Interviewees from the first two sessions of the 'They Know: Anatomy' intervention were positive about the link between shared decision-making and their learning experiences, particularly the process of discussing the correct answers to questions with their team members.

This reflects previous findings in the area of cooperative learning that have shown that activities that support peer tutoring can increase learner's comprehension of subject matter [72]. The participants in the present study felt that the process of reaching a consensus on the correct answer to a question helped them reinforce and internalise the correct answer. The participants also noted that discussions with team members expanded their knowledge, as individuals could share what they knew with the group and in turn learn new information from their team members of which they were previously unaware. These findings supported previous research on peer instruction and feedback that has shown that the process of discussing with or explaining subject matter to other learners can improve academic performance [249].

The participants felt that the shared decision-making process reinforced their knowledge and had a positive effect on their learning; however, some participants noted that their team members often answered questions incorrectly. In some circumstances, a group's consensus could be directed to the wrong answer if no one knew the correct answer. However, the participants did feel that even giving incorrect answers, highlighted shared gaps in their knowledge. This also made participants feel more comfortable with the aspects of anatomy that they did not know very well. Some participants raised concerns about the value of peer discussion when no one in the team knew the answer. However, the literature on cooperative learning suggests that even when no one in a group of learners knows an answer, the discussion among the group can still improve understandings of the subject matter [250].

The participants in the 'Qstream: Cancer Cup Challenge' intervention were of the view that participating in a team-based game was exciting. They also noted that while the individual competition was the most engaging part of the program, the idea of being involved in a team intervention was more motivating than completing a single person program. Due to the asynchronous nature of the program, it was challenging for participants to participate in shared decision-making. However, despite the challenges related to interacting with other team members in the program, the participants observed the potential value of making decisions as a team.

Game elements that facilitate shared decision-making

Many game elements can facilitate shared decision-making; however, the results of the present study showed that some elements are particularly effective at facilitating the process. To facilitate shared decision-making in multiplayer games, there needs to be an accessible means of supporting communication between team members. In the 'They Know: Anatomy' intervention, the participants had access to an in-game chat system and were also co-situated with team members. Thus, there were two avenues for discussion between team members. However, due to the speed of the game, participants often did not have time to use the in-game chat system to interact and instead had to communicate verbally with teammates. Similarly, previous research on the use of in-game chat systems has shown that this form communication is inadequate in many games due to the pace of the games and that oral communication is usually preferred if it can be supported [251].

In the 'Qstream: Cancer Cup Challenge' intervention, an online forum was used to encourage interactions between participants; however, the forum for the program was not widely used. Previous research has shown that learners need access to multiple communication tools that have been designed to support informal and formal interactions if online communication is to be facilitated [93]. The small number of posts that appeared in the forum may also have perpetuated a cycle of disuse, as the participants may have felt that there was no value in posting in a forum that was largely inactive. Previous research has shown that encouraging participation in online forums with a low level of posts can be challenging [94]. In the present study, the participants had some platforms that they could use to interact with their team members should they choose to do, such as email or an online forum; however, the participants showed little or no engagement with these tools.

It has been shown that it is necessary to have some type of structured approach to guide users in their initial use of a form of communication to encourage interactions in online environments [92]. It is likely the use of such structured activities in the forum for the 'Qstream: Cancer Cup

Challenge' interaction might have increased participants' interactions on the platform. However, research needs to be conducted to determine which activities could be used to achieve this effect in the program. Previous research has shown that the structure of the activities in cooperative learning needs to be linked to the types of interactions that they have been designed to promote to encourage successful group interaction moving forward [85].

The use of timers on questions was another element that encouraged team members to cooperate when making decisions. Placing limits on the time that participants had to answer questions incentivised team members to interact to determine the correct answer and also motivated individual players to answer questions as quickly as possible. However, it should be noted that difficulties arose in determining the appropriate time limits for responses to questions in the 'They Know: Anatomy' intervention matches. Numerous participants noted that they did not have sufficient time to consider their answers to questions and type in their responses in matches. Additionally, one participant felt that these time limits were potentially more stressful than motivating. Thus, participants' views on the use of timers were mixed; however, these time limitations did create challenges in the game and created conditions similar to those present in tests. Previous research on the *testing* effect has shown that the act of being tested can extend (rather than simply assess) learners' knowledge [226, 227] and that testing may have benefits for long-term knowledge retention [228]. However, the findings of the present study suggest that while there may be benefits to using timers to simulate the testing effect in a game, these timers can also have negative effects.

Finally, an element that incentivised some learners to make shared decisions with their team members was the granting of rewards for quick or accurate responses to questions. In the 'Qstream: Cancer Cup Challenge' intervention, the allocation of points was used to elicit fast and accurate responses by participants. Specifically, players' were allocated points for being the first to answer a question correctly. This provided a strong motivation for participants to do this. Under the 'Qstream: Cancer Cup Challenge's' reward system, points were also allocated to participants based on the number of attempts made to answer a question correctly (i.e., the fewer the attempts made the more points awarded). Gamification research has shown that the use of rewards can effectively increase the speed of players' responses [30, 252]. However, awarding points does not appear to affect the accuracy of responses [252]. The reward system used in the 'Qstream: Cancer Cup Challenge' intervention should have motivated players to discuss their answers with their team members if they did not know an answer and share information, as doing so would have increased their likelihood of answering correctly. However, due to the asynchronous nature of the program, it was more difficult for participants in this intervention to interact with their team members than it was for participants in the 'They

Know: Anatomy' intervention. Thus, in practice, the participants did not draw on the knowledge of their team members when making decisions.

8.2.3 Working towards a shared goal

The findings of the present study showed that the process of working towards a shared goal created a valuable experience that can be supported by multiplayer digital games and gamification platforms. The second year medical students in the 'They Know: Anatomy' intervention reported that working with team members to win a game was a rewarding experience that evoked a sense of personal fulfilment. Further, the participants stated that they had not encountered any other methods for revising anatomy and histology that created this type of experience. The early career doctors who participated in the 'Qstream: Cancer Cup Challenge' intervention were geographically separated from their team members and played entirely online. Consequently, they bonded with their team members in a different way to the 'They Know: Anatomy' participants and had different insights into how they engaged with the team-based aspects of the program. The participants reflected on their experiences of contributing to a shared goal of winning a challenge with their team members and how this affected their engagement with the program.

The effects of working towards a shared goal on learning experiences

The results of the 'They Know: Anatomy' intervention showed that participants found that the experience of working towards a shared goal to revise a subject created a distinctive experience. The participants viewed the use of digital games as complementing the methods of revision traditionally used to reinforce knowledge (e.g., reading literature or listening to lecture recordings). Further, the participants suggested that working towards a shared goal during the game directly affected their learning experiences, as they felt a strong desire to master the anatomy content and share their knowledge to help their team obtain a shared victory.

To date, little research has been conducted into team dynamics in multiplayer educational digital games. However, research on team formation in commercial strategy games has shown that team members are aware that their combined choices improve the chances of a team victory. Using this information, players of commercial strategy games make choices during a game match that they think will complement the choices of their team members [253]. The results of the present study suggest that the same phenomenon occurred in the team-based strategy games for education and that the process used to determine complimentary styles of play encouraged reflection on individual and team knowledge. Some participants in the 'They Know: Anatomy' intervention noted that they felt a desire to think 'harder' to recall information that they may not have accessed recently, as they felt a strong sense of obligation to help their team win the game. This desire was also motivated by their wish to experience feelings of fulfilment related to succeeding as part of a group rather than on their own.

Like the medical students who participated in the 'They Know: Anatomy' intervention, the early career doctors who participated in the 'Qstream: Cancer Cup Challenge' program described the team-based approach to learning as a novel experience. The results of the 'Qstream: Cancer Cup Challenge' intervention showed that working towards a shared goal affected some players more strongly than others. One participant stated that they enjoyed seeing how their peers were doing on the leader boards and seeing how the points they accumulated contributed to their team's score. However, further structures need to be introduced to the program to increase the enjoyment participants derive from seeing how their individual points help the team. Such structures could also increase participants' desire to encounter the subject matter content and ensure that participants feel that their individual knowledge is directly contributing to their team's success.

Game elements that foster a desire among team members to work towards a shared goal

The rewards system of a digital game-based learning platform is one element that encourages team members to work together to achieve a shared goal. The results of the present study showed that it is particularly important players are aware of how their actions during a game result in rewards, as this allows players to create links between their actions, their rewards and their team's achievements. In the 'Qstream: Cancer Cup Challenge' intervention, participants received points for completing components of the online program. The participants of the 'Qstream: Cancer Cup Challenge' intervention noted that the use of leader boards was a very engaging aspect of the program; however, some of the participants interviewed noted that it was not always clear as to how points were awarded for completing questions or how many points received for answering questions. The need for participants to feel that there is transparency around how and when their actions will be rewarded has been found to be directly linked to the level of appeal the gamification platform had for learners [30]. Feelings of uncertainty about how to complete activities on the 'Qstream: Cancer Cup Challenge' intervention were linked to the points system used to reward the activities completed by players and their team members and limited some participants' motivation to progress with the program.

In addition to the links between activities and rewards being clear to participants, the effort a player has to exert to achieve a reward must be viewed as proportionate to the effort required to complete each activity within a game. Ensuring these two elements are incorporated into serious digital games is particularly important in the use of gamification. At the conclusion of the 'Qstream: Cancer Cup Challenge' intervention it became apparent that it was not clear to participants how their involvement in the program was linked to the success of their team. This finding suggests that gamification platforms have to use processes that illustrate to participants of a program how their rewards contribute to their team's achievements. Previous research has shown that it is possible to motivate individuals with game mechanics (e.g., badges) that display both an individual's progress and the rewards that other players have achieved at the end of a game [254]. Similarly, showcasing an individual's achievements alongside those of their team members may motivate individuals in teams.

Conversely, it is also necessary to consider the effects of failing to succeed at an activity and any associated penalties that a player or a team may receive for such failures. In the 'They Know: Anatomy' intervention, many elements had to be adjusted to create a balance between a failure to complete an activity and the penalty received. For example, a decision had to be made as to how much to reduce players' 'health' by when they answered a question incorrectly. If in the game, answering one question incorrectly caused players to loose all of their health, it is likely that players would view this as unfair and quickly disengage from the gameplay experience. However, loss of health was a key element in encouraging players to cooperate during the game, as players' health could only be restored if team members shared questions with one another.

The research on the use of rewards to motivate individuals indicates that it can be complicated to implement rewards successfully [25, 252, 254]. General research on intrinsic motivation has shown that rewards can undermine intrinsic motivations [255]. Further, it may be that rewards only reliably increase motivation in individuals who are already intrinsically motivated and interested in an activity [256]. The results of the present study supported the findings of previous research that balancing activities and rewards in digital game-based learning is a complex process that often requires elements within a game and game environment to be iterated upon. However, if a balance is reached between the rewards and the activities through which players earn rewards, highly motivating digital game-based learning experiences can be created for learners.

Finally, to use rewards effectively to encourage team members to work together to reach a shared goal, there has to be a way to identify whether a balance between an activity and a reward has been achieved once the game has been implemented. Players' views as to whether the balance between the rewards received for completing an activity and the effort required to complete that activity is suitable need to be determined. Additionally, there must be elements in the design of a game that allow for modifications to be made as necessary to adjust the balance between the rewards and the activities through which rewards are achieved. It has been suggested that one approach to strengthening the use of gamification in learning programs would be to let participants select the rewards for a program and decide which activities should be used to achieve those rewards [28].

8.2.4 Creating a sense of investment in a team

The results of the present study also showed that multiplayer digital games and gamification platforms can develop players' sense of investment in their teams and that this process enables games to support cooperation and collaboration. However, similar to the results found in relation to shared decision-making, the use of a multiplayer game alone is insufficient to ensure that participants feel invested in working with their team members during the game. A combination of game elements and environmental factors must be used to foster players' sense of investment in their teams.

The effects of creating a sense of investment in a team on learning experiences

The results of the present study showed that having a sense of investment in a team encourages players to undertake deeper reflection to recall their subject matter knowledge. However, the effects of fostering a sense of team investment in a team were broader than merely supporting learning. Participants in the 'They Know: Anatomy' intervention noted that feeling invested in a team reduced their sense of social isolation and helped them to identify similarities in the challenges that they and their peers faced learning anatomy and histology. Additionally, as participants' sense of investment in the team grew, individual players were inclined to work harder to recall information to support their team. Additionally, the findings of this study showed that the support system of a team-based game incentivised students with different strengths and weaknesses to collaborate. Thus, while creating a sense of investment in a team can be challenging, the results of the present study suggested that when if it is done successfully, learners derive significant benefit from their learning experiences.

Game elements that create a sense of investment in a team

Certain game elements can be used to encourage participants to become invested in a team (as opposed to feeling that they are only a member of a team). In serious multiplayer games, predisposing activities have been shown to successfully increase players' sense of investment in their teams. In relation to the use of multiplayer digital games or gamification platforms in education, the inclusion of an initial activity before playing encourages interactions between players from the start of the game. Similarly, previous research on cooperative learning has shown that a predisposing activity effectively encourages connection between group members and increases the likelihood of team members interacting effectively in the future [69].

This study collected new data on the use of tutorials as predisposing activities among players of serious multiplayer games. In the 'They Know: Anatomy' intervention, the predisposing activity of delivering a tutorial to participants was effective, as it encouraged team members to interact. However, due to the complexity of the games and learners' varying ranges of commercial game experiences, the findings of the intervention also showed that delivering tutorials in multiplayer digital games is challenging. In the intervention, three different approaches were used to deliver a tutorial to participants. Each approach had its advantages and disadvantages. Each of the three approaches required individual players to help their team members to understand the game and thus created initial interactions between players who did not know each other well. It has recently been postulated the learning curve that arises in serious digital games could be overcome if instructors were used to facilitate gameplay sessions [257]. The results of the present study suggested that in multiplayer digital games, other learners involved in the gameplay experience could be used to facilitate this process rather than outside instructors.

The ability of players to develop a sense of investment in their team was also affected by whether or not they could identify the other participants. In the 'They Know: Anatomy' intervention, identity was not an issue, as participants played the game in the same room and thus had many opportunities to get to know each other. Conversely, in the 'Qstream: Cancer Cup Challenge' intervention, no structured activities were undertaken before the program to facilitate initial interactions between team members. An email was sent to the ‘Qstream: Cancer Cup Challenge’ participants introducing the challenge to them and advising them of the aliases of the participants who were on their team. The email also provided instructions on the program and notified the participants that there was a forum in which they could interact with other players; however, no further information was provided. The results of the ‘Qstream: Cancer Cup Challenge’ intervention showed that participants were less motivated to participate in the team activity of the program than they did with the individual competition activity. The de-identification of participants in the ‘Qstream: Cancer Cup Challenge’ intervention made it significantly more difficult for participants to become acquainted with their team members. However, when asked their views about whether team members should be identified in future iterations of the program, participants expressed concern that this would foster unfriendly competition. The idea of negative or unfriendly competition was also raised by some participants in the ‘They Know: Anatomy’ intervention; however, it should be noted no negative interactions were observed between the medical students during any of the game matches.

The research on anonymity in online interactions is inconclusive as to whether it creates negative of positive interactions. Previous research has suggested that being anonymous encourages participation in online discussions, as it creates a non-threatening environment [96]. Research has also suggested that de-anonymising participants in online communities reduces antisocial behaviours [95]. The results of the present study suggested that the de-identification of participants significantly reduced players' engagement with the team-based digital games. Further, despite the challenges related to engaging de-identified participants in the games, the results also suggested that participants have reservations about being members of identified teams and thus may be less likely to play multiplayer digital games in which players are identifiable.

8.3 Designing digital game-based learning environments for adults

Previous research into game-based learning, particularly in adult education, has tended to focus on the outcomes of using serious digital games rather than the processes related to their design and implementation. The lack of research into how digital games can be designed and implemented to support adult learners makes it challenging for the granular findings of an individual study to be generalised and used to inform the design of tertiary curricula, online professional development programs or any other types or forms of adult education programs. To date, very little research has been conducted into the design of digital games or game-based learning for adult learners. The research that has been conducted on the design of serious digital games has drawn heavily on the principles of commercial digital game design based on the commonalities between the two. However, the design of serious digital games differs from the design of commercial digital games. Certain distinctive characteristics must be considered when designing serious digital games. Further, these characteristics require special consideration when implementing digital game-based learning.

A primary characteristic of serious digital games that requires consideration during the design phase is a balance between entertainment and education. If a balance is not reached, games may be created that are fun, but that are not particularly educational or that are educational (i.e., focused on learning outcomes), but that are not particularly fun [115]. It should be noted that developers of serious games rarely have access to the same budgets or development time frames as commercial digital games [116]. Consequently, serious digital games may lack the quality of digital games that have been developed primarily for entertainment [116].

The results of the present study suggested that not all of the design characteristics pertinent to serious games have been identified. Notably, the results of the present study showed that the designs of serious games need to include more elements that can be accessed and manipulated by end users. The present study also identified two broad areas that affect the implementation of game-based learning in adult education: (i) the creation of immersive and interactive learning environments using digital games; (ii) the relevance of content to adult learners and how this can be increased through co-design. These areas are explored further below.

8.3.1 Creating immersive learning environments using gamification and digital games

A wide range of formats (e.g., face-to-face, blended and wholly online) are used to deliver adult education. Adult education can also be delivered through synchronous activities whereby learners can complete components of a program together or asynchronously (i.e., at a place and time that suits their schedules). The results of the present study showed that changes made to the ways in which multiplayer digital game-based learning is implemented affects participants' immersion and engagement with a game. One factor that had a considerable effect on players' immersion in the gameplay experience is whether the digital game-based learning is delivered synchronously or asynchronously online. The findings on the use of digital games and gamification platforms in both a synchronous and an asynchronous setting are explored further below.

First, the synchronous use of games and gamification to support collaborative game-based learning can encourage interactions between players. Notably, synchronous settings enable players to communicate with each other with ease during the gameplay sessions. In the 'They Know: Anatomy' intervention, the majority of participants were co-situated in one of two computer laboratories while playing multiple matches of the game. Players on the same team attended and shared one computer laboratory while players on the opposing team attended and shared a different laboratory. Each player had access to a computer to play the game. The computers were placed on a shared table to facilitate communication between players on the same team.

The decision to co-situate players was informed by the literature on Local Area Network (LAN) events. LANs enable individuals to play commercial multiplayer games in a shared spaced on a shared computer network and seek to enhance the gameplay experience [104]. In one match, two opposing teams were co-situated in the same room. Co-situating the two teams in the same room significantly increased the interactions among players. However, rather than increasing interactions among players on the same team, it increased interactions among players on opposing teams. Further, while players interacted with their team members during the matches, a significant portion of this interaction was not related to the anatomy or histology subject matter. Rather, the conversations between team members focused on social topics that did not relate to anatomy and histology. However, while these conversations did not directly relate to revising the subject matter, the participants did perceive the interactions between themselves and their team members as beneficial.

In relation to the digital games and gamification platforms used, the process for successfully implementing game-based learning to immerse players asynchronously online differed to that used in synchronous settings. In the second intervention, 'Qstream: Cancer Cup Challenge' participants experienced the program asynchronously from each other. The program was delivered to participants this way, as they were health professionals, not students. The use of asynchronous online approach to deliver training is often necessary, as it increases the flexibility that professionals have in accessing learning resources [59]. In the 'Qstream: Cancer Cup Challenge' intervention, the participating early career doctors had to complete the program around their clinical schedules. Additionally, the online delivery of the program enabled participants to be recruited from a number of countries. A number of participants cited the international competition as a significant motivator for completing the program, observing that it allowed them to ascertain how they ranked alongside their international peers.

Two factors affected the level of connectedness learners experienced with members of their team: (i) the asynchronous nature of the program; and (ii) the anonymity of the players. Due to the asynchronous nature of the program, participants had fewer touch points with their team members and thus did not develop any strong social ties or bonds with their team members. Compounding this issue, the lack of identifying information about team members acted as a significant barrier, inhibiting players' level of investment in their team. Extensive research has been conducted on communities of practice and online education to ascertain whether individuals need information about their online peers feel comfortable interacting with them online [91]; however, this issue has received little attention in the area of serious games. In the present study, team members could see the de-identified avatars of other players; however, they did not have enough information to create a social connection with their team members. Previous research has shown that anonymity reduces interactions among participants in online communities [95]. The results of the present study indicated that when implementing serious games in which team members are geographically isolated and/or their identities are anonymous, additional scaffolding must be provided to increase participants' sense of social belonging. For example, if players' true identities are to remain anonymous, pre-game icebreaker activities should be used to help participants develop connections with other players and their team members.

8.3.2 End users as co-designers

To date, no research has explored the use of User Generated Content (UGC) in digital games in relation to health education. Further, no research has been conducted on how game platforms can be used to support health educators, designers and learners in creating serious digital games to achieve personalised learning outcomes. Limited research has been conducted on how the use of UGC in mobile games can effectively engage players [134], but few studies have sought to determine its affect on any aspect of the learning experience. This study gathered data on participants' perceptions of UGC in serious games and user-generated games and explored how this could be used to shape the gameplay experience. Thus, the findings of the present study extend understandings about the potential use of UGC in digital games. Specifically, the results of this study provide novel insights into learners' attitudes towards the use of UGC in digital games in the area of health education.

Currently, very few game engines or platforms exist that allow learners to create games by inputting content or designing aspects of games. Some research has been conducted on the ability of platforms, such as *Scratch* and *eAdventure*, to support the development of user-created games by adolescent learners [258, 259]; however, no comparable platforms exist in the area of serious games for health education. The two platforms used in the present study have the capacity to support the users to design various aspects of their gameplay experience in two ways. First, these platforms allow users to create, edit and add questions and/or change the order in which the questions are asked, so the act of creating UGC. Second, these platforms involve users in the design/development process in relation to a specific game or program, which is a form of co-design.

Semi-structured interviews were conducted with all intervention cohorts to ascertain the potential of these platforms to engage learners with digital games that supported the first type of user creation. When developing the 'Qstream: Cancer Cup Challenge' intervention, efforts were made to engage end users in the development of subject matter and the game design process. Conversely, in the 'They Know: Anatomy' intervention, the end users were not involved in the development stages of the game, but were able to offer insights into how future learners could be engaged in future iterations of the game. The insights gained from both groups of participants provided invaluable insights into the ways in which digital game platforms can be used to engage learners in the design of content and the serious games themselves. In the context of adult education, the use of UGC can create unique learning experiences that provide learners with different experiences throughout the design cycle.

Early career doctors were actively involved in the development of the 'Qstream: Cancer Cup Challenge' intervention from the ideation phase until the deployment of the program. The early career doctors who developed the content for the program were senior medical oncology trainees and were working with the junior trainees who later participated in the program. As content developers, these early career doctors played a central role in identifying the key clinical scenarios that would be used to develop multiple-choice questions for the program. Early career doctors from each of the three participating countries were asked to be involved in the process of developing questions for the program, as they had both subject matter expertise and recent clinical experience as early career doctors, which enabled them to identify what sort of questions and scenarios would be most relevant to doctors at an early stage of their careers. In addition to providing a driving force in content development, these early career doctors were also consulted on the design of gamification components, such as the international challenge, to gain their feedback on the extent to which the components would motivate an early career doctor to complete the program.

It was postulated that drawing on the expertise of early career doctors in the content development would ensure that the 'Qstream: Cancer Cup Challenge' intervention resonated with the participants. The results of the intervention indicated that the question in the program were clinically relevant to participants; however, some participants felt that the questions were too simple. This may be because the health professionals who developed the questions had only limited experience. The literature on UGC suggests that the collaborative process of developing content can also build the knowledge of the content developers [135], but the output quality of learner-generated content is much more variable. However, it should be noted that the quality of the content could be increased if frameworks were used to guide learners in the development of the content [136].

Conversely, the subject matter in the 'They Know: Anatomy' intervention was not user-created. Indeed, it was developed by content experts from the faculty of medicine to ensure it aligned with the second year medical curricula. It was postulated that this approach to content development would be most beneficial to study participants. Compared to those in the

‘Qstream: Cancer Cup Challenge’ intervention, the participants in the ‘They Know: Anatomy’ intervention consistently reported that the anatomy and histology questions in the game were difficult. The results of this intervention revealed a schism between the expectations of students as to how challenging the anatomy subject matter should be and the expectations of the educators developing the content. In the first two sessions, some participants not only commented on the challenging nature of the questions, but also queried whether student-generated questions would have been more appropriate for the game. The possibility of incorporating questions developed by students into the game was discussed with interviewees to gain insight into the potential impact of user developed content for use in serious games in health education. The participants interviewed had mixed views about the use of UGC in digital games, particularly in relation to the quality of the content. Some participants expressed concerns that the use of UGC would lead to the creation of poor quality or irrelevant subject matter questions. However, while the participants in the ‘They Know: Anatomy’ intervention were concerned about UGC, the literature suggests that learners can develop effective questions for use as potential examination questions and that quality issues can be managed via peer review [137].

Participants in the ‘They Know: Anatomy’ intervention had suggestions as to how to address concerns about the quality of user-generated questions. One interviewee supported the use of user-generated questions, but guidelines needed to be implemented to ensure the content developed was relevant. Another interviewee stated that a peer review system could provide an effective means of supporting user-generated questions. However, it should be noted that while research shows that peer review provides an effective means of ensuring the quality of questions and that learners are happy to review their peers' questions, learners are noticeably less happy to have their questions peer reviewed [137, 260]. Regardless of whether or not they were supportive of UGC, all of the participants interviewed were supportive of having access to an anatomy revision game with faculty-developed content. Participants also expressed the view that student-generated content should be reviewed and moderated by faculty members to ensure its alignment with the curricula.

Differences of opinion in relation to UGC are also evident in the literature. Some commentators have argued that the peer review process for UGC is often more rigorous than traditional knowledge dissemination methods, as UGC is reviewed by potentially hundreds or thousands of reviewers while traditional knowledge dissemination methods (e.g., journals) are only reviewed by a handful of editors and experts [261]. Conversely, others have argued that the quality of UGC is variable and users should be dubious as to the reliability of content given that the authors are often anonymous [262]. Further, it has been argued that the use of UGC in education disrupts the traditional balance of power in formal education and removes some of the control that educators have over learning [263].

Opinions vary as to the quality of UGC and its related peer review process; however, some of the challenges identified in the literature could be overcome. For example, collaborative spaces in which learners and faculty members come together could be used to develop content. Such spaces would allow students to create their content that could then be moderated by experts to reduce any biases and inaccuracies [261]. A similar approach was suggested by participants of the 'They Know: Anatomy' intervention who perceived the benefits of using an online game to disseminate faculty-created content in a network that suited the needs of individual learners.

In addition to UGC, some interviewees in the 'They Know: Anatomy' intervention were interested in the opportunity that the game platform provided to develop game maps. Interest in supporting learner-generated games has increased. Further, the tools necessary to build games are now more readily available to learners [133]. An emerging body of research has explored the valuable learning experience that the process of designing digital games provides to individuals [132]. Participants of the 'They Know: Anatomy' intervention expressed great enthusiasm towards the idea that users could design their own game maps using questions created by content experts.

One benefit of user-designed maps is the ability of such maps to link subject nodes in a manner that is logically consistent for participants and that can be changed in response to their knowledge needs. One participant noted that designing well-balanced maps could be challenging for users. This issue has been raised in the literature on amateur designed games. The participants were interested in the idea of map development; however, it is unclear whether they would have the time to develop maps in practice. Very little research has been conducted on users as the co-creators of serious educational games; however, this appears to be an emerging area of interest [264]. The studies that have explored the creation of content for commercial games by participants suggests that the experience of creating, sharing and reviewing content is rewarding and enjoyable [265].

One characteristic of adult learners, whether they have a tertiary level of education or higher, is their desire to be autonomous and self-directive in their learning experiences [36]. The potential of digital games to provide such experiences to learners was demonstrated in both the 'They Know: Anatomy' and the 'Qstream: Cancer Cup Challenge' interventions. In both interventions, participants expressed a desire to have control over the development of content or at least the structuring of the learning areas aligned with individual knowledge structures.

Learners' desire to have some control over their learning environments was consistent across both interventions; however, the type of autonomy sought varied. The 'They Know: Anatomy' participants were more focused on designing their maps and were sceptical of their peers' ability to develop relevant content. Conversely, the 'Qstream: Cancer Cup

Challenge' content was developed by early career doctors who were peers of the study's participants. Consequently, the adverse event cases used in the program resonated with the clinical experiences of the participants; however, issues arose in relation to the extent to which participants' found the content challenging. The differences between needs of the second year medical students and the junior doctors who participated in the research may merely reflect their different stages of training. The medical students were working in a world of abstracted knowledge and are focused on passing exams rather than long term knowledge retention. Conversely, the junior doctors' were focused on practical applications and how the knowledge aligned with or challenged their experiences.

8.3.3 Digital game based learning and evaluation frameworks

Effective use of digital game based learning in health education also involves consideration of recognised evaluation frameworks. Consideration of evaluation frameworks when designing digital game based learning in health education allows stakeholders to contextualise the educational impact of the digital game. One framework that is well suited to health education is Kirkpatrick's framework for evaluating training in organisations [164].

Findings from the They Know: Anatomy intervention showed a strong alignment to Level 1 of Kirkpatrick's Framework: Reaction. Participants indicated a strong positive reaction to the training, finding it engaging and enjoyable. There was also alignment with Level 2: Learning, as participants indicated They Know: Anatomy had the intended effect of improving their confidence in learning anatomy. However, due to the laboratory based nature of the intervention, findings from the intervention align less clearly with Level 3: Behaviour and Level 4: Results of the intervention. In contrast, findings from the Qstream: Cancer Cup Challenge Intervention align with Level 1, Level 2 and Level 3 of Kirkpatrick's evaluation framework. Findings from the intervention partially aligned with Level 4: Results as the intervention was designed to achieve specific outcomes for the healthcare organisation the intervention was piloted in. However, the intervention did not specifically evaluate how representatives from the organisation viewed the impact of the intervention and as such it is unclear how the Qstream: Cancer Cup Challenge intervention aligned with Level 4 of Kirkpatrick's framework.

As has been shown through the application of Kirkpatrick's framework [164] the two interventions in this dissertation, the use of evaluation frameworks can be effective understanding the educational impact of intervention. Furthermore, such frameworks can help contextualise interventions against the broader literature, even when different digital games are being used.

8.4 Limitations

The study had a number of limitations. First, the primary limitation of this study is that the evaluation method used relied heavily on participants' reflecting upon their individual experiences with the games. Participant reflection is a valuable means of exploring the feasibility and acceptability of a game for learners; however, other measures are required to obtain additional insights into how multiplayer digital games foster cooperative learning experiences. (Examples include behavioural observation and objective performance measures.) A further limitation is that self-reported data can vary in accuracy depending on the individual and the task. Second, all of the individuals who participated in this research were medical students or junior oncology doctors. Further, the participants in the study were self-selected. Thus, the generalisability of these findings may be limited in relation to other health students and other medical schools and hospitals. Third, this study considered only two game-based learning genres (i.e., gamification platforms and strategy games). Thus, caution must be exercised in generalising the results of these studies to games in other genres. Future studies should seek to explore the attitudes of other health students and health professionals in respect of multiplayer digital games. Finally, this study focused on the process of designing game-based learning in the area of health education which may limit its generalisability to areas outside the health sector.

8.5 Chapter summary

In this chapter, the results of this study were analysed in relation to previous research on the use of digital games - in health education and more generally. The ways in which serious digital games can be used to support cooperative learning were reviewed. Particular attention was directed towards the elements of digital games that support cooperation between learners and learners' perceptions of the value of multiplayer games in subject matter retention. Finally, this chapter explored the features of a game's design that appeal to and can support adult learners. This discussion considered the potential for the more widespread implementation of UGC developed by health professionals for health professionals in future iterations of game-based learning. In the next chapter, conclusions are drawn regarding the use of game-based learning in health education, with a particular focus on the role of multiplayer games.

Conclusions

Chapter 9

This chapter summarises the study's key findings and outlines the novel insights that this study has provided in relation to specific issues in the research area. This chapter also makes a number of practical recommendations to non-game designers, particularly health educators, who are interested in the use of digital game-based learning in adult education. Finally, this chapter outlines a number of questions that need to be addressed and require further research in the future.

9.1 Contextualising this study's findings on the use of digital game-based learning in health education

As commercial digital games have transitioned from a hobbyist pursuit to a mainstream activity that is common to modern culture, the use of digital games in non-recreational activities has also become increasingly popular. In the education sector, digital games and gamification have been perceived as particularly appealing, as they have been proven to successfully motivate learners, particularly adolescents and pre-adolescents, to interact with educational resources. However, the use digital games and gamification to augment education at the tertiary and adult level is notably less widespread. Further, the lack of use of digital game-based learning in tertiary and adult education is particularly evident in the health sector. The results of this study have shown that digital games can appeal to adult learners if they provide learning experiences that individuals are unlikely to encounter in other training activities. Further, the results of this study and the broader literature suggest that adult learners, especially those studying at the tertiary level, are interested in using new forms of media, such as digital games, in their training activities, if they are used to enhance their learning experiences.

Within the literature on digital game-based learning in adult education, particularly in the area of health education, the issue of whether digital games need to be used to engage learners who have had high levels of recreational exposure to commercial games has been the subject of extensive research. The notion that digital natives (i.e., individuals who have a high affinity for technology) expect technology to be used in the delivery of education and training was first articulated in the early 2000s. This contention has since been widely rejected by members of the education community. However, despite this rejection, the term 'digital native' has continued to dominate and be widely used in modern culture. The concept of digital natives is also still common in the literature on health education. Due to the continued acceptance of this concept in the literature on health education, there has been a tendency only use digital game-based learning among groups of learners who are likely to be heavy users of digital technologies. Thus, this concept has prevented the implementation of digital game-based learning in contexts in which learners are perceived as not being 'tech savvy' or interested in digital games. However, some groups of health students appear to have similar characteristics to tertiary learners in the broader literature. Medical students, seem to rarely use commercial digital games, despite the fact that such learners could be classified as digital natives. In spite of the varied use of digital games by medical students, even learners with little or no experience or interest in using commercial digital games for recreational purposes seem open to using them in learning if the games have been well designed and implemented. Thus, an understanding of the context in which a specific digital game will be applied and an ability to identify which digital game will be suitable for that context is far more important in determining whether experiences will be unique and engaging for learners than their level of experience with recreational digital games.

Serious multiplayer games have been greatly underused in the context of health education, specifically, but also in educational research more broadly. Multiplayer digital games have the potential to support cooperative learning experiences through a range of team-based activities. Learners have reported that multiplayer digital games successfully reinforce subject matter knowledge and can be used to effectively engage them with content that they would otherwise find challenging or complex. The number of multiplayer games being developed for recreational use in the commercial games sector continues to increase. Further, multiplayer games are now being used to support the development of communities that are larger than the games themselves, such as those that form around eSports. The communities that have formed around eSports are centred on gameplay experiences, but have also led to the creation of more extensive social networks. In the context of games-based learning, compared to single player games, multiplayer games can be used to provide learners with a wider diversity of experiences and can enable players to engage in more aspects of gameplay. Thus, the use of multiplayer games could be used in contexts in which learners have a range of motivations and expectations in relation to their training environments, including in the area of adult education.

Finally, while the literature on the design and implementation of digital games and gamification continues to grow, considerable gaps in understanding remain as to how they can be effectively designed and implemented. Gaps in understandings on the use of digital games and gamification by tertiary and adult learners are particularly pronounced because very little research has been conducted into the use of serious digital games in this area. Further, if game-based learning is to be implemented among adult learners, a wider range of dissemination pathways need to be accommodated. A portion of adult training is still delivered in traditional didactic and classroom settings; however, a significant amount is now also delivered online or via a blended format. Determining how to use digital games across a variety of delivery methods requires an understanding of how to assess particular learning environments to determine the suitability of digital games for different environments.

The findings from this dissertation compliment the existing literature on the use of digital game-based learning in adult learning, and expand on the understand of how detail games can be used in education. Conclusions have been drawn from a mix of practical work (design, implementation and evaluation) involving two digital game-based learning platforms and theoretical work (structured review of the literature). The outcomes of this dissertation include both practical recommendations on the acceptability of digital games in adult education, and insights on design features that improve implementation of digital game-based learning in adult education (particularly a need for features that enable data-informed customisation of educational digital games).

9.2 Practical recommendations for using digital game-based learning in health education

One objective of this study was to provide practical recommendations on the design and implementation of digital game-based learning in tertiary and adult education. Digital games and gamification have the capacity to engage learners of all ages in unique and meaningful learning experiences; however, it cannot be guaranteed that the use of digital games will always produce such outcomes. Extensive research needs to be conducted to determine how digital game-based learning can be applied to health education effectively. The findings of this study have provided some preliminary insights into how both designers and educators should approach the development and implementation of game-based learning in the health sector.

First, as with most educational initiatives, when evaluating whether to use digital games in a particular educational setting, the initial step is to consider the learners and their needs. The first question is whether the learners will be focused solely on the acquisition of new knowledge or whether they also need to develop a wider set of skills (e.g., their ability to manage their learning, their capacity to collaborate with their peers or their capacity to link factual information to particular contexts). The next question that needs to be asked is how the learners in the cohort have been interacting (i.e., whether the learners know each other and if so, how well they know each other or whether they are geographically dispersed and anonymous). The answers to these questions provide a useful foundation for determining if game-based learning is suitable to a particular context and in ascertaining which types of games will align with learners' needs. Finally, consideration needs to be given to whether the learners will be inclined to use digital games as part of their learning experiences. It is not always possible to acquire this information;

however, if this information can be obtained it can be used to determine the suitability of a digital game to a particular learning environment.

Consideration also needs to be given to the needs of the learners. Thus, the second step when using digital game-based learning is to determine the type of game suitable to each specific context. Three broad categories of games have been used in the context of health education: repurposed digital games, bespoke digital games and gamification platforms. Determining which of these categories is best suited to specific learning environments can be difficult. Currently, bespoke games have been used across a wider range of health education areas than repurposed digital games or gamification platforms. It is unlikely that the use of repurposed commercial games will become more widespread, as numerous challenges arise in aligning the existing content of such games with specific learning outcomes in health education. Conversely, the augmentation of existing platforms using gamification continues to grow in popularity due to the flexibility with which gamification can be implemented. Regardless of the category adopted, it is essential to explore which platforms (i.e., bespoke games or approaches for embedding gamification in educational programs) are available for use in delivering health education. The use of an already tested platform can facilitate implementation, as prior knowledge can be used to formulate a dissemination strategy.

If a suitable game-based learning platform does not exist for a specific health education setting, a new game can be created. However, this process requires a union between game designers, programmers, educational designers, content experts, educators and learners. Further, to ensure that the game created can be used successfully in the future, building a bespoke game can involve significant investments of time and/or financing and may require organisational support. In this study, experienced game platform developers drove the technical side of the projects, but held periodic meetings with educational designers to discuss the pedagogical considerations and how they could be accommodated in the game platform to ensure that the game balanced entertainment and education.

When embedding game-based learning in health education, it is important evaluate the overall learning experience that the game or gamification platform is providing rather than only the outcomes, such as the game's effect on knowledge. Digital games and gamification platforms can do more than extend learners' knowledge, they can encourage interactions between learners who would not otherwise interact regularly and they can change the ways in which learners and educators communicate. Further, they offer a means of supporting interactivity in blended and online environments. Thus, when determining how to evaluate the implementation of digital game-based learning in health education, it is important to consider why each digital game or gamification platform was selected. Consideration should be given to determine how learning experiences were altered because of the use of game-based learning. This information should also be used to assess the most appropriate aspects of game-based learning in relation to specific health education environments.

9.3 Extending the literature on the design and implementation of digital-based learning in adult education

The findings of this study extended current understandings of the use of serious digital games in adult education and how multiplayer digital games can be used to engage health professionals and trainees. It is well established that adult learners are time poor. Adult learners may recognise the need to undertake professional development and engage lifelong learning activities, but they may not always be motivated to find the time to do so. This a particular concern when using digital game-based in adult education, as many adults do not see the value of playing digital games, regardless of whether these games were designed for serious or recreational purposes. However, the findings of this present study showed that under the right circumstances, adult learners will play serious digital games and will also acknowledge the benefits associated with doing so. The circumstances in which adult learners may choose to play educational games are as follows.

9.3.1 Circumstances in which adult learners may choose to play educational digital games

Adult learners may use educational games to learn or reinforce subject matter content with which it is difficult to engage.

For example, anatomy and histology content comprises complex terminologies that can be overwhelming for and can demotivate learners.

Adult learners may use educational games to engage with peers when it is difficult to do so because of factors such as geographical or social isolation.

For example, junior doctors specialising in a particular area may not have many peers at their hospital and may wish to connect with their peers in the global community.

Adult learners may use educational games to sample a large quantity of subject matter and to have access to a quick method for identifying strengths and deficits in their knowledge.

For example, tertiary students need to learn and retain foundational content that will be essential to their later professional careers. Adults engaging in lifelong learning may also need to quickly identify their knowledge and strengths and deficits and ascertain any areas or more recent knowledge that they might not have grasped.

Adult learners may use educational games to interact with subject matter in periods of downtime or to break up large periods of revision.

For example, junior doctors may choose to play a short duration digital game whilst commuting to or from work, in order to take advantage of small periods of free time.

9.3.2 Using game mechanics to support cooperative learning

This study provided novel insights into how game mechanics can be used to support cooperative learning in adult education. Four processes were identified as supporting cooperation in digital games and gamification platforms. The individual game mechanics and elements underpinning these processes were also identified. To date, very little research has been conducted on the use of multiplayer digital games in the delivery of adult education, particularly in the area of health education. Thus, the results of the present study address a considerable gap in the research. The four processes identified for supporting cooperative learning in this dissertation study are:

Developing team strategy to win the game

A number of game elements support the development of a team strategy to win the game, including short duration gameplay sessions, the repetition of content, game layout and post-game debriefings.

Facilitating shared decision-making

A number of game elements support shared decision-making, including efficient and accessible communication pathways and the use of time pressure to complete tasks (e.g., answering questions).

Working towards a shared goal

A number of game elements support working towards a shared goal, including reward systems that appeal to players and an appropriate balance between the effort required to complete activities and the rewards received.

Creating a sense of investment in a team

A number of game elements can be used to create a sense of investment in a team, including the use of pre-disposing activities that enable players to get to know one another.

9.3.3 Co-designing educational digital games and gamification platforms

The findings of this study provided novel insights into designing digital games for adult learners. This study drew an important conclusion that was not currently evident in the literature; that is, that there are two groups of individuals who are key participants in the successful creation of digital game-based learning in adult education: game designers and non-game designers. Currently, in the typical process for designing serious digital games, the game designers are the primary drivers of the game design process, but input may be obtained from other individuals, such as content experts. Much of the literature on digital game-based learning has been directed towards a game development process driven by game designers rather than non-game designers. Consequently, the current literature on the development of digital games for serious applications emphasises the technical aspects of developing serious digital games. However, the results of this study suggest that non-game designers are key individuals who need to be involved in the process of designing and implementing serious games in adult education. Non-game designers may include the teaching staff or educators who intend to implement the digital game in their learning environments or adult learners who are interested in ways of supporting lifelong learning in their peer groups. Traditionally, supporting teaching staff and learners have played a passive role, acting only as the end users or recipients of games that have been created and delivered by game designers.

However, many advantages could result if supporting teaching staff and learners were to play active roles in the design and implementation of serious games for adult learners; for example, gameplay experiences could be created that were more flexible and personalised. However, if individuals who are not experts in game design are to have an element of control over the design and specific implementation of a game, game designers must design serious digital game platforms with this flexibility in mind. Further, if non-game designers are to design elements of a digital game for specific learning environments, game designers must take into account three issues when building serious digital game platforms for adult learners.

Game designers must provide a means by which teachers or learners can adjust elements of games to improve gameplay experiences or subject matter interactions in specific learning contexts.

The results of this study revealed a number of elements in multiplayer digital games that can affect gameplay experiences or subject matter interactions if they are adjusted across individual game sessions. These elements include the win conditions of a game, the duration of a game, the rewards granted for completing activities and the layout of the subject matter in a game.

Game designers must provide a means by which elements can be adjusted to achieve the desired levels of subject matter interactions in specific learning contexts.

If serious digital game platforms are to allow educators and/or learners to adjust elements of a game to create an optimal fit for specific educational settings, there needs to be a means of identifying which elements should be adjusted and when such adjustments should occur. Collecting data on the elements of a game that can be modified to enhance the implementation of a serious digital game requires the presence of mechanisms in the game platform that provide data on which elements should be altered in a given situation. Teachers and/or learners need to have access to data about how users interact with games if they are to make modifications to educational games between gameplay sessions.

Game designers must provide a means by which learners can play multiple cycles of a game to identify the optimal configuration for a specific learning context

Should game designers start to design serious digital game platforms that allow educators to adjust elements to suit a specific learning environment, issues will still arise in relation to how these elements can be adjusted effectively. To identify the effects of adjusting elements in a digital game, it is necessary to obtain feedback from players about the effects of any such adjustments. Thus, educators need to know the end effect that they would like to achieve from a game and be able to implement multiple cycles of a game, collect player feedback and iterate and re-implement the game.

Game designers must provide a means by which the factors of a particular game-based learning environment that affect learners' experiences can be examined, regardless of the game platform

The use of digital games, including games designed specifically for education, does not guarantee a valuable learning outcome. Numerous game design and learning environment elements work together to create engaging gameplay experiences. To support the interactions between games and learning environments, elements need to be incorporated that allow players to create links between their experiences in the game and their learning outcomes. From an implementation perspective, consideration must be given to how the environment of a digital game affects the gameplay experience.

9.4 Future research

The use of digital games to support education and training in the health sector is increasing; however, significant gaps in the literature remain in relation to the use of such games. Future research should seek to address the following three gaps in the literature:

1. How can different categories of digital games be evaluated for use in health education?

2. How can tertiary health curricula and programs be designed to incorporate game-based learning?

3. How can digital games be used to support cooperation and collaboration among health professionals by supporting lifelong learning?

The findings of this study extended understandings of, and provided novel insights into, all of these areas; however, further research needs to be conducted. The following paragraphs explore gaps in the current research in relation to each of these three areas. Consideration is also given to issues related to the implementation of game-based learning in the area of health education.

9.4.1 How can different categories of digital games be evaluated for use in health education?

Three broad categories of game-based learning have been identified in the health education literature: repurposed commercial games, bespoke digital games and gamification platforms. Of these, significant research has been conducted into repurposed commercial digital games because of their ability to predict and improve trainees' performance on surgical simulators. Despite the prevalence of this research, there is almost no replication of the particular commercial games that have being repurposed in the literature. The repurposing of commercial digital games has produced some benefits in health education; however, it is difficult to generalise these findings to determine when and how these games could be implemented outside the contexts of specific studies. Similarly, the literature on bespoke digital games tends to lack replication and relies heavily on digital games that have been purpose built for a particular study. Very few re-evaluations have been undertaken of specific bespoke games; thus, it is again difficult to draw broad conclusions about their widespread implementation. Notably, the bespoke game, GeriatriX, was evaluated by two separate studies. In both these studies, medical students participated in the study and randomised pre-and post-test methodologies were used to evaluate the game. One significant gap in the literature exists regarding how researchers, educators and students evaluate digital games for use in health education.

In relation to the third category (i.e., gamification platforms), a small but growing amount of research has sought to evaluate their use in the delivery of health education. To date, extensive research has been conducted on the use of gamification in the delivery of training targeted at patients (e.g., smartphone applications have been developed to encourage patients to adopt lifestyle changes). However, very few studies have considered the use of gamification in targeting health professionals to change their knowledge or behaviours. This gap in the literature is surprising given the potential of gamification to deliver professional development and training aimed specifically at health professionals and not just trainees. Given its capacity to provide learners with engaging experiences in a more conservative way than digital games, gamification would appears to be well suited to this audience. Thus, gamification could appeal to health professionals undertaking professional development and would not be instantly disregarded as childish.

9.4.2 How can tertiary health curricula and programs be designed to incorporate game-based learning?

Currently, understandings are limited as to: (i) how digital game-based learning can be implemented in curricula or health education programs; and (ii) the long-term sustainability of digital game-based learning if and when it is implemented. These research gaps may be correlated with the lack of literature on how specific games can be generalised into new contexts. Previous research on the generalisation of particular serious games in health education has sought to explore their use in patient education. For example, the game Re-Mission was developed to support adolescents with cancer. It has been researched in multiple contexts and among different cohorts to explore possibilities for its dissemination. Other examples of serious games being generalised for different health education specialities are difficult to find. Similarly, no research appears to have been conducted on the long-term sustainability of serious games in health education or sought to determine guidelines as to when and how they can be optimally implement in educational curricula. Thus, significant gaps remain in the current literature that require further investigation.

9.4.3 How can digital games be used to support cooperation and collaboration between health professionals?

Finally, further research needs to be conducted into the use of multiplayer digital games in health education. The results of the present study showed that health professionals and trainees are interested in using digital games to engage in cooperative learning experiences. However, multiplayer games could also be used to support collaborations between health professionals and/or trainees. The incorporation of genres of digital games capable of fostering in-game experiences and game communities, similar to those that have formed around eSport games, could potentially enhance online health education. To remain up-to-date with evidence-based health practices, health professionals are required to engage in continual training either through mandated programs or informal approaches, such as peer discussions. Digital games may provide an effective means for supporting engagement in health education communities. However, further research is required to identify which type of digital games are conducive to developing communities of practice relevant to adult learners. Finally, to gain a deeper understanding of how digital games and gamification platforms support cooperation between health professions, further research needs to be conducted on the effects that individual game mechanics have on players' gameplay experiences.

The research undertaken in the present study provided preliminary insights into how game mechanics can support cooperative learning processes in multiplayer digital games and gamification platforms. However, many questions remain unanswered as to whether game mechanics can be used to encourage cooperation between health professionals. Research needs to be conducted into how individual game mechanics affect learning outcomes, whether individual game mechanics affect the long-term retention of subject matter and whether some combinations of game mechanics are more likely to lead to long-term professional collaborations than others.

9.5 Concluding Remarks

The primary objective of this study was to explore the ways in which serious digital games and gamification platforms can support cooperative learning in adult education. Over the course of multiple iterative cycles, this study demonstrated that four processes (as outlined above) can be used to support cooperative learning. This study also addressed its three secondary objectives. First, a structured review of the literature identified how digital game-based learning has been used in the delivery of health education. Second, the study investigated whether digital game-based learning could appeal to learners across different health areas (i.e., medical students studying anatomy and histology and early career doctors undertaking oncology adverse events training). Finally, by adopting a methodology to research digital game-based learning in health education, this study increased understandings of how serious digital games and gamification platforms could be designed to support adult learners.

References

1. Laird JE: History of Computer Games. *EECS Department* 2005, 9(7):05.
2. Digital gaming sales hit record $61 billion in 2015: Report [http://www.cnbc.com/2016/01/26/digital-gaming-sales-hit-record-61-billion-in-2015-report.html]
3. Rideout VJ, Foehr UG, Roberts DF: Generation M²: Media in the Lives of 8-to 18-Year-Olds. *Henry J Kaiser Family Foundation* 2010.
4. Tettegah S, McCreery M, Blumberg F: Toward a Framework for Learning and Digital Games Research. *Educational Psychologist* 2015, 50(4):253-257.
5. Entertainment NI: Video gamers in Europe–2005. Prepared for the Interactive Software Federation of Europe 2005.
6. Brand JE, Todhunter S: Digital Australia 2016. In. Eveleigh, NSW: IGEA; 2015.
7. Apperley TH: Genre and game studies: Toward a critical approach to video game genres. *Simulation & Gaming* 2006, 37(1):6-23.
8. Rosas R, Nussbaum M, Cumsille P, Marianov V, Correa M, Flores P, Grau V, Lagos F, López X, López V: Beyond Nintendo: design and assessment of educational video games for first and second grade students. *Computers & Education* 2003, 40(1): 71-94.
9. Vorderer P, Hartmann T, Klimmt C: Explaining the enjoyment of playing video games: the role of competition. In: Proceedings of the second international conference on Entertainment computing: 2003: Carnegie Mellon University; 2003: 1-9.
10. Prensky M: Fun, play and games: What makes games engaging. In., vol. 5: McGraw-Hill, California; 2001: 1-05.
11. Garris R, Ahlers R, Driskell JE: Games, Motivation, and Learning: A Research and Practice Model. *Simulation & Gaming* 2002, 33(4):441-467.
12. Jayakanthan R: Application of computer games in the field of education. *The Electronic Library* 2002, 20(2):98-102.
13. Ryan RM, Rigby CS, Przybylski A: The Motivational Pull of Video Games: A Self-Determination Theory Approach. *Motivation and Emotion* 2006, 30(4):344-360.
14. Fabricatore C: Gameplay and game mechanics: a key to quality in videogames. 2007.
15. Arango F, Aziz E-S, Esche SK, Chassapis C: A review of applications of computer games in education and training. In: *Frontiers in Education Conference, 2008 FIE 2008 38th Annual: 2008*: IEEE; 2008: T4A-1-T4A-6.
16. Flexible Learning: Proceedings of the National Academy for Integration of Research, Teaching and Learning Annual Conference (4th, Dublin, Ireland, October 6-7, 2010). *National Academy for Integration of Research, Teaching and Learning* 2011.
17. Oberdörfer S, Latoschik ME: Develop your strengths by gaming: Towards an inventory of gamificationable skills. In: *GI-Jahrestagung: 2013*; 2013: 2346-2357.
18. Gee JP: What do video games have to teach us about learning and literacy. New York: Palgrave Macmillan; 2003.
19. Chanel G, Rebetez C, Bétrancourt M, Pun T: Emotion assessment from physiological signals for adaptation of game difficulty. *IEEE Transactions on Systems, Man, and Cybernetics-Part A: Systems and Humans* 2011, 41(6):1052-1063.

20. Yannakakis GN, Hallam J: Evolving opponents for interesting interactive computer games. *From animals to animats* 2004, 8:499-508.
21. Deci EL: The relation of interest to the motivation of behavior: A self-determination theory perspective. 1992.
22. Hoffman B, Nadelson L: Motivational engagement and video gaming: A mixed methods study. *Educational Technology Research and Development* 2010, 58(3):245-270.
23. Deterding S, Dixon D, Khaled R, Nacke L: From game design elements to gamefulness: defining gamification. In: Proceedings of the 15th international academic MindTrek conference: Envisioning future media environments: 2011: ACM; 2011: 9-15.
24. Sicart M: Defining game mechanics. *Game Studies* 2008, 8(2):1-14.
25. Nevin CR, Westfall AO, Rodriguez JM, Dempsey DM, Cherrington A, Roy B, Patel M, Willig JH: Gamification as a tool for enhancing graduate medical education. *Postgraduate medical journal* 2014, 90(1070):685-693.
26. Kim S: Fundamental Strategic Approach for Gamification: How to Start a Gamification in Your Organization. 2013.
27. McDaniel R, Fanfarelli J: Building Better Digital Badges: Pairing Completion Logic With Psychological Factors. *Simulation Gaming* 2016, 47(1):73-102.
28. Nicholson S: A user-centered theoretical framework for meaningful gamification. *Games+ Learning+ Society* 2012, 8(1):223-230.
29. Nicholson DT, Chalk C, Funnell WR, Daniel SJ: Can virtual reality improve anatomy education? A randomised controlled study of a computer-generated three-dimensional anatomical ear model. *Med Educ* 2006, 40(11):1081-1087.
30. Landers RN, Landers AK: An Empirical Test of the Theory of Gamified Learning The Effect of Leaderboards on Time-on-Task and Academic Performance. *Simulation & Gaming* 2015:1046878114563662.
31. Wolf MJ: Genre and the video game. The medium of the video game 2001:113-134.
32. Gros B: Digital games in education: The design of games-based learning environments. *Journal of Research on Technology in Education* 2007, 40(1):23-38.
33. Salas E, Bowers CA, Rhodenizer L: It is not how much you have but how you use it: Toward a rational use of simulation to support aviation training. *The international journal of aviation psychology* 1998, 8(3):197-208.
34. Kunkler K: The role of medical simulation: an overview. The International Journal of Medical Robotics and Computer Assisted Surgery 2006, 2(3):203-210.
35. Dykman CA, Davis CK: Part one-The shift toward online education. *Journal of Information Systems Education* 2008, 19(1):11.
36. Cercone K: Characteristics of adult learners with implications for online learning design. *AACE journal* 2008, 16(2):137-159.
37. Sigala M: Investigating the factors determining e-learning effectiveness in tourism and hospitality education. *Journal of Hospitality & Tourism Education* 2004, 16(2): 11-21.
38. Kanuka H, Nocente N: Exploring the effects of personality type on perceived satisfaction with web-based learning in continuing professional development. *Distance Education* 2003, 24(2):227-244.
39. King KP: Identifying success in online teacher education and professional development. *The Internet and Higher Education* 2002, 5(3):231-246.
40. Choules A: The use of elearning in medical education: a review of the current situation. *Postgraduate medical journal* 2007, 83(978):212-216.

41. Kinash S, Brand J: Does social media breed learner laziness? 2014.
42. Richardson J, Swan K: Examing social presence in online courses in relation to students' perceived learning and satisfaction. 2003.
43. Wani HA: The Relevance of e-Learning in Higher Education. *Jurnal Kajian Pendidikan* 2013, 3(2):181-194.
44. Eysenbach G: What is e-health? Journal of medical Internet research 2001, 3(2):e20.
45. Booth RG: Educating the future eHealth professional nurse. International Journal of Nursing Education Scholarship 2006, 3(1).
46. Marsch LA, Gustafson DH: The role of technology in health care innovation: A commentary. *Journal of dual diagnosis* 2013, 9(1):101-103.
47. Rosenberg L: Are healthcare leaders ready for the real revolution? *The journal of behavioral health services & research* 2012, 39(3):215-219.
48. Mallin M, Schlein S, Doctor S, Stroud S, Dawson M, Fix M: A survey of the current utilization of asynchronous education among emergency medicine residents in the United States. *Academic Medicine* 2014, 89(4):598-601.
49. Ruiz JG, Mintzer MJ, Leipzig RM: The impact of e-learning in medical education. *Academic medicine* 2006, 81(3):207-212.
50. Link TM, Marz R: Computer literacy and attitudes towards e-learning among first year medical students. *BMC Med Educ* 2006, 6:34.
51. Cook DA, Levinson AJ, Garside S, Dupras DM, Erwin PJ, Montori VM: Internet-based learning in the health professions: a meta-analysis. *Jama* 2008, 300(10):1181-1196.
52. Davis J, Chryssafidou E, Zamora J, Davies D, Khan K, Coomarasamy A: Computer-based teaching is as good as face to face lecture-based teaching of evidence based medicine: a randomised controlled trial. *BMC medical education* 2007, 7(1):23.
53. Wutoh R, Boren SA, Balas EA: ELearning: a review of Internet–based continuing medical education. *Journal of Continuing Education in the Health Professions* 2004, 24(1):20-30.
54. Harris Jr JM, Elliott TE, Davis BE, Chabal C, Fulginiti JV, Fine PG: Educating generalist physicians about chronic pain: Live experts and online education can provide durable benefits. *Pain Medicine* 2008, 9(5):555-563.
55. Lovell MR, Luckett T, Boyle FM, Phillips J, Agar M, Davidson PM: Patient education, coaching, and self-management for cancer pain. *Journal of Clinical Oncology* 2014, 32(16):1712-1720.
56. Robinson T, Janssen A, Kirk J, DeFazio A, Goodwin A, Tucker K, Shaw T: New Approaches to Continuing Medical Education: a QStream (spaced education) Program for Research Translation in Ovarian Cancer. *Journal of Cancer Education* 2015:1-7.
57. Kerfoot BP, Fu Y, Baker H, Connelly D, Ritchey ML, Genega EM: Online spaced education generates transfer and improves long-term retention of diagnostic skills: a randomized controlled trial. *Journal of the American College of Surgeons* 2010, 211(3): 331-337. e331.
58. Wong G, Greenhalgh T, Pawson R: Internet-based medical education: a realist review of what works, for whom and in what circumstances. *BMC medical education* 2010, 10(1):1.
59. Cook DA, Dupras DM: Teaching on the web: automated online instruction and assessment of residents in an acute care clinic. *Medical teacher* 2004, 26(7):599-603.

60. Fall LH, Berman NB, Smith S, White CB, Woodhead JC, Olson AL: Multi-institutional development and utilization of a computer-assisted learning program for the pediatrics clerkship: the CLIPP Project. *Academic Medicine* 2005, 80(9):847-855.
61. Nathoo AN, Goldhoff P, Quattrochi JJ: Evaluation of an Interactive Case-based Online Network (ICON) in a problem based learning environment. *Advances in health sciences education* 2005, 10(3):215-230.
62. Cook DA: Web-based learning: pros, cons and controversies. *Clinical Medicine* 2007, 7(1):37-42.
63. Alur P, Fatima K, Joseph R: Medical teaching websites: do they reflect the learning paradigm? *Medical Teacher* 2002, 24(4):422-424.
64. Shaw T, Barnet S, Mcgregor D, Avery J: Using the Knowledge, Process, Practice (KPP) model for driving the design and development of online postgraduate medical education. *Medical teacher* 2015, 37(1):53-58.
65. Boulos MNK, Maramba I, Wheeler S: Wikis, blogs and podcasts: a new generation of Web-based tools for virtual collaborative clinical practice and education. *BMC medical education* 2006, 6(1):41.
66. Moreno-Ger P, Burgos D, Martínez-Ortiz I, Sierra JL, Fernández-Manjón B: Educational game design for online education. *Computers in Human Behavior* 2008, 24(6): 2530-2540.
67. Karnad A: Trends in educational technologies. 2014.
68. Kron FW, Gjerde CL, Sen A, Fetters MD: Medical student attitudes toward video games and related new media technologies in medical education. *BMC Medical Education* 2010, 10(1):1.
69. Slavin RE: Cooperative Learning and Academic Achievement: Why Does Groupwork Work? *Anales de Psicología/Annals of Psychology* 2014, 30(3):785-791.
70. Damon W: Peer education: The untapped potential. Journal of applied developmental psychology 1984, 5(4):331-343.
71. Callender AA, McDaniel MA: The limited benefits of rereading educational texts. *Contemporary educational psychology* 2009, 34(1):30-41.
72. Keer H: Fostering reading comprehension in fifth grade by explicit instruction in reading strategies and peer tutoring. *British Journal of Educational Psychology* 2004, 74(1):37-70.
73. Mathes PG, Torgesen JK, Allor JH: The effects of peer-assisted literacy strategies for first-grade readers with and without additional computer-assisted instruction in phonological awareness. *American Educational Research Journal* 2001, 38(2):371-410.
74. Johnson DW, Johnson RT: Social interdependence theory and cooperative learning: The teacher's role. In: *The teacher's role in implementing cooperative learning in the classroom.* edn.: Springer; 2008: 9-37.
75. Battistich V, Solomon D, Delucchi K: Interaction processes and student outcomes in cooperative learning groups. *The Elementary School Journal* 1993, 94(1):19-32.
76. Slavin RE: Cooperative Learning and Intergroup Relations. 1995.
77. Roseth CJ, Johnson DW, Johnson RT: Promoting early adolescents' achievement and peer relationships: The effects of cooperative, competitive, and individualistic goal structures. *Psychological bulletin* 2008, 134(2):223.
78. Johnson DW, Johnson RT: Cooperation and competition: Theory and research: Interaction Book Company; 1989.
79. Johnson RT, Johnson DW: Cooperative learning in the science classroom. *Science and children* 1986, 24:31-32.

80. Johnson DW, Johnson RT, Smith KA: Cooperative learning returns to college what evidence is there that it works? *Change: the magazine of higher learning* 1998, 30(4): 26-35.
81. Klein JD, Schnackenberg HL: Effects of informal cooperative learning and the affiliation motive on achievement, attitude, and student interactions. *Contemporary educational psychology* 2000, 25(3):332-341.
82. Baker M, Hansen T, Joiner R, Traum D: The role of grounding in collaborative learning tasks. Collaborative learning: Cognitive and computational approaches 1999:31-63.
83. Webb NM: Learning in small groups. In: *21st century education: A reference handbook.* edn. Edited by Good TL: Sage Publications; 2008: 203-211.
84. Doise WD: L'articulation psychosociologique et les relations entre groupes. 1976.
85. Molinari G, Sangin M, Dillenbourg P, Nüssli M-A: Knowledge interdependence with the partner, accuracy of mutual knowledge model and computer-supported collaborative learning. *European journal of psychology of education* 2009, 24(2):129.
86. Graham CR, Misanchuk M: Computer-mediated learning groups: Benefits and challenges to using groupwork in online learning environments. *Online collaborative learning: Theory and practice* 2004, 1(8):1-202.
87. Swan K, Shen J, Hiltz SR: Assessment and collaboration in online learning. *Journal of Asynchronous Learning Networks* 2006, 10(1):45-62.
88. Rodriguez BCP, Armellini A: Interaction and effectiveness of corporate e-learning programmes. *Human Resource Development International* 2013, 16(4):480-489.
89. Curtis DD, Lawson MJ: Exploring collaborative online learning. Journal of Asynchronous learning networks 2001, 5(1):21-34.
90. Graham CR: Factors for effective learning groups in face-to-face and virtual environments. *Quarterly Review of Distance Education* 2002, 3(3):307-319.
91. Misanchuk M, Anderson T: Building Community in an Online Learning Environment: Communication, Cooperation and Collaboration. 2001.
92. Janssen A, Robinson T, Shaw T: The Evolution of a Professional Practice Forum: Balancing Peer-to-Peer Learning With Course Objectives. *JMIR research protocols* 2014, 3(4).
93. Rubin B, Fernandes R, Avgerinou MD: The effects of technology on the Community of Inquiry and satisfaction with online courses. *The Internet and Higher Education* 2013, 17:48-57.
94. Resnick PJ, Janney AW, Buis LR, Richardson CR: Adding an online community to an internet-mediated walking program. Part 2: strategies for encouraging community participation. *Journal of medical Internet research* 2010, 12(4):e72.
95. Kilner PG, Hoadley CM: Anonymity options and professional participation in an online community of practice. In: Proceedings of th 2005 conference on Computer support for collaborative learning: learning 2005: the next 10 years!: 2005: International Society of the Learning Sciences; 2005: 272-280.
96. Hathorn LG, Ingram AL: Cooperation and collaboration using computer-mediated communication. *Journal of Educational Computing Research* 2002, 26(3):325-347.
97. Johnson SD, Aragon SR: An instructional strategy framework for online learning environments. *New directions for adult and continuing education* 2003, 2003(100):31-43.
98. Childress MD, Braswell R: Using massively multiplayer online role−playing games for online learning. *Distance Education* 2006, 27(2):187-196.

99. Wouters P, Van der Spek ED, Van Oostendorp H: Current practices in serious game research: A review from a learning outcomes perspective. In: Games-based learning advancements for multi-sensory human computer interfaces: techniques and effective practices. edn.: IGI Global; 2009: 232-250.
100. Michael DR, Chen SL: Serious games: Games that educate, train, and inform: Muska Lipman/Premier-Trade; 2005.
101. Squire K: Changing the Game: What Happens When Video Games Enter the Classroom? *Fischler School* 2005, 1(6).
102. Squire K: Cultural Framing of Computer:Video Games. *Game Studies* 2002, 2(1): 13.
103. Association IDS: State of the industry report (2000-2001). *Washington, DC* 2001.
104. Seo Y, Jung S-U: Beyond solitary play in computer games: The social practices of eSports. *Journal of Consumer Culture* 2014:1469540514553711.
105. Bornemark O: Success factors for e-sport games. *USCCS 2013* 2013, 1.
106. Weiss T, Schiele S: Virtual worlds in competitive contexts: Analyzing eSports consumer needs. *Electronic Markets* 2013, 23(4):307-316.
107. Kiili K, Devlin K, Perttula A, Tuomi P, Lindstedt A: Using video games to combine learning and assessment in mathematics education. *International Journal of Serious Games* 2015, 2(4):37-55.
108. Clark DB, Tanner-Smith EE, Killingsworth SS: Digital games, design, and learning: A systematic review and meta-analysis. *Review of educational research* 2016, 86(1):79-122.
109. McLaren BM, Adams DM, Mayer RE, Forlizzi J: A computer-based game that promotes mathematics learning more than a conventional approach. In: *Gamification in Education: Breakthroughs in Research and Practice.* edn.: IGI Global; 2018: 415-437.
110. Randel JM, Morris BA, Wetzel D, Whitehill BV: The Effectiveness of Games for Educational Purposes: A Review of Recent Research. *Simulation Gaming* 1992, 23(3):15.
111. Van Eck R: Digital Game-Based Learning- It's Not Just the Digital Natives Who Are Restless…. *EDUCAUSE Review* 2006, 41(2).
112. Oblinger D, Oblinger J: Is it age or IT: First steps toward understanding the net generation. *Educating the net generation* 2005, 2(1-2):20.
113. Prensky M: Engage me or enrage me. *Educase Review* 2005, 40(5):61-64.
114. Bennett S, Maton K: Beyond the ‘digital natives’ debate: Towards a more nuanced understanding of students' technology experiences. *Journal of computer assisted learning* 2010, 26(5):321-331.
115. Denham AR: Improving the Design of a Learning Game Through Intrinsic Integration and Playtesting. *Technology, Knowledge and Learning* 2016, 21:19.
116. Franzwa C, Tang Y, Johnson A: Serious game design: Motivating students through a balance of fun and learning. In: Games and Virtual Worlds for Serious Applications (VS-GAMES), 2013 5th International Conference on: 2013: IEEE; 2013: 1-7.
117. Sedighian K, Sedighian A: Can Educational Computer Games Help Educators Learn About the Psychology of Learning Mathematics in Children? 1996.
118. Blunt R: Does game-based learning work? Results from three recent studies. In: Proceedings of the Interservice/Industry Training, Simulation, & Education Conference: 2007; 2007: 945-955.
119. Squire KD, Jan M: Mad City Mystery: Developing scientific argumentation skills with a place-based augmented reality game on handheld computers. *Journal of Science Education and Technology* 2007, 16(1):5-29.

120. Kebritchi M, Hirumi A, Bai H: The effects of modern mathematics computer games on mathematics achievement and class motivation. *Computers & education* 2010, 55(2):427-443.
121. Brom C, Preuss M, Klement D: Are educational computer micro-games engaging and effective for knowledge acquisition at high-schools? A quasi-experimental study. *Computers Education* 2011, 57(3):1971-1988.
122. van Roy R, Zaman B: Moving beyond the effectiveness of gamification. In: *Gamification Workshop, CHI: 2015*; 2015.
123. de-Marcos L, García-López E, García-Cabot A, Medina-Merodio J-A, Domínguez A, Martínez-Herráiz J-J, Diez-Folledo T: Social network analysis of a gamified e-learning course: Small-world phenomenon and network metrics as predictors of academic performance. *Computers in Human Behavior* 2016, 60:312-321.
124. Knaving K, Björk S: Designing for fun and play: exploring possibilities in design for gamification. In: Proceedings of the First International Conference on Gameful Design, Research, and Applications: 2013: ACM; 2013: 131-134.
125. Worm BS, Buch SV: Does competition work as a motivating factor in e-learning? A randomized controlled trial. *PloS one* 2014, 9(1):e85434.
126. Caponetto I, Earp J, Ott M: Gamification and Education: A Literature Review.
127. Attali Y, Arieli-Attali M: Gamification in assessment: Do points affect test performance? *Computers Education* 2015, 83:57-63.
128. Denny P: The effect of virtual achievements on student engagement. In: Proceedings of the SIGCHI conference on human factors in computing systems: 2013: ACM; 2013: 763-772.
129. Jacobson MJ, Wilensky U: Complex systems in education: Scientific and educational importance and implications for the learning sciences. *The Journal of the learning sciences* 2006, 15(1):11-34.
130. Jacobson MJ, Kapur M, Reimann P: Conceptualizing debates in learning and educational research: Toward a complex systems conceptual framework of learning. *Educational Psychologist* 2016, 51(2):210-218.
131. Kafai YB: Playing and Making Games for Learning: Instructionist and Constructionist Perspectives for Game Studies. *Games and Culture* 2006, 1(1):36-40.
132. Kukulska-Hulme A: Will mobile learning change language learning? *ReCALL* 2009, 21(02):157-165.
133. Casey S, Kirman B, Rowland D: The gopher game: a social, mobile, locative game with user generated content and peer review. In: Proceedings of the international conference on Advances in computer entertainment technology: 2007: ACM; 2007: 9-16.
134. Lee MJ, McLoughlin C, Chan A: Talk the talk: Learner−generated podcasts as catalysts for knowledge creation. *British Journal of Educational Technology* 2008, 39(3): 501-521.
135. Pérez-Mateo M, Maina MF, Guitert M, Romero M: Learner generated content: Quality criteria in online collaborative learning. *European Journal of Open, Distance and E-learning* 2011, 14(2).
136. Wilson EV: ExamNet asynchronous learning network: augmenting face-to-face courses with student-developed exam questions. *Computers & Education* 2004, 42(1):87-107.
137. Egenfeldt-Nielsen S: Overview of research on the educational use of video games. *Digital kompetanse* 2006, 1(3):184-213.

138. Kebritchi M, Hirumi A, Bai H: The effects of modern mathematics computer games on mathematics achievement and class motivation. *Computers education* 2010, 55(2):427-443.
139. Din FS, Caleo J: Playing Computer Games Versus Better Learning. 2000.
140. Bai H, Pan W, Hirumi A, Kebritchi M: Assessing the effectiveness of a 3–D instructional game on improving mathematics achievement and motivation of middle school students. *British Journal of Educational Technology* 2012, 43(6):993-1003.
141. Papastergiou M: Digital game-based learning in high school computer science education: Impact on educational effectiveness and student motivation. *Computers & Education* 2009, 52(1):1-12.
142. Squire K, Barab S: Replaying history: Engaging urban underserved students in learning world history through computer simulation games. In: *Proceedings of the 6th international conference on Learning sciences: 2004*: International Society of the Learning Sciences; 2004: 505-512.
143. Adams PC: Teaching and learning with SimCity 2000. *Journal of Geography* 1998, 97(2):47-55.
144. Ebner M, Holzinger A: Successful implementation of user-centered game based learning in higher education: An example from civil engineering. *Computers education* 2007, 49(3):873-890.
145. Coller BD, Scott MJ: Effectiveness of using a video game to teach a course in mechanical engineering. *Computers Education* 2009, 53(3):900-912.
146. Afari E, Aldridge J, Fraser B: Effectiveness of using games in tertiary-level mathematics classrooms. *International Journal of Science and Mathematics Education* 2012, 10(6):1369-1392.
147. Kazimoglu C, Kiernan M, Bacon L, Mackinnon L: A serious game for developing computational thinking and learning introductory computer programming. *Procedia-Social and Behavioral Sciences* 2012, 47:1991-1999.
148. Chua AY: The design and implementation of a simulation game for teaching knowledge management. *Journal of the American Society for Information Science and Technology* 2005, 56(11):1207-1216.
149. Bosworth A: Keas: developing a successful game-based employee wellness program. GAMES FOR HEALTH: Research, Development, and Clinical Applications 2012, 1(3):189-191.
150. Rednic E, Toma A, Apostu A, Chen Z, Lopez-Neri E: Organize distributed work environments in a game-like fashion. *Recent Advances in Knowledge Engineering and Systems Science* 2013:213-218.
151. Brown SJ, Lieberman DA, Gemeny B, Fan YC, Wilson D, Pasta D: Educational video game for juvenile diabetes: results of a controlled trial. *Medical Informatics* 1997, 22(1):77-89.
152. Kato PM, Cole SW, Bradlyn AS, Pollock BH: A video game improves behavioral outcomes in adolescents and young adults with cancer: a randomized trial. *Pediatrics* 2008, 122(2):e305-e317.
153. Levine HG: Simulation in Medical Education at UTMB Assesses Decision Making, Not Just Facts. *Simulation/Gaming/News* 1974, 13(15):74.
154. Sward KA, Richardson S, Kendrick J, Maloney C: Use of a web-based game to teach pediatric content to medical students. *Ambulatory Pediatrics* 2008, 8(6):354-359.
155. Lagro J, van de Pol MH, Laan A, Huijbregts-Verheyden FJ, Fluit LC, Rikkert MGO: A randomized controlled trial on teaching geriatric medical decision making

and cost consciousness with the serious game GeriatriX. *Journal of the American Medical Directors Association* 2014, 15(12):957. e951-957. e956.
156. Rosser JC, Lynch PJ, Cuddihy L, Gentile DA, Klonsky J, Merrell R: The impact of video games on training surgeons in the 21st century. *Archives of surgery* 2007, 142(2): 181-186.
157. Lynch J, Aughwane P, Hammond TM: Video games and surgical ability: a literature review. *J Surg Educ* 2010, 67(3):184-189.
158. Ou Y, McGlone ER, Camm CF, Khan OA: Does playing video games improve laparoscopic skills? *International Journal of Surgery* 2013, 11(5):365-369.
159. Graafland M, Schraagen J, Schijven MP: Systematic review of serious games for medical education and surgical skills training. *British journal of surgery* 2012, 99(10): 1322-1330.
160. Akl EA, Kairouz VF, Sackett KM, Erdley WS, Mustafa RA, Fiander M, Gabriel C, Schunemann H: Educational games for health professionals [Systematic Review]. *Cochrane Database of Systematic Reviews* 2013, 3:3.
161. Burke CT: The influences of teaching strategies and reinforcement techniques on health care workers' learning and retention. 2001.
162. Telner D, Bujas-Bobanovic M, Chan D, Chester B, Marlow B, Meuser J, Rothman A, Harvey B: Game-based versus traditional case-based learning. *Canadian Family Physician* 2010, 56(9):e345-e351.
163. Kirkpatrick DL: Evaluating training programs: Tata McGraw-Hill Education; 1975.
164. Moher D, Liberati A, Tetzlaff J, Altman DG, Group P: Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS medicine* 2009, 6(7):e1000097.
165. Adams BJ, Margaron F, Kaplan BJ: Comparing video games and laparoscopic simulators in the development of laparoscopic skills in surgical residents. *J Surg Educ* 2012, 69(6):714-717.
166. Boyle E, Kennedy AM, Traynor O, Hill AD: Training surgical skills using non-surgical tasks--can Nintendo Wii improve surgical performance? *J Surg Educ* 2011, 68(2):148-154.
167. Giannotti D, Patrizi G, Di Rocco G, Vestri AR, Semproni CP, Fiengo L, Pontone S, Palazzini G, Redler A: Play to become a surgeon: impact of Nintendo Wii training on laparoscopic skills. *PloS one* 2013, 8(2):e57372.
168. Li J, Xu Y, Yue P, Sun L, Guo M, Xiao S, Ding S, Cui Y, Li S, Yang Q: 3D CPR Game Can Improve CPR Skill Retention. *Studies in health technology and informatics* 2014, 216:974-974.
169. Chan WY, Qin J, Chui YP, Heng PA: A serious game for learning ultrasound-guided needle placement skills. IEEE transactions on information technology in biomedicine : a publication of the IEEE Engineering in Medicine and Biology Society 2012, 16(6):1032-1042.
170. Enochsson L, Isaksson B, Tour R, Kjellin A, Hedman L, Wredmark T, Tsai-Fellander L: Visuospatial skills and computer game experience influence the performance of virtual endoscopy. *Journal of Gastrointestinal Surgery* 2004, 8(7):876-882; discussion 882.
171. Harper JD, Kaiser S, Ebrahimi K, Lamberton GR, Hadley HR, Ruckle HC, Baldwin DD: Prior video game exposure does not enhance robotic surgical performance. *Journal of endourology / Endourological Society* 2007, 21(10):1207-1210.

172. Madan AK, Harper JL, Frantzides CT, Tichansky DS: Nonsurgical skills do not predict baseline scores in inanimate box or virtual-reality trainers. *Surg Endosc* 2008, 22(7):1686-1689.
173. Shane MD, Pettitt BJ, Morgenthal CB, Smith CD: Should surgical novices trade their retractors for joysticks? Videogame experience decreases the time needed to acquire surgical skills. *Surg Endosc* 2008, 22(5):1294-1297.
174. Schlickum MK, Hedman L, Enochsson L, Kjellin A, Fellander-Tsai L: Systematic video game training in surgical novices improves performance in virtual reality endoscopic surgical simulators: a prospective randomized study. *World J Surg* 2009, 33(11): 2360-2367.
175. Ju R, Chang PL, Buckley AP, Wang KC: Comparison of Nintendo Wii and PlayStation2 for enhancing laparoscopic skills. JSLS : Journal of the Society of Laparoendoscopic Surgeons / Society of Laparoendoscopic Surgeons 2012, 16(4):612-618.
176. Hedman L, Schlickum M, Fellander-Tsai L: Surgical novices randomized to train in two video games become more motivated during training in MIST-VR and GI Mentor II than students with no video game training. *Studies in health technology and informatics* 2013, 184:189-194.
177. de Araujo TB, Silveira FR, Souza DLS, Strey YTM, Flores CD, Webster RS: Impact of video game genre on surgical skills development: a feasibility study. *journal of surgical research* 2016, 201(1):235-243.
178. Kennedy AM, Boyle EM, Traynor O, Walsh T, Hill AD: Video gaming enhances psychomotor skills but not visuospatial and perceptual abilities in surgical trainees. *Journal of Surgical Education* 2011, 68(5):414-420.
179. Rosenthal R, Geuss S, Dell-Kuster S, Schafer J, Hahnloser D, Demartines N: Video gaming in children improves performance on a virtual reality trainer but does not yet make a laparoscopic surgeon. *Surg Innov* 2011, 18(2):160-170.
180. Khatri C, Sugand K, Anjum S, Vivekanantham S, Akhtar K, Gupte C: Does video gaming affect orthopaedic skills acquisition? A prospective cohort-study. *PloS one* 2014, 9(10):e110212.
181. Cook NF, McAloon T, O'Neill P, Beggs R: Impact of a web based interactive simulation game (PULSE) on nursing students' experience and performance in life support training—A pilot study. *Nurse education today* 2012, 32(6):714-720.
182. Millard HAT, Millard RP, Constable PD, Freeman LJ: Relationships among video gaming proficiency and spatial orientation, laparoscopic, and traditional surgical skills of third-year veterinary students. *Journal of the American Veterinary Medical Association* 2014, 244(3):357-362.
183. Rosenberg BH, Landsittel D, Averch TD: Can video games be used to predict or improve laparoscopic skills? *Journal of endourology / Endourological Society* 2005, 19(3): 372-376.
184. Nelson CD, et al.: Diagnose: A Medical Computer Game Utilizing Deductive Reasoning. *Journal of Medical Education* 1979, 54(1):55-56.
185. Verdaasdonk EG, Dankelman J, Schijven MP, Lange JF, Wentink M, Stassen LP: Serious gaming and voluntary laparoscopic skills training: a multicenter study. *Minimally Invasive Therapy & Allied Technologies: Mitat* 2009, 18(4):232-238.
186. Graafland M, Vollebergh MF, Lagarde SM, van Haperen M, Bemelman WA, Schijven MP: A serious game can be a valid method to train clinical decision-making in surgery. *World journal of surgery* 2014, 38(12):3056-3062.

187. Kanthan R, Senger JL: The impact of specially designed digital games-based learning in undergraduate pathology and medical education. *Arch Pathol Lab Med* 2011, 135(1):135-142.
188. Lin CC, Li YC, Bai YM, Chen JY, Hsu CY, Wang CH, Chiu HW, Wan HT: The evaluation of Game-Based e-learning for medical education: a preliminary survey. *AMIA* 2005, Annual Symposium Proceedings / AMIA Symposium.:1032.
189. Buttussi F, Pellis T, Cabas Vidani A, Pausler D, Carchietti E, Chittaro L: Evaluation of a 3D serious game for advanced life support retraining. *International journal of medical informatics* 2013, 82(9):798-809.
190. Day-Black C: Gamification: An Innovative Teaching-Learning Strategy for the Digital Nursing Students in a Community Health Nursing Course. *ABNF Journal* 2015, 26(4).
191. Verdaasdonk EG, Dankelman J, Schijven MP, Lange JF, Wentink M, Stassen LP: Serious gaming and voluntary laparoscopic skills training: a multicenter study. *Minimally Invasive Therapy Allied Technologies: Mitat* 2009, 18(4):232-238.
192. Diehl LA, Souza RM, Alves JB, Gordan PA, Esteves RZ, Jorge MLSG, Coelho ICM: InsuOnline, a serious game to teach insulin therapy to primary care physicians: design of the game and a randomized controlled trial for educational validation. *JMIR Research Protocols* 2013, 2(1):e5.
193. Duque G, Fung S, Mallet L, Posel N, Fleiszer D: Learning while having fun: the use of video gaming to teach geriatric house calls to medical students. *J Am Geriatr Soc* 2008, 56(7):1328-1332.
194. Kerfoot BP, Baker H, Pangaro L, Agarwal K, Taffet G, Mechaber AJ, Armstrong EG: An online spaced-education game to teach and assess medical students: a multi-institutional prospective trial. *Academic Medicine* 2012, 87(10):1443-1449.
195. Roubidoux MA, Chapman CM, Piontek ME: Development and Evaluation of an Interactive Web-Based Breast Imaging Game for Medical Students. *Academic Radiology* 2002, 9(10):1169-1178.
196. Hannig A, Kuth N, Ozman M, Jonas S, Spreckelsen C: eMedOffice: a web-based collaborative serious game for teaching optimal design of a medical practice. *BMC Med Educ* 2012, 12:104.
197. Mann BD, Eidelson BM, Fukuchi SG, Nissman SA, Robertson S, Jardines L: The development of an interactive game-based tool for learning surgical management algorithms via computer. *The American Journal of Surgery* 2002, 183(3):305-308.
198. Mann BD, Eidelson BM, Fukuchi SG, Nissman SA, Robertson S, Jardines L: The development of an interactive game-based tool for learning surgical management algorithms via computer. *American Journal of Surgery* 2002, 183(3):305-308.
199. Antoniou PE, Athanasopoulou CA, Dafli E, Bamidis PD: Exploring design requirements for repurposing dental virtual patients from the web to second life: a focus group study. *Journal of medical Internet research* 2014, 16(6):e151.
200. Fonseca LMM, Dias DMV, Goes FDSN, Seixas CA, Sochi CGS, Martins JCA, Rodrigues MA: Development of the e-Baby serious game with regard to the evaluation of oxygenation in preterm babies: contributions of the emotional design. *Computers Informatics Nursing* 2014, 32(9):428-436.
201. Chien JH, Suh IH, Park SH, Mukherjee M, Oleynikov D, Siu KC: Enhancing fundamental robot-assisted surgical proficiency by using a portable virtual simulator. In: *Surgical innovation.* vol. 20; 2013: 198-203.

202. Hoffman SB, et al.: Geriatrix: A Role-Playing Game. *Gerontologist* 1985, 25(6): 568-572.
203. Pol MH, Lagro J, Fluit LR, Lagro−Janssen TL, Rikkert O, Marcel G: Teaching Geriatrics Using an Innovative, Individual−Centered Educational Game: Students and Educators Win. A Proof−of−Concept Study. *Journal of the American Geriatrics Society* 2014, 62(10):1943-1949.
204. Zimmerman J, Forlizzi J, Evenson S: Research through design as a method for interaction design research in HCI. In: Proceedings of the SIGCHI conference on Human factors in computing systems: 2007: ACM; 2007: 493-502.
205. Edelson DC: Design research: What we learn when we engage in design. *The Journal of the Learning sciences* 2002, 11(1):105-121.
206. Van den Akker J, Gravemeijer K, McKenney S, Nieveen N: Introducing educational design research. *Educational design research* 2006, 1:3-7.
207. Wang F, Hannafin MJ: Design-based research and technology-enhanced learning environments. *Educational technology research and development* 2005, 53(4):5-23.
208. Anderson T, Shattuck J: Design-based research a decade of progress in education research? *Educational researcher* 2012, 41(1):16-25.
209. Hoadley CM: Methodological alignment in design-based research. *Educational psychologist* 2004, 39(4):203-212.
210. Hickey DT, Ingram-Goble AA, Jameson EM: Designing assessments and assessing designs in virtual educational environments. *Journal of Science Education and Technology* 2009, 18(2):187-208.
211. Fay I: The most important process for making great games. In: *Learning, Education and Games: 2014*: ETC Press; 2014: 253-263.
212. Tashakkori A, Creswell JW: Editorial: The new era of mixed methods. *Journal of mixed methods research* 2007, 1(1):3-7.
213. Tavakol M, Sandars J: Quantitative and qualitative methods in medical education research: AMEE Guide No 90: Part II. *Med Teach* 2014:1-11.
214. Oliver M: An introduction to the evaluation of learning technology. *Educational Technology & Society* 2000, 3(4):20-30.
215. Oliver M, Harvey J: What does 'impact'mean in the evaluation of learning technology. *Educational Technology & Society* 2002, 5(3):18-26.
216. De Freitas S, Oliver M: How can exploratory learning with games and simulations within the curriculum be most effectively evaluated? *Computers & education* 2006, 46(3):249-264.
217. Braun V, Clarke V: Using thematic analysis in psychology. *Qualitative research in psychology* 2006, 3(2):77-101.
218. Creswell JW: Research design: Qualitative, quantitative, and mixed methods approaches: Sage publications; 2013.
219. Lange B, Flynn S, Rizzo A: Initial usability assessment of off-the-shelf video game consoles for clinical game-based motor rehabilitation. *Physical Therapy Reviews* 2009, 14(5):355-363.
220. Chen AM, Kiersma ME, Yehle KS, Plake KS: Impact of the Geriatric Medication Game® on nursing students' empathy and attitudes toward older adults. *Nurse education today* 2015, 35(1):38-43.
221. Creutzfeldt J, Hedman L, Fellander-Tsai L: Effects of pre-training using serious game technology on CPR performance--an exploratory quasi-experimental transfer study. *Scandinavian Journal of Trauma, Resuscitation Emergency Medicine* 2012, 20:79.

222. They Know [https://www.playtheyknow.com]
223. Qstream Inc [https://qstream.com]
224. Carpenter SK: Cue strength as a moderator of the testing effect: the benefits of elaborative retrieval. *Journal of Experimental Psychology: Learning, Memory, and Cognition* 2009, 35(6):1563.
225. Kromann CB, Jensen ML, Ringsted C: The effect of testing on skills learning. *Medical education* 2009, 43(1):21-27.
226. McDaniel MA, Anderson JL, Derbish MH, Morrisette N: Testing the testing effect in the classroom. *European Journal of Cognitive Psychology* 2007, 19(4-5):494-513.
227. Agarwal PK, Karpicke JD, Kang SH, Roediger HL, McDermott KB: Examining the testing effect with open-and closed-book tests. *Applied Cognitive Psychology* 2008, 22(7):861-876.
228. Raaijmakers JG: Spacing and repetition effects in human memory: Application of the SAM model. *Cognitive Science* 2003, 27(3):431-452.
229. Cepeda NJ, Vul E, Rohrer D, Wixted JT, Pashler H: Spacing effects in learning: A temporal ridgeline of optimal retention. *Psychological science* 2008, 19(11):1095-1102.
230. Ellis H: Teaching in the dissecting room. *Clinical Anatomy* 2001, 14(2):149-151.
231. Jones DG, Harris RJ: Curriculum developments in Australasian anatomy departments. *Clinical Anatomy* 1998, 11(6):401-409.
232. Pandey P, Zimitat C: Medical students' learning of anatomy: memorisation, understanding and visualisation. *Medical education* 2007, 41(1):7-14.
233. Fitzgerald J, White M, Tang S, Maxwell-Armstrong C, James D: Are we teaching sufficient anatomy at medical school? The opinions of newly qualified doctors. *Clin Anat* 2008, 21(7):718-724.
234. Kerfoot BP, Kearney MC, Connelly D, Ritchey ML: Interactive spaced education to assess and improve knowledge of clinical practice guidelines: a randomized controlled trial. *Annals of surgery* 2009, 249(5):744-749.
235. Jagsi R, Kitch BT, Weinstein DF, Campbell EG, Hutter M, Weissman JS: Residents report on adverse events and their causes. *Archives of Internal Medicine* 2005, 165(22):2607-2613.
236. Haller G, Myles PS, Taffé P, Perneger TV, Wu CL: Rate of undesirable events at beginning of academic year: retrospective cohort study. *Bmj* 2009, 339:b3974.
237. Kerfoot BP, Baker H: An online spaced-education game to teach and assess residents: a multi-institutional prospective trial. *Journal of the American College of Surgeons* 2012, 214(3):367-373.
238. Bouca M: Angry birds, uncommitted players. Local and Global-Games in Culture and Society 2012:1-13.
239. Bennett S, Maton K, Kervin L: The ‘digital natives’ debate: A critical review of the evidence. *British journal of educational technology* 2008, 39(5):775-786.
240. Kennedy G, Dalgarno B, Gray K, Judd T, Waycott J, Bennett SJ, Maton KA, Krause K-L, Bishop A, Chang R: The net generation are not big users of Web 2.0 technologies: Preliminary findings. 2007.
241. Bartle R: Hearts, clubs, diamonds, spades: Players who suit MUDs. *Journal of MUD research* 1996, 1(1):19.
242. Armstrong S: Games for doctors. 2014.
243. Cook DA, Levinson AJ, Garside S, Dupras DM, Erwin PJ, Montori VM: Instructional design variations in internet-based learning for health professions education: a systematic review and meta-analysis. *Academic Medicine* 2010, 85(5):909-922.

244. Meeuwisse M, Severiens SE, Born MP: Learning environment, interaction, sense of belonging and study success in ethnically diverse student groups. *Research in Higher Education* 2010, 51(6):528-545.
245. Joyce C, Veitch C, Crossland L: Professional and social support networks of rural general practitioners. *Australian journal of rural health* 2003, 11(1):7-14.
246. Mann K, Gordon J, MacLeod A: Reflection and reflective practice in health professions education: a systematic review. *Advances in health sciences education* 2009, 14(4): 595.
247. Griffith I: Generation, evaluation, and optimisation of procedural 2D tile-based maps in turn-based tactical video games. In.; 2016.
248. Crouch CH, Mazur E: Peer instruction: Ten years of experience and results. *American journal of physics* 2001, 69(9):970-977.
249. Smith MK, Wood WB, Adams WK, Wieman C, Knight JK, Guild N, Su TT: Why peer discussion improves student performance on in-class concept questions. *Science* 2009, 323(5910):122-124.
250. Schwabe G, Goth C: Navigating and interacting indoors with a mobile learning game. In: Wireless and Mobile Technologies in Education, 2005 WMTE 2005 IEEE International Workshop on: 2005: IEEE; 2005: 8 pp.-199.
251. Attali Y, Arieli-Attali M: Gamification in assessment: Do points affect test performance? *Computers & Education* 2015, 83:57-63.
252. Pobiedina N, Neidhardt J, Moreno MdCC, Grad-Gyenge L, Werthner H: On Successful Team Formation: Statistical Analysis of a Multiplayer Online Game. 2013:55-62.
253. McDaniel R, Fanfarelli J: Building Better Digital Badges: Pairing Completion Logic With Psychological Factors. *Simulation & Gaming* 2016, 47(1):73-102.
254. Deci EL, Benware C, Landy D: The attribution of motivation as a function of output and rewards. *Journal of Personality* 1974, 42(4):652-667.
255. Ryan RM, Deci EL: Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American psychologist* 2000, 55(1):68.
256. Choi GW, Pursel BK, Stubbs C: Supporting Educational Games in Higher Education: the Creation and Implementation of Custom Game Engine for a University. *TechTrends* 2017:1-8.
257. Burgos D, Moreno-Ger P, Sierra JL, Fernandez-Manjon B, Koper R: Authoring game-based adaptive units of learning with IMS Learning Design and e-Adventure. *International Journal of Learning Technology* 2007, 3(3):252-268.
258. Ke F: An implementation of design-based learning through creating educational computer games: A case study on mathematics learning during design and computing. *Computers & Education* 2014, 73:26-39.
259. Corbitt G, Wright L, Martz B: Addressing the challenges of the future: Implementing a collaborative student environment at a university business school. In: *Systems Sciences, 1999 HICSS-32 Proceedings of the 32nd Annual Hawaii International Conference on: 1999*: IEEE; 1999: 15 pp.
260. McGee JB, Begg M: What medical educators need to know about "Web 2.0". *Medical teacher* 2008, 30(2):164-169.
261. Cox C, Burgess S, Sellitto C, Buultjens J: The role of user-generated content in tourists' travel planning behavior. *Journal of Hospitality Marketing & Management* 2009, 18(8):743-764.

262. Kukulska-Hulme A, Traxler J, Pettit J: Designed and user-generated activity in the mobile age. *Journal of Learning Design* 2007, 2(1):52-65.
263. Djaouti D, Alvarez J, Jessel J-P: Can Gaming 2.0 help design Serious Games?: a comparative study. In: Proceedings of the 5th ACM SIGGRAPH Symposium on Video Games: 2010: ACM; 2010: 11-18.
264. Koutsouras P, Cairns PA: User-generated content as cues for performance in LittleBigPlanet. In*: 2013*; 2013.

Appendix

They Know: Anatomy baseline survey questions

1. **How would you rate the following formats for recreational activities (hate, dislike, like, love)?**

competitive one-on-one recreational activities / competitive team recreational activities / non-competitive team activities / non-competitive solitary activities

2. **What's the earliest game you regularly played?**

3. **How often do you play games on a smart phone device?**

never / occasionally / 1 - 2 days per week /3 - 5 days per week /1 - 3 hours a day / 3+ hours a day

4. **How often do you play games on a dedicated gaming device such as an Xbox, PS3 or Wii?**

never / occasionally / 1 - 2 days per week /3 - 5 days per week /1 - 3 hours a day / 3+ hours a day

5. **How often do you play games on a handheld gaming device such as a Nintendo DS or Playstation Vita?**

never / occasionally / 1 - 2 days per week /3 - 5 days per week /1 - 3 hours a day / 3+ hours a day

6. **How often do you play games on a PC or Mac?**

never / occasionally / 1 - 2 days per week /3 - 5 days per week /1 - 3 hours a day / 3+ hours a day

7. **How often do you play non-digital games such as boardgames, card games, role playing games (RPGs)?**

never / occasionally / 1 - 2 days per week /3 - 5 days per week /1 - 3 hours a day / 3+ hours a day

8. **Approximately how much time do you normally spend playing digital games in a normal recreational session?**

less than an hour / 1 - 3 hours / 4 - 5 hours /6 + hours /N/a

9. **Which commercial digital games or game genres do you play frequently?**

10. **What do you like or dislike about digital games as a recreational activity?**

11. **How would you rate your skills/experience in digital games on a 1 - 4 scale where 1 = amateur and 4 = expert?**

12. **How would you describe your player personality?**

competitive / disruptive /explorative /collaborative

13. **Do you play multiplayer games? Why or why not?**

14. **If you do, what's your favourite multiplayer game, digital or non-digital?**

15. **When you play your favourite multiplayer games, how far ahead do you plan your strategy on a 1 - 4 scale where 1 = ad hoc and 4 = long-term strategy?**

16. **What's the most satisfying way to win a game?**

overwhelming assault / flair, cunning, creativity, misdirection /any way that works

17. **How often do you study with peers outside of your scheduled courses?**

daily / weekly /monthly/ running up to exams / rarely / never

18. **If you do, what methods do you use to interact?**

face to face / email correspondence /google groups/ teleconferencing/ other

19. **How often do you study alone outside of your scheduled courses?**

daily / weekly /monthly/ running up to exams / rarely / never

20. **Which tools do you use when you study alone?**

course recommended readings / journals /phone apps/ blogs / wikis / flash cards/ other

21. How do you decide which of these learning tools to use?

22. How do you identify areas you need to revise?

23. What barriers, if any, do you run up against in independent study?

They Know: Anatomy Match Likert rankings

Please rate your experiences during this gameplay session on the scales below, where 1 indicates a negative score and 6 indicates a positive one.

Challenge

1	2	3	4	5	6

Competitiveness

1	2	3	4	5	6

Engagement

1 2 3 4 5 6

Enjoyment

1 2 3 4 5 6

Replay likelihood

1 2 3 4 5 6

Thank you!!!!

They Know: Anatomy Semi-structured Interview schema

1. How experienced are you with commercial digital games?

2. Do you have an experience with educational digital games?

3. How did you find your experiences with the game?

4. Do you feel more confident in your understanding of the subject area than you did before undertaking the game?

5. Did you find this format of learning fun?

6. Did you find this format of learning engaging?

7. How frequently did you discuss the game subject matter with your team mates outside of the game matches?

8. Did you seek advice from teammates when you were unsure of how to answer a question in the game?

9. How did you find interacting with your teammates whilst playing the game?

10. Do you anticipate interacting with your teammates from the game session more in future then you do currently in your degree?

Qstream: Cancer Cup Challenge Post-program survey

1. Could you please describe your expectations as a registrar prior to beginning your year at this hospital?

2. Where these expectations consistent with the actual experience?

3. Did you find the introduction to oncology lectures conducted in March this year beneficial to your experiences as a registrar?

4. Did you feel your personal needs as a registrar were supported during the first six months as a registrar?

5. Did you feel your professional needs as a registrar were supported during the first six months as a registrar?

6. Have you had an opportunity to explore the new registrar orientation hub?

7. Did you find it useful?

8. Do you have any questions you would like to ask us?

Qstream: Cancer Cup Challenge Semi-structured interview schema

1. **Please rate the following statements below in relation to course content on a scale of 1 - 5, where 1 = least agree and 5 = most agree:**

I found the questions interesting.

I found the questions relevant.

I found the questions realistic.

I found the pre-prepared feedback useful.

The questions allowed for exploration of common adverse events in cancer care.

The questions allowed for exploration of uncommon adverse events in cancer care.

The course exposed me to new issues I hadn't previously considered.

2. **Please rate the following items relating to course format on a scale of 1 - 5, where 1 = least agree and 5 = most agree:**

I liked receiving the cases via email.

I found repeating incorrect answers beneficial to my understanding.

I liked interacting in the discussion forum.

I found the duration of the course suited my needs.

I enjoyed the competitive aspect of the course.

I enjoyed the team aspect of the course.

3. **If you did not participate in the course forum could you please comment on why not and on how it could be made more useful in future?**

4. **As a result of completing the course I feel more confident handling the adverse events covered in this course.**

5. **What did you LIKE about the course?**

6. **What would you CHANGE about the course?**

7. **Do you have any GENERAL COMMENTS about the course?**

Publications arising from this dissertation

Janssen A, Shaw T, Goodyear P, Kerfoot BP. Using multiplayer digital games to support collaboration in Health Education. IRLn 2017.

Janssen A, Shaw T, Bradbury L, et al. (2016) A mixed methods approach to developing and evaluating oncology trainee education around minimization of adverse events and improved patient quality and safety. BMC Medical Education

Janssen A, Shaw T, Goodyear P. et al. (2015) A Little Healthy Competition: Using mixed methods to pilot a team-based digital game for boosting medical student engagement with anatomy and histology content. BMC Medical Education

Janssen A, Shaw T, & Goodyear P. (2015). Using video games to enhance motivation states in online education: protocol for a team-based digital game. *JMIR research protocols.*

Janssen A, Robinson T, Shaw TJ. (2014) The Evolution of a Professional Practice Forum: Balancing Peer-to-Peer Learning With Course Objectives. JMIR Research Protocols

DOI: https://doi.org/10.3217/978-3-85125-530-0-16

Using Multiplayer Digital Games to Support Collaboration in Health Education

Anna Janssen (anna.janssen@sydney.edu.au) [1], Professor Tim Shaw [2], Peter Goodyear [3], B. Price Kerfoot [4]

1. Sydney Medical School, University of Sydney, Sydney, Australia
2. Research in Implementation Science and eHealth Group, Faculty of Health Sciences, University of Sydney, Sydney, Australia
3. Centre for Research on Learning and Innovation, Faculty of Education and Social Work, University of Sydney, Sydney, Australia
4. Surgical Service, Veterans Affairs Boston Healthcare System, Harvard Medical School

Abstract: The research described in this article explores the value of a multiplayer game for supporting cooperation and collaboration in health education. The digital game was built using the game platform They Know. This platform was used because it enabled the development of team based strategy games in any subject area. The aim of a They Know game is for small teams of players to take control of the opposing teams home base, in order to win the game. The first team to take control of an opposing teams home base wins the game. To achieve this players have to cooperate within their team to develop strategy and share their knowledge about the subject matter in the game. To design a game in the platform subject matter is distributed across a game map in a network, with each node containing multiple choice questions relating to a specific learning objective or curriculum. In the context of this study the game platform was used for the development of an anatomy revision game, They Know: Anatomy.

Keywords: serious game, health education, multiplayer, synchronous learning

1 Introduction

Interest in the use of digital games for serious applications has been increasing since the early 2000s. However, there is a significant gap in the research into their use in health education. Although researchers have shown considerable interest in the repurposing of commercial games for enhancing surgical skills training, there are significant gaps in the broader application of games based learning in the health sector [1]. Currently, the literature on the use of digital games in health education has explored a diverse range of areas including their use for educating medical students about the delivery of care for geriatric patients [2], the use of digital games to assess mental preparedness of health professional sin training [3], and a number of studies investigating the impact of exposure to commercial digital games on predicting and enhancing surgical skills [4-5]. Further research is warranted into the effective use of digital games in health education and how they can be used to engage learners. This is particularly evident in regard to the use of multiplayer games to deliver immersive and collaborative learning experiences, as there is currently almost no research into their use in health education.

DOI: https://doi.org/10.3217/978-3-85125-530-0-16

A core component of health education is delivering training around foundational sciences such as anatomy and histology. Although these subjects are integral to health education, they are often challenging subjects for students to learn, due to the breadth of knowledge that has to be internalised [7] and also because of the complexity of the subject matter [6]. Students can also experience other challenges learning anatomy and histology such as a lack of confidence in their understanding of the material, as well as stress and anxiety attempting to internalise core elements [8,9]. As a result of these challenges there is considerable interest in the use of new technologies and tools for the delivery of anatomy and histology education to health students. There are currently two studies that have looked at the use of analogue games to deliver training to this group, a board game developed for medical students [6] and a card game developed for optometry students [10]. Both studies demonstrated the value of the games for improving anatomy knowledge of participants, and also for increasing their engagement with the subject matter.

The aim of this study presented in this article was to explore how multiplayer digital games support student engagement with anatomy and histology subject matter. Although there is some evidence that games can engage health students in anatomy revision, there is currently very little looking specifically at multiplayer digital games.

2 Methods

A mixed methodology was used to evaluate a multiplayer digital game used to support anatomy revision by medical students. Quantitative data collected included game platform metrics such as the number of subject matter nodes encountered by participants, the number of question cards encountered by participants and the number of question cards answered correctly by participants. Qualitative methods included unstructured observations of gameplay sessions, post-match surveys and semi-structured interviews with participants.

The anatomy game used in this study was disseminated using the They Know game platform. This platform was used because it supported multiplayer games, specifically team based strategy games. To win the game players cooperate with their team mates to cross the game map and take control of the opposing teams home base (Refer to Figure 1 for a screenshot of the game used in this study [4]). The game map distributes subject matter across a network of themed nodes relating to a specific learning objective or curriculum area. Each node contains multiple choice questions relating to its learning objective. Players start at their team's home node, which their team controls, and work their way across the network of themed nodes until they reach the opposing teams base. To cross the map players click on a node adjacent to the one they are on and attempt to take control of it for their team. To take control of a node players answer multiple choice questions until enough have been answered correctly to take control of it. A line of control must be created from the player's home base, through the themed nodes to the opposing teams home base in order to take control of it and win the game.

DOI: https://doi.org/10.3217/978-3-85125-530-0-16

Fig. 1. A screenshot of the game They Know: Anatomy showing how subject matter nodes are distributed across the game map [4].

In order to develop the questions for the game a team of content developers were identified. The content experts developed a suite of 240 multiple choice questions, which were distributed across 15 subject nodes. The subject nodes covered a breadth of areas including: Upper Limb Muscles – forearm and hand, Lower Limb – nerves, and Head and Neck Anatomy Once the content had been finalized a member of the research team used graph paper to design multiple maps, one of which would be used for the final game layout. Draft map designs were developed over a series of week in order to determine a layout that would encourage players to cooperate with their team mates in order to explore the maximum number of nodes. The successful map design was digitized and used during pilot sessions of the game in 2014.

Second year medical students were recruited in February 2014 to participate in gameplay sessions. During recruitment they were advised that the game was team based and that it had been designed to help them revise anatomy and histology subject matter that they had encountered as first year students. Participants were assigned to a game session, which consisted of at least two matches of the digital game spaced three days apart. Each match in a session was intended to be no longer than 60 minutes in duration. Participants who had expressed interest in participating in a gameplay session were emailed the dates of each session and invited to sign up for one that suited their availability. Up to eight participants could participate in a session, with participants being assigned to one of two teams of four players. All participants in a session played the game synchronously with the other players. Participants on the same team were co-situated in a single computer lab, but each had access to their own desktop computer. They controlled their own player avatar, but could see the movements of all other players across the map. Their team mates had blue avatars and those on the opposing team had red ones.

At the end of each match, participants completed a ranking of their engagement with the game. Once they had completed a session (consisting of multiple matches) participants were invited to participate in semi-structured interviews to explore the gameplay experience of each participant with the game. Each semi-structured interview was transcribed, de-identified and then analysed to identify common themes regarding the gameplay experience. Data collect from a session was analysed prior to the subsequent session being undertaken, so that the research team could iterate on

DOI: https://doi.org/10.3217/978-3-85125-530-0-16

aspects of the game itself and the gameplay environment, in order to explore different aspects of how multiplayer games supported cooperation and collaboration between participants.

3 Results

A total of three gameplay sessions were conducted during the study. There were eight participants in each session, with a total of 24 participants across all three. The demographic breakdown of the participants across all the sessions was 9 female and 13 male, with two female and six male participants in each of the first two sessions and six female and two male participants in the final session.

During these three sessions 43 post-match engagement rankings were returned by participants. Analysis of the post-match rankings indicated participants experienced a high level of engagement with the digital game, with 83% of participants ranking their experience engaging or very engaging (n=35). The post-match rankings identified competition as a particularly enjoyment aspect of the gameplay experience, with 90% of respondents ranking competition as enjoyable or very enjoyable (n=38). Finally, the majority of participants, 84%, agreed or strongly agreed with the statement that the game was repayable (n=36).

A total of 21 participants agreed to participate in semi-structured interviews to reflect on their experiences with the digital game. Interviews took between 10 minutes and 40 minutes, but most were around 20 minutes duration, and where conducted either over the phone or face to face at the participants' discretion. Thematic analysis of interview data indicated participants found the game beneficial for revising anatomy and histology content. The multiplayer aspect of the game was considered a novel way to support revision of anatomy subject matter that complimented existing autonomous learning approaches. It was identified that multiplayer digital games fostered collaboration through four elements: supporting the development of a team strategy to win the game, facilitating shared decision making to overcome obstacles during the game, working towards a shared goal, and creating a sense of investment in a team. The first element, developing a team strategy, was commented on most frequently by interviewees. It was considered beneficial for identifying the subject matter strengths and weaknesses of individual participants, and inform how the team traversed across the map. However, one interviewee commented that developing a team strategy may also have had made players less willing to expose themselves to subject nodes they felt under confident with, which could limit their exposure to new knowledge. The second element, shared decision making to overcome obstacles during the game, was identified by participants as an unexpectedly rewarding experience. Interviewees found the process of discussing questions and subject matter areas as a team provided them with insight about how well their peers knew the subject matter. This process made individual participants feel closer to their team mates during the game. Additionally, interviewees noted that the process could reduce feelings of social isolation and made them feel that other students were struggling with the same issues they were when learning anatomy and histology. The third element, working towards a shared goal, was identified as a positive attribute of multiplayer serious games by all the interviewees. Interviewees felt they had autonomy throughout the game to progress across the map as individuals, but also felt highly motivated to answer as many questions as possible correctly due to their sense of investment in the team. One interviewee also commented that they found the use of

DOI: https://doi.org/10.3217/978-3-85125-530-0-16

a multiplayer game were teams worked together to win for revising anatomy and histology subject matter quite novel, which made the overall experience more fun. The final element that that fostered cooperation and collaboration between participants was the structure of the team itself, and the way that encouraged participants to feel invested in their team. This element was not discussed by all the interviewees, but those that did raise it noted that it was a valuable one. Interviewees that discussed this element thought it gave them a sense they had a support system they could draw on if they need it. It was noted that the support provided to students though the support system may be enhance if teams were not randomly assigned, but instead structured to combine students who were stronger and weaker in the subject area.

In addition to reflecting on their own experiences during the gameplay sessions, interviewees discussed how they felt the game might be useful if it was implemented outside the confines of the study. Interviewees were particularly interested in the potential of the game to support user generated content, both in the form of the multiple choice questions themselves and also in the layout of game maps. Although the majority of interviewees raised the possibility of allowing students to create their own questions for future versions of the game, interviewees were divided about how this could be implemented. Some interviewees thought students should be engaged to write questions so that they aligned with their individual revision needs. However, other interviewees felt that students did not know what questions aligned with the anatomy and histology curriculum. To address this problem one interviewee suggested that students should create the questions for future games, and that a content expert should review them for relevance. Another interviewee suggested that some form of question development guidelines could be developed to reduce the likelihood of irrelevant questions being developed. Finally, a third group of interviewees felt that there would be no real benefit of getting students to develop the individual questions in the game, as that should be left to the experts. These interviewees felt it would be interesting if students could design their own game maps and distribute subject matter in a way that was relevant to them.

Finally, interviewees discussed the potential of multilayer games to encourage cooperation and teamwork more broadly in health curriculums. Participants suggested that embedding the multiplayer game early in the academic year could be beneficial for overcoming the challenge of encouraging interaction between students in large units of study. Finally, playing the game allowed participants to identify peers with subject matter knowledge and skills that complimented their own. This information was viewed as useful for making more informed decisions about forming study groups to strengthen self-directed learning and revision.

We acknowledge that this study had some limitations. The primary limitation is that the evaluation used relied heavily on participant reflection on their experiences with the game. Whilst that is a valuable means of exploring feasibility and acceptability of the game for learners, other measures are required to obtain additional insights into how multiplayer digital games foster cooperative learning experiences. Additionally, the demographic used in this study was exclusively medical students which limits the generalizability of our findings to other student populations. It would be interesting to explore the attitudes of other health students to multiplayer digital games in future studies.

DOI: https://doi.org/10.3217/978-3-85125-530-0-16

4 Conclusion

Multiplayer digital games have the potential to support collaboration in health education and to offer diverse and flexible and immersive experiences to learners. Additionally, they provide new avenues for supporting self-directed learning and encouraging cooperation between large groups of students, such as those in a tertiary unit of study. However, further research is still needed into the degree to which multiplayer games impact learning outcomes and value across a range of educational contexts.

5 References

1. Graafland, M., Schraagen, J. M., & Schijven, M. P. (2012). Systematic review of serious games for medical education and surgical skills training. British journal of surgery, 99(10), 1322-1330.
2. Alfarah, Z., et al. (2010). "Educational games in geriatric medicine education: A systematic review." BMC Geriatrics **10**(1): 1.
3. Lin CC, Li YC, Bai YM, Chen JY, Hsu CY, Wang CH, et al. The evaluation of game-based e-learning for medical education: a preliminary survey. In: AMIA Annual Symposium Proceedings. Bethesda, USA: American Medical Informatics Association; 2005. p. 1032.
4. Plerhoples, T. A., et al. (2011). "Another use of the mobile device: warm-up for laparoscopic surgery."
5. Graafland, M., et al. (2012). "Systematic review of serious games for medical education and surgical skills training." British Journal of Surgery **99**(10): 1322-1330.
6. Anyanwu EG. Anatomy adventure: a board game for enhancing understanding of anatomy. Anat Sci Educ. 2014;7(2):153–60.
7. Ellis H. Teaching in the dissecting room. Clin Anat. 2001;14(2):149–51.
8. McKeown PP, Heylings DJA, Stevenson M, McKelvey KJ, Nixon JR, McCluskey D. The impact of curricular change on medical students' knowledge of anatomy. Med Educ. 2003;37(11):954–61.
9. Jones DG, Harris RJ. Curriculum developments in Australasian anatomy departments. Clin Anat. 1998;11(6):401–9.
10. Choudhury B, Gouldsborough I, Gabriel S. Use of interactive sessions and e-learning in teaching anatomy to first year optometry students. Anat Sci Educ. 2010;3(1):39–45.
11. Janssen, A., Shaw, T., Goodyear, P., Kerfoot, B. P., & Bryce, D. (2015). A little healthy competition: using mixed methods to pilot a team-based digital game for boosting medical student engagement with anatomy and histology content. *BMC medical education*, *15*(1), 173.

Janssen et al. BMC Medical Education (2016) 16:91
DOI 10.1186/s12909-016-0609-1

BMC Medical Education

RESEARCH ARTICLE Open Access

A mixed methods approach to developing and evaluating oncology trainee education around minimization of adverse events and improved patient quality and safety

Anna Janssen[1*], Tim Shaw[2], Lauren Bradbury[3], Tania Moujaber[3], Anne Mette Nørrelykke[3], Jessica A. Zerillo[4], Ann LaCasce[4], John Patrick T. Co[5], Tracy Robinson[6,7], Alison Starr[8] and Paul Harnett[3]

Abstract

Background: Adverse events are a significant quality and safety issue in the hospital setting due to their direct impact on patients. Additionally, such events are often handled by junior doctors due to their direct involvement with patients. As such, it is important for health care organizations to prioritize education and training for junior doctors on identifying adverse events and handling them when they occur. The Cancer Cup Challenge is an educational program focuses on quality improvement and adverse event awareness targeting for junior oncology doctors across three international sites.

Methods: A mixed methodology was used to develop and evaluate the program. The Qstream spaced learning platform was used to disseminate information to participants, as it has been demonstrated to impact on both knowledge and behavior. Eight short case based scenarios with expert feedback were developed by a multidisciplinary advisory committee containing representatives from the international sites. At the conclusion of the course impact on participant knowledge was evaluated using analysis of the metrics collected by the Qstream platform. Additionally, an online survey and semi-structured interviews were used to evaluate engagement and perceived value by participants.

Results: A total of 35 junior doctors registered to undertake the Qstream program, with 31 (88.57 %) successfully completing it. Analysis of the Qstream metrics revealed 76.57 % of cases were answered correctly on first attempt. The post-program survey received 17 responses, with 76.47 % indicating cases for the course were interesting and 82.35 % feeling cases were relevant. Finally, 14 participants consented to participate in semi-structured interviews about the program, with feedback towards the course being generally very positive.

Conclusions: Our study demonstrates that an online game is well accepted by junior doctors as a method to increase their quality improvement awareness. Developing effective and sustainable training for doctors is important to ensure positive patient outcomes are maintained in the hospital setting. This is particularly important for junior doctors as they are working closely with patients and learning skills and behaviors, which will influence their practice throughout their careers.

* Correspondence: anna.janssen@sydney.edu.au
[1]Research in Implementation Science and e-Health Group (RISe), Faculty of Health Sciences, Sydney West Translational Cancer Research Centre, The University of Sydney, Sydney, NSW, Australia
Full list of author information is available at the end of the article

Background

The rate of adverse event reports in hospitals globally has remained consistent over the last 20 years [1, 2], which is particularly disappointing given their direct impact on patient quality care. Adverse events are usually defined as incidents that result in harm to a patient–for example, either a short-term or permanent disability or in extreme cases patient death. Not only do adverse events have a severe impact on the patient, but the literature suggests that as many as one third of these events are preventable [3]. Hospital-based adverse events cover a wide range or of incidents, many of which can be classified as due to either systemic or human factors [4, 5], and negatively impact on patient quality of care.

Doctors in training represent a group of health professionals that maybe particularly vulnerable to involvement in adverse events due to their high patient contact, workload and relative inexperience [6]. This is evident in a number of studies that have reported on a phenomena referred to as the 'July Effect' where there have been reported increases in adverse events early in the academic training year [7].

Effective education and rigorous training has been recognized as an important component of developing safe and efficient health professionals. This is reflected by organizations such as the Accreditation Council for Graduate Medical Education (ACGME) mandating that residency programs provide education for residents and fellows in safety and quality [8]. Quality improvement has emerged as an increasingly important focus of activity in health services and it is essential that clinicians understand the effectiveness of such interventions [9]. In addition, current international training curricula include key competencies in safety and quality [10]. This highlights the need for guidance on how to design and research quality improvement and safety programs. In spite of this focus, the delivery of effective education to health professionals in training remains a key challenge and under-researched area.

Physicians in training are required to demonstrate skills and knowledge across an increasingly large number of competencies while developing skills in their chosen discipline [11, 12]. Even though adult learning principles have long identified that education and training must be contextually relevant and directly linked to practice [13], many safety and quality programs in hospitals are delivered via didactic lectures or workshops that are not specific to the training environment or practice [14]. While online learning is increasingly employed for the scalable delivery of education to doctors in training, there is little evidence in the literature regarding whether computer-based online educational methodologies are effective in actually changing behavior. Furthermore, if online programs are to include education and training in safety and quality to meet mandatory training requirements then it is essential that researchers can demonstrate evidence of their impact.

Qstream is a novel, evidence-based form of online education that has been demonstrated to improve knowledge acquisition and recall [15]. It has also been repeatedly demonstrated to change participant behavior and maintain that change over time [16, 17]. Participants in Qstream courses receive repeating, short, case-based multiple choice questions with feedback via email in a reinforcing pattern over a number of weeks. The methodology is based on two core psychological research findings: the spacing and testing effects. The *spacing effect* refers to the finding that educational encounters that are repeated over time increase the acquisition and retention of knowledge. The *testing effect* refers to the finding that the process of testing does not only measure knowledge, but also improves retention [18, 19]. It has further been demonstrated that participants find repetition of cases via email effective for completing the course due to the ease of completing cases in existing schedules [16].

In a randomized trial this Qstream platform was found to increase learning efficiency by over 35 % over a non Qstream program with identical content. In addition, Qstream includes a gamification element whereby participants can compete as both individuals and teams and review their progress against de-identified leader boards [20]. Gamification refers to the use of individual game mechanics such as leader boards in order to enhance another online tool such as an online course. The use of gamification can be beneficial in online education as it has the ability to both engage and motivate learners, strengthen social ties and preserve the original focus of the learning activity [21]. The use of gamification elements in e-learning has also been demonstrated to result in more accurate results on quizzes due to the use of competition, which stimulates learners to interact more with their peers and the content of the course [22].

This study evaluated the feasibility and acceptability of using Qstream to deliver safety and quality education in an oncology-specific context to doctors in training in the United States, Australia and Denmark. In particular, the program focused on frequently encountered urgent clinical scenarios, adverse events from cancer treatments, and event reporting of errors and near misses to demonstrate key learning points. The study also evaluated the impact of competition in motivating participation through promoting the program as a friendly competition between the countries titled the 'Cancer Cup Challenge'.

Methods

Setting

The aim of the Cancer Cup Challenge was to develop a program targeting key safety and quality issues that are encountered by physicians training in medical oncology. An expert Advisory Committee was convened in March 2014 to oversee the development of the program. This Committee consisted of senior medical oncologists, quality improvement staff, educational designers, senior oncology registrars and research fellows across participating sites.

The program was developed by representatives from international sites in Australia, Denmark and The United States of America (USA). This included individuals from the Sydney West Translational Cancer Research Centre in Sydney, Australia; Aarhus University Hospital in Denmark; and the Partners Program in Boston, the United States of America.

Curriculum development

The Advisory Committee oversaw the development of a set of key learning objectives which were turned into one sentence take-home messages to be used for the Qstream cases. These key take-home messages related to specific practice points on safety and quality for oncology patients. They included items such as fertility preservation and drug interactions, particularly in regard to oral chemotherapy. The take home messages were derived from a number of sources including: a review of the literature; a review of local adverse events or near-miss reports at each site and 2 consensus building workshops attended by senior oncologists and senior oncology trainees in Australia and the United States. An initial set of 34 key take home messages was developed that was ultimately refined to eight through an interactive review process by the Advisory Committee. *Refer to* Fig. 1 *for an example Qstream case from the Cancer Cup Challenge.*

Once the take home messages had been identified, the Advisory Committee worked collaboratively to write short clinical case scenarios that reinforced the specific messages. The correct answer was identified and input as a multiple choice response. This was augmented by three distractor options which could be equally plausible

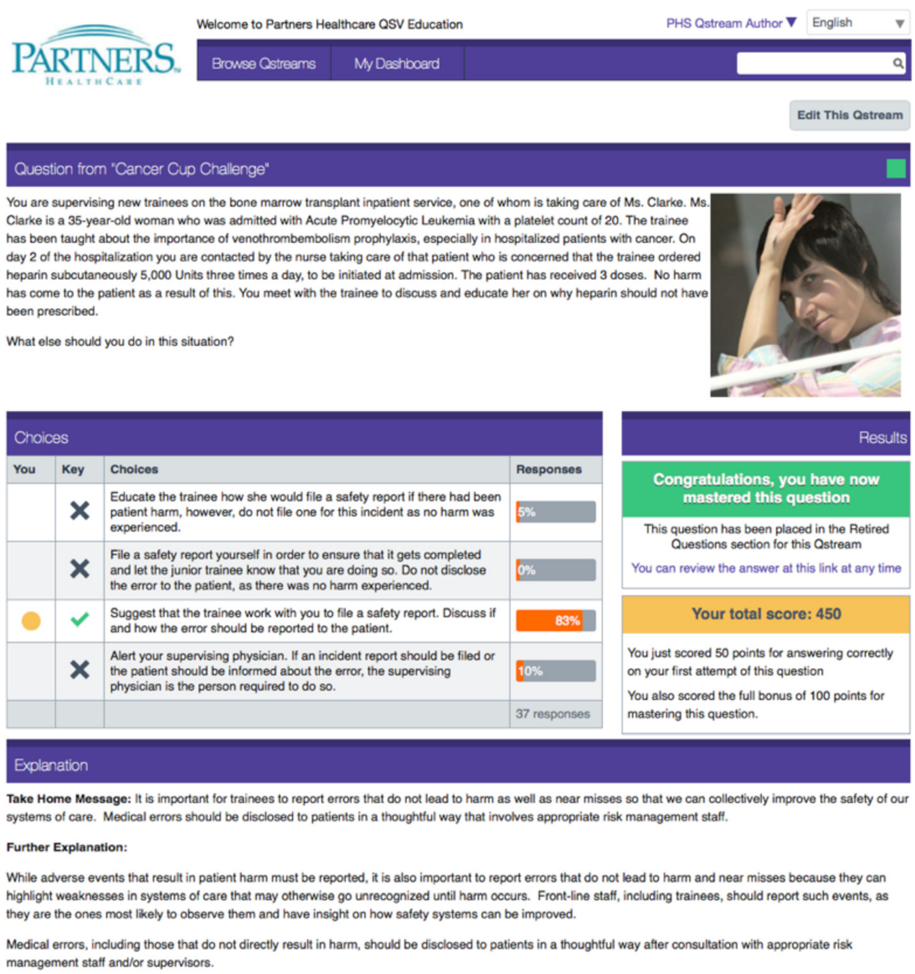


Fig. 1 An example Qstream case from the Qstream: Cancer Cup Challenge

to a participant. The final stage of building a case was developing the expert feedback. This expanded on the take home message in more detail and provided additional resources for further reading.

Participant recruitment

Junior oncology trainees were recruited to participate in the study from the Basic Science in Oncology Course (BSOC) in Australia, Aarhus University Hospital in Denmark and the Partners Program in the United States of America in October 2014. The research team was provided with contact details for a recruitment coordinator at each site. This coordinator was provided with generic text to create an expression of interest email for participants at their site. This was emailed to all medical oncology trainees at the site. Once recruitment had been completed participants were allocated to teams based on their country of origin and then were emailed a link to access the Qstream spaced learning system on which the Qstream: Cancer Cup Challenge was running by a member of the research team. The research team did not give participants access to any patient safety or dverse events training prior to undertaking the Qstream: Cancer Cup Challenge.

Course administration

Once participants enrolled in the course cases were emailed to them and could be completed on a personal computer, tablet or smart phone. The cases were sent to participants in the following spaced manner:

- Each participant received an email every 2 days containing at least 2 cases
- If they answered a case incorrectly, it was re-sent 5 days later
- Once a case was answered correctly it was retired
- The course was completed once all questions had been retired.

Each Qstream case consists of an evaluative component (a clinically-relevant multiple-choice question) and an educational component (the correct answer and a detailed explanation of the answer). Participants submit an answer, receive immediate feedback, and compare their performance with peers. To harness the educational benefits of the spacing effect, the case is repeated until the participant answers the case correctly. The decision to repeat only incorrect cases was made based on data from previous Qstream programs at the clinical sites. This data indicated that repeating correct cases increased the likelihood participants would not complete the program.

During the Cancer Cup Challenge participants were allocated to teams to evaluate the impact of the gamification element. Upon answering a question, participants were presented with a de-identified league table that indicated how they were performing compared to their peers. Participants were sent periodic emails containing team scores.

Analysis

Mixed methods were used to evaluate the impact of the Cancer Cup Challenge on participant knowledge, skills and team engagement. Quantitative data collected by the Qstream system was analyzed for participant response accuracy. Qualitative data was collected through semi-structured interview and online survey to assess participant experience of the program regarding content and format. Qualitative data from interviews was transcribed and thematically analyzed.

Upon completion of the Cancer Cup Challenge participants were emailed a link to the online survey. This survey asked them to rank aspects of the course format and course content using a Likert ranking scale. They were also given the opportunity to leave free-text comments on their views of the course. A reminder to complete the survey was emailed out 1 week after the initial survey link was disseminated.

Participants were also invited to participate in a brief interview within 4 weeks of completing the course to explore the perceived impact of the Qstream education program on their knowledge and behavior in relation to adverse events in cancer care. Interviews were conducted over the phone or in person and took between 10 and 20 min to complete. The interviews were semi-structured without set questions. However, an interview guide was developed to maintain a consistent structure for all the interviews. Interviews first explored registrar and fellow needs in regards to adverse events training and how the Qstream program engaged participants and impacted on their educational experience.

Permission to conduct this study has been received from the Western Sydney Local Health District Human Research and Ethics Committee.

Results

Participation and case performance

Of 50 medical oncology trainees invited to participate across the three sites, 35 registered for the course. Thirty one (88.57 %) of these participants went on to successfully complete each case presented via the Qstream platform. Overall, 35 participants answered at least one question (70 % of those invited and 100 % of those who enrolled), and 31 participants completed the program (62 % of those invited and 89 % of those who enrolled). The demographic breakdown for the 35 participants was:16 male (46 %), 15 female (43 %) and four (11 %) did not indicate a gender. *Refer to* Table 1 *for a comparison of* *participation based on country. Refer to* Table 2 *for a gender distribution of participants by country.*

76.57 % of cases were answered correctly on the first attempt. However, only one case was answered correctly by all participants on the initial try. All the others had at least two participants answer incorrectly on the first attempt. One case had significantly more incorrect answers than all others with seven participants requiring two or more attempts to retire it. The case explored the challenges of monitoring toxicities that cancer patients experience at home.

Case performance was also reviewed across the three international teams. All teams had three cases which all participants answered correctly on the first attempt. However, only one case was answered correctly by all teams on the first attempt, the case dealt with treating neutropenic fever. In Addition, the Australian team scored 100 % on the first attempt for two cases, one on spinal cord compression, and one on oral chemotherapy drug interactions. The Danish team scored 100 % on the first attempt for a case on error reporting for trainees, and one on appropriate use of growth factor support. The US team scored 100 % of on the first attempt for a case on poor patient medication compliance, as well as a case on managing toxicities in patients as closely as would be done if observed in the hospital setting. *Refer to* Table 3 *for an overview of the percentage of participants who answered each case correctly on first attempt compared to case take home message.*

Four participants who begun undertaking the Qstream course, but did not complete it. Of this group one participant answered three cases before discontinuing, two participants completed four cases before discontinuing, and one participant answered seven cases before discontinuing. One participant did not answer a single case incorrectly before discontinuing the course, with the other three only answering one case incorrectly. Only one participant discontinued the course directly after answering a case incorrectly, the remaining three discontinued after answering a case correctly. Two participants that discontinued the course answered the same case incorrectly, a case which related to oral chemotherapy interactions.

Table 1 Details of the number of participants who enrolled in the Qstream: Cancer Cup Challenge compared to the number who completed

Country	Number enrolled	Percentage enrolled	Number completed	Percentage completed
Australia	12	75 %	11	92 %
Denmark	11	79 %	11	100 %
The United States of America	12	63 %	10	83 %

Table 2 Demographic breakdown of the number of participants enrolled in the Qstream: Cancer Cup Challenge based on nationality

Country	Male participants	Female participants	Unspecified gender
Australia	6	4	2
Denmark	4	6	1
The United States of America	6	5	10

A representative of the research team contacted each of the four participants who did not complete the course to find out why. Unfortunately, none of the non-completers responded to this contact.

Participant experience

At the conclusion of the Cancer Cup Challenge all participants were asked to complete a brief online survey. Seventeen participants responded to this request and completed the online survey. Participants were asked to rate a range of questions on the content and structure of the course using a 1–5 scale, where 1 was lowest agreement and 5 represented highest agreement. A majority of respondents, 76.47 %, agreed that the cases for the course were interesting. Additionally, 82.35 % of respondents felt the cases were relevant to them. In regard to the format of the course, 47.05 % of respondents indicated that they enjoyed the team-based aspect of the course. In contrast 82.36 % of respondents indicated they enjoyed the individual competition. *A visualization of these Likert responses is provided in* Fig. 2.

Participants were also given the opportunity to leave free-text comments regarding strengths and weakness, along with any general comments about the Cancer Cup Challenge. There were 32 free-text comments about the Cancer Cup Challenge, with some respondents leaving more than one comment. Of those, 21 comments indicated the course was a generally positive experience. Reasons respondents enjoyed the course included the expert feedback on cases, the competitive aspect of the course, and the flexibility and manageability of the course format. One respondent indicated they appreciated that the cases covered scenarios that were less commonly considered issues in education and training.

Of the participants who did not find the course beneficial, the most commonly cited reason was that the cases were too easy. This was closely followed by respondents stating they would prefer receiving more cases.

Interview thematic review

A total of 14 participants volunteered to participate in semi-structured interviews about the Cancer Cup Challenge. Of the 14 interviewees a total of five were

Table 3 Thematic overview of cases compared to percentage of participants who answered correctly on first attempt

Case take home message	Total % correct responses on first attempt combined	Average number of attempts required to retire case	Minimum number of attempts to retire case	Maximum number of attempts to retire case
For patients at home, toxicities are serious and must be monitored and managed as closely as any reactions observed in the clinic or hospital. Ipilimumab can result in an autoimmune phenomenon that requires treatment with steroids.	64.29 %	1	1	4
Fertility preservation should be discussed with all patients of child bearing age, including sperm banking which should be offered whenever possible before a young man begins chemotherapy.	67.44 %	1	1	2
Spinal cord compression is an emergency and requires neurosurgical or radiation intervention.	71.05 %	1	1	2
Patients may not volunteer that they are not taking their medications as prescribed. Physicians should work with ancillary and nursing services to address these issues as low adherence can cause poorer clinical outcomes.	71.79 %	1	1	2
It is important for trainees to report errors that do not lead to harm as well as near misses so that we can collectively improve the safety of our systems of care. Medical errors should be disclosed to patients in a thoughtful way that involves appropriate risk management staff.	78.38 %	1	1	3
Drug/drug interactions are vital to review when prescribing oral chemotherapy. Capecitabine can potentiate warfarin levels and result in life-threatening bleeding.	78.95 %	1	1	2
Recognize the inappropriate, appropriate and required indications for use of growth factor support.	87.88 %	1	1	1
Due to the risk of life-threatening infection, it is vital to immediately treat neutropenic fever. Steroids can mask a fever so clinical judgment must be used to watch for signs/symptoms.	100 %	1	1	5

from Australia, two were from Denmark and 12 were from the United States of America. Once interviews had been conducted they were transcribed, de-identified and then content reviewed to identify key themes. A total of five broad themes emerged from the analysis: Impact of course on knowledge and confidence, enjoyment and engagement, motivation for course completion, online learning/Qstream format, and course content in general.

Of the 14 participants interviewed nine specifically commented on the level of engagement and enjoyment of the course. All of these respondents indicated that they found the course engaging and enjoyable. Three

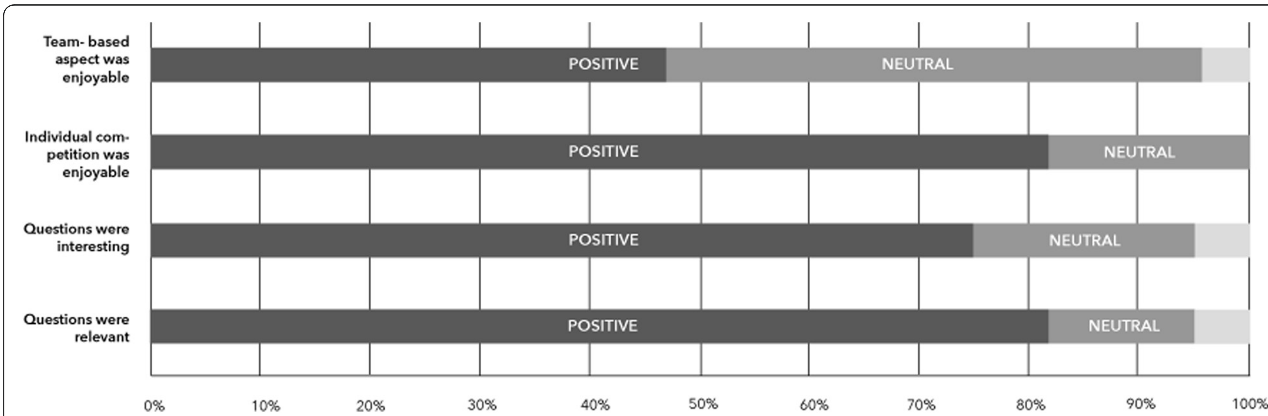


Fig. 2 A visualization of Likert responses showing participant engagement in the Qstream: Cancer Cup Challenge

participants noted that this was due to the format itself, the below being representative of these comments:

> "*It was engaging. It didn't take very long to do so it wasn't a burden.*"

A further two participants made comments stating their engagement and enjoyment of the course was linked to the content. One participant specifically noted that the Cancer Cup Challenge could have been more engaging with revised content.

The topic of motivation to complete the Cancer Cup Challenge was another theme that emerged from the analysis. Interestingly, respondents were quite divided when it came to their motivation to continue completing cases for the course. Five respondents commented that their primary driver was knowledge acquisition, or interest in the topics covered in the course. Other respondents indicated that the leaderboards and individual competition was a motivator to continue, though not necessarily the primary one.

In regard to the gamified aspect of the course and its impact on their motivation, participants held mixed views. Three respondents specifically indicated that they did not feel the team based competition motivated them to complete the course, but they didn't think it was problematic either. In contrast, another three respondents indicated they specifically liked this aspect of the course, finding competition to be a significant driver as well as the excitement of competing with teams from around the world. The below quote is representative of this:

> "I think even though we didn't know exactly who was in our team, it was still a good motivation to actually provide a little bit of excitement to the thing rather than just turning it into another exercise we had to do. I think that was certainly a good motivation to complete at least the next case. I quite enjoyed that."

It should also be noted that there was one interesting outlying response made by a participant. The participant noted that they were motivated by a desire to help evaluate an online tool which may be developed for specialist training in future:

> "Primarily it was to do you a favour in a way because the med said you wanted to develop some e-learning and I think that's very important because if you can develop some good e-earning which can be part of our specialist training that would be excellent."

Participants also had mixed responses in relation to the impact of the Cancer Cup Challenge had on their knowledge and confidence of the learning points. Several participants indicated the course increased their knowledge and confidence, or had a small impact on reinforcing their current knowledge. Only one participant felt that the course had no impact at all. However, a majority of respondents suggested that much of the case content, whilst interesting, was a little too simplistic for their current level of training. Nevertheless, most participants also rated the program as highly useful and relevant:

> "It certainly prompted me to think about some of the alternative pathways that I could've taken in each situation and why they might be incorrect or less correct and putting my own best answer into context. I found it useful from that end even though most of the questions I felt I knew exactly which answer I wanted to put down."

Of the respondents who felt the course impacted on their knowledge, the majority suggested this was because of the applicability of the cases to their clinical practice. Several respondents indicated they had dealt with situations during their training that were covered by the cases. One also added that they could easily see themselves encountering the case scenarios in practice.

Finally, two respondents noted that the course was valuable for illustrating similarities and differences in cancer care globally. One participant noted:

> "It was helpful to know that there was a shared terminology globally (across institutions). Everyone is dealing with the same problems internationally and people are working in the same framework. It was nice to see this is what everyone, everywhere is dealing with."

Interview participants frequently commented on the Qstream format, with all but one finding it appealing. Eleven respondents indicated that flexibility and the ability to answer cases at their convenience was an advantage of the platform. Four respondents made particular note of the fact they completed the course on their smart phones in between other activities. Seven participants specifically commented on the user friendly interface.

Additionally, five respondents mentioned the appeal of the way the Qstream platform disseminates cases. Several noted that the way the system prompted participants to complete cases they may have forgotten about was very useful. One respondent commented:

> "I thought it was very good that the prompt came through and it would come through again if you didn't answer the question. That kind of reminded me that the course was there because you can forget these things."

The final theme that emerged from analysis of the interviews was generalised comments about course content. Seven participants gave responses regarding content that could be included in future courses, three of whom specifically asked for more cases on chemotherapy errors, drug interactions and other issues. In addition, three respondents made general comments about the length of the course, expressing a desire for there to be more cases.

Discussion

This study demonstrated the feasibility of Qstream as a delivery vehicle for specialty-specific content in the area of safety and quality. The completion rates for the program, which was entirely voluntary, were encouraging and indicate a high level of engagement by participants in each country. This finding aligns with other studies using Qstream in the context of residency training [20]. Once again, the case-based and bite-sized nature of the program was found to be appealing to busy doctors in training. Feedback from trainees indicates that the use of oncology specific scenarios motivated participation. While this finding is perhaps not surprising, it does demonstrate that junior doctors are interested in using non-traditional training delivery methods such as online course games.

The ability of the gamification element of the program to motivate participation supports the use of friendly competition in health professional training programs and is consistent with findings in other contexts [23]. However, further research is needed to explore using this innovative approach in medical education in the clinical setting as there is no other research on the topic. This is a significant gap due to the busy schedules of health professionals and the difficulty of engaging this group in online education. Incorporation of game based approaches can be used to increase learner motivation to complete an online program, particularly if it is asynchronous, as was demonstrated in this study. The use of international competition clearly motivated a number of participants and the use of high-profile organizations in each country likely enhanced this. However, it was interesting to note that the individual competition appeared a more significant motivating factor than the international team-based competition. This indicates the value in establishing competition just at a program level to stimulate participation.

The use of doctors in training to develop the core cases in this program also provides a mechanism to meet training recommendations from organisations such as the ACGME which mandate direct engagement of residents and fellows in educational activities to enhance high quality patient care [8]. Literature shows that residents and junior doctors may perceive events and actions in unique ways due to their frequent interactions with patients. In particular they may be well suited to identifying near misses and other incidents not normally captured in current reporting structures [6]. Case-based programs in safety and quality such as Qstream engage trainees and serve as effective tools to teach critical topics such as patient safety and quality improvement.

Strengths of the study include that over 50 % of participants completed the feedback survey and 14 participants took part in semi-structured interviews allowing for further valuable assessment of the value of the program. Limitations of the study include the lack of available measures to judge impact on practice and relatively low total number of participants in the study. Although the sample size was small comparative to the number of junior doctors in the clinical setting, medical oncology junior doctors represent a sub-set of trainees which is much smaller. In this study all medical oncology junior doctors at the three sites were invited to participate in this study and there was a high participation of oncology trainees at each site. In future studies it may be beneficial to use a pre and post test approach in order to precisely measure knowledge change amongst participants. Additionally, the inclusion of more hospital sites may be a benefit in increasing the number or individuals eligible to participate in the course.

Conclusion

Qstream represents a tool that can be used by individuals and organizations to engage junior doctors in patient safety and quality improvement training. The ability of Qstream to motivate participation, combined with its previously demonstrated impact on behaviour, has implications for directors of training programs. Our findings also illustrate the benefits of tailoring content to the specialty-specific context of the trainee, as well as introducing a gamification element to enhance participation.

Ethics approval and consent to participate

Permission to conduct this study has been received from the Western Sydney Local Health District Human Research and Ethics Committee.

Availability of data and materials

Data will not be shared due to restrictions stipulated by the ethics committee that approved this study.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

TS and PH made a substantial contribution to study design, and contributed to data analysis and manuscript preparation. AJ made a substantial contribution to study design, data collection and analysis and manuscript preparation. LB, TM, AMN, JZ, JC, TR, and PS contributed to study design and manuscript preparation. All authors read and approved the final manuscript.

Acknowledgments
The authors wish to thank the program coordinators across the international sites who greatly assisted with the promotion of this program to potential study participants. Additionally, thank you to all participants in the study for volunteer ring their time to assist with this research project.

Funding
This study was financed through the Sydney West Translational Cancer Research Centre grant from the Cancer Institute New South Wales.

Author details
[1]Research in Implementation Science and e-Health Group (RISe), Faculty of Health Sciences, Sydney West Translational Cancer Research Centre, The University of Sydney, Sydney, NSW, Australia. [2]Research in Implementation Science and e-Health Group (RISe), Faculty of Health Sciences, The University of Sydney, Sydney, NSW, Australia. [3]Crown Princess Mary Cancer Care Centre, Westmead Hospital, Westmead, NSW, Australia. [4]Dana-Farber Cancer Institute, Boston, MA, USA. [5]Partners HealthCare, Boston, MA, USA. [6]Faculty of Health, Disciplines of Nursing and Midwifery, University of Canberra, Canberra, ACT, Australia. [7]Sydney West Translational Cancer Research Centre, WestmeadHospital, Sydney, NSW, Australia. [8]Western Sydney Local Health District, Westmead, NSW, Australia.

Received: 27 November 2015 Accepted: 4 March 2016
Published online: 12 March 2016

References

1. Wilson RM, Runciman WB, Gibberd RW, et al. The quality in Australian health care study. Med J Aust. 1995;163:458–71.
2. Neale G, Woloshynowych M, Vincent C. Exploring the causes of adverse events in NHS hospital practice. J R Soc Med. 2001;947:322–30.
3. Scott IA. Errors in clinical reasoning: causes and remedial strategies. BMJ. 2009;338.
4. Vincent C. Understanding and responding to adverse events. N Engl J Med. 2003;348:1051–6.
5. de Vries EN, Ramrattan MA, Smorenburg SM, et al. The incidence and nature of in-hospital adverse events: a systematic review. Qual Saf Health Care. 2008;17:216–23.
6. Jagsi R, Kitch BT, Weinstein DF, et al. Residents report on adverse events and their causes. Arch Intern Med. 2005;165:2607–13.
7. Haller G, Myles PS, Taffé P, et al. Rate of undesirable events at beginning of academic year: retrospective cohort study. BMJ. 2009;339.
8. Weiss KB, Bagian JP, Wagner R. CLER Pathways to excellence: expectations for an optimal clinical learning environment (executive summary). J Grad Med Educ. 2014;6:610–3.
9. Reed JE, McNicholas C, Woodcock T, et al. Designing quality improvement initiatives: the action effect method, a structured approach to identifying and articulating programme theory. BMJ Qual Saf. 2014;23:1040–8.
10. Graham IS, Gleason AJ, Keogh GW, et al. Australian curriculum framework for junior doctors. Med J Aust. 2007;186:S14.
11. Benstead K. What is valuable for specialist registrars to learn in order to become good consultant clinical oncologists? Clin Oncol. 2006;18:549–54.
12. Van Der Weyden MB. Challenges and change in medical training: the Australian Curriculum Framework for Junior Doctors. Med J Aust. 2007;186:332.
13. Shaw T, Barnet S, Mcgregor D, et al. Using the Knowledge, Process, Practice (KPP) model for driving the design and development of online postgraduate medical education. Med Teach. 2015;37:53–8.
14. Fischer MA, Mazor KM, Baril J, et al. Learning from mistakes. J Gen Intern Med. 2006;21:419–23.
15. Kerfoot BP, Kearney MC, Connelly D, et al. Interactive spaced education to assess and improve knowledge of clinical practice guidelines: a randomized controlled trial. Ann Surg. 2009;249:744–9.
16. Robinson T, Janssen A, Kirk J, DeFazio A, Godwin A, Tucker K, et al. New aproaches to continuing medical education: a Qstream (spaced education) program for research translation in ovarian cancer. J Cancer Educ. 2015. doi:10.1007/213187-015-0944-7.
17. Bruckel J, Carballo V, Kalibatas O, Soule M, Wynne KE, Ryan MP, Shaw T, Co JPT. Use of spaced education to deliver a curriculum in quality, safety and value for postgraduate medical trainees: trainee satisfaction and knowledge. Postgrad Med J. postgradmedj; 2015; 0:1-8.
18. Kerfoot BP, DeWolf WC, Masser BA, Church PA, Federman DD. Spaced education improves the retention of clinical knowledge by medical students: a randomised controlled trial. Med Educ. 2007;41(1):23–31.
19. Vlach HA, Sandhofer CM. Distributing learning over time: the spacing effect in children's acquisition and generalization of science concepts. Child Dev. 2012;83(4):1137–44.
20. Kerfoot BP, Baker H. An online spaced-education game to teach and assess residents: a multi-institutional prospective trial. J Am Coll Surg. 2012;214:367–73.
21. Knaving K, Björk S. Designing for fun and play: exploring possibilities in design for gamification. Proceedings of the First international Conference on Gameful Design, Research and Applications. 2013. p. 131–34.
22. Worm BS, Buch SV. Does competition work as a motivating factor in E-learning? A randomized controlled trial. PloS one. 2014;9, e85434.
23. Papastergiou M. Exploring the potential of computer and video games for health and physical education: a literature review. Comput Educ. 2009;53:603–22.

Janssen et al. BMC Medical Education (2015) 15:173
DOI 10.1186/s12909-015-0455-6

BMC Medical Education

RESEARCH ARTICLE Open Access

A little healthy competition: using mixed methods to pilot a team-based digital game for boosting medical student engagement with anatomy and histology content

Anna Janssen[1*], Tim Shaw[1], Peter Goodyear[2], B. Price Kerfoot[3] and Deborah Bryce[4]

Abstract

Background: Digital games have been demonstrated to be beneficial for a range of non-recreational purposes, with a particular focus on their value for education. There is a limited amount of research supporting their use for medical education, but their are several studies on their use in areas such as surgical training, and life-support re-training. However, a significant gap exists in demonstrating how they engage with learners and games can be used most effectively in medical education. This pilot study assessed the value of digital games for teaching anatomy, by evaluating participant engagement and their attitudes towards a team-based strategy game.

Methods: A digital game platform was designed, and then populated with anatomy questions developed by subject matter experts. Second year medical students were recruited to play three matches of the game. At the end of each match participants were asked to complete a Likert rating of their experiences of the game across five domains. Semi-structured interviews were conducted to assess engagement with the platform and perceived value to learners.

Results: Sixteen participants volunteered to participate. Post-match ratings indicated that participants had a generally positive experience with the game, with 89 % of respondents agreeing the game was engaging, 93 % of respondents agreeing the game was challenging and 74 % indicating they would like to play the game again if given the opportunity.

A total of fourteen participants agreed to be interviewed after playing three matches of the game. Interview responses supported the findings of the post-match ratings that the game was considered enjoyable and engaging. Participants noted they particularly enjoyed the competitive aspect of the game, particularly the opportunity to play against peers they consider their academic equals.

In addition to finding the game engaging interview participants indicated they perceived the game impacted on their knowledge around anatomy. In particular, participants noted that the game provided them unique insight into their knowledge strengths and deficits.

Conclusions: This study demonstrated that digital games can engage medical students in traditionally-challenging areas such as anatomy and offer learners unique insights into their knowledge strengths and deficits.

* Correspondence: anna.janssen@sydney.edu.au
[1]Research in Implementation Science and e-Health Group (RISe), Faculty of Health Sciences, The University of Sydney, Sydney, NSW 2006, Australia
Full list of author information is available at the end of the article

Background

This paper describes a pilot study of the online team-based strategy game They Know: Anatomy. The aim of the pilot was to explore how medical students interact with the game and each other, including how they experienced the challenge, level of competitiveness, engagement, enjoyment and their desire to replay the game. It provides preliminary data on the power of games to motivate ongoing learning in a topic considered by many students to be difficult and hard to learn.

The use of digital games for non-recreational purposes is an important area of research for health educators today. It is also an area of research that has been gaining attention in the broader educational literature, with multiple studies exploring the value of digital games in areas such as developing spatial visualization skills and improving memory retention [1–3]. Much of this research has focused on demonstrating whether games can be used by educators as effective learning tools, particularly in primary and secondary education [4]. As a result there is currently a significant amount of research suggesting video games can be used productively for education: whether they can be tailored to teaching specific learning objectives, and the type of games best suited to doing so, awaits further study.

In general, the educational research community has moved away from demonstrating whether games can be used to increase knowledge, towards investigating how and why they do so [5]. However, within the health sector a significant amount of the literature continues to focus on whether digital games can improve knowledge at all. To date, the benefits of digital games has been successfully demonstrated in areas as broad as life support retraining [6], pediatric training [7], and surgical skills development [8]. A smaller portion of the literature has looked at more divergent themes such as the role of digital games in assisting mental preparedness [9]. However, further research is warranted into how to effectively utilise digital games in health education and how such tools engage learners.

In medical education core subjects like anatomy may benefit from the targeted adoption of technology-based learning tools such as digital games. Anatomy is considered a challenging subject for medical students to learn due to the complexity of the subject [10], and the breadth of the medical curriculum [11]. The literature suggests that other problems in effectively learning anatomy may include finding the topic stressful, struggling to understand the complexities of the subject and lack of confidence with the material [12, 13].

In spite of this, there appears to be no literature on the use of digital games to teach anatomy in medical education. There is one study that used a board game to encourage collaborative learning and reduce loss of confidence and concentration with medical students learning anatomy [10]. Additionally a card game was used to help reinforce content from lectures for optometry students learning anatomy [14]. Both studies were able to demonstrate playing the game resulted in a significant knowledge improvement in participants when results of a pre-test were compared to those of a post-test. Participant surveys were then used to demonstrate each games value for engaging with students and fostering collaboration amongst learners.

They Know: Anatomy is an adaption of the They Know platform for anatomy and histology. They Know is an online platform that allows educators to build team-based strategy games to support a range of curriculums. The team-based digital strategy game genre (typically) involves short-duration games in which two teams compete to meet a clear winning goal, usually over multiple matches [15]. These games are distinctive in that they cross a wide range of settings; as a result, they are able to appeal to a broad demographic of players [15]. Although research has begun to explore commercial digital games in the team-based strategy genre [16, 17], their use in medical education has not been investigated.

The focus of this study was on how players interacted with each other and how this impacted on engagement with the platform. Additionally, metrics collected by the game platform were reviewed to determine if there was an increase in the number of questions participants answered correctly across two game matches. Demonstrating a knowledge change is always important, but it is difficult to replicate the benefits of a digital game in different learning contexts without an understanding of the how and the why they are useful educational tools. It is particularly important for health educators to have information on how digital games help learners structure and enhance their knowledge, so they can successful implement them in their specific training context.

This pilot study aimed to explore how team-based digital games allowed learners to explore their existing knowledge of anatomy and histology. It also investigated how this medium was able to support team-based learning and support participant engagement with the anatomy and histology content.

Methods

Our research study used a mixed methodology to explore the way player-player and player-platform interaction occurs in the context of an educational digital game. Our qualitative methods included self-administered participant engagement surveys, video recorded observations and semi-structured interviews. Quantitive data included metrics collected by the digital game platform on accuracy of responses to anatomy content.

Development of the game

They Know is a platform designed for the creation of team-based strategy games in an educational setting and can be used for a variety of educational disciplines. In this study the game platform was used to develop a game, called They Know: Anatomy, to support an anatomy curriculum for medical students at The University of Sydney.

The aim of any They Know game is to encourage co-operation between team mates to develop and implement a strategy to take control of the opposing teams home base. [Refer to Fig. 1 for a brief overview of game rules] [Refer to Figs. 2, 3, 4 for screenshots of the game interface] Developing a game in the platform involves distributing knowledge across a game map in a network, with each node in the network containing a set of multiple choice questions relating to a specific course objective or curriculum area.

Players start at their team's home node, which is fully controlled by their team. When a player clicks on their current node, a question from the node's question set is drawn randomly and posed to them. Every question has the same chance of being drawn. When a player correctly answers a question from a node connected to a node controlled by their team, the player gains more influence of their node for their team, and decreases that of their opponents. When enough influence has been gained, the node becomes controlled, turning fully blue. Players in that team can then try to take control of a neighbouring node. The first team to control their enemy's home node wins the game.

An independent game designer developed the platform They Know over a period of twelve months. A representative of the research team met frequently with the designer to gain insight into the development process of

Goal: To win the game by either taking control of the opposing teams 'home base' OR 'controlling the most territory at the end of the game.

Players: In and ideal set up there will be eight players, with four players divided between two teams.

Basic Rules*:*

1) *The game is played on a* ***map****, with points* ***(nodes)*** *on the map representing* key learning objectives or curriculum points, and with paths connecting them.

2) Each team has a home node, at opposing ends of the map, indicated by a capitol star. The player's team is always blue, the enemy is always red.

3) A player is always at a node. They can move to any node connected to their present one, provided they are not being attacked and have not too recently moved.

4) One team may have influence over a node. A node starts as **neutral**, and as influence increases becomes **controlled** and then **aggressive**. At the start of the game, the home nodes are aggressive, influenced by their respective teams, while all others are neutral.

5) Nodes contain questions related to the topic they represent. A player may **explore** the node their avatar inhabits to be attacked with one of these questions.

6) An **aggressive** node will automatically attack enemy players at that node.

7) Correctly answering a node's question will increase the influence of the node in the player's team's favor, but *only* if it is connected to another node **controlled** by that team.

8) Players have a **collection** of questions. Whenever they are attacked by a new question, their collection gains a copy of that question.

9) Players have a **hand** of questions, randomly drawn from their collection. Players may choose to attack, with any question in their hand, any other players at the same node as them.

10) When a player fails to correctly answer a question by an enemy or a node that is not controlled by their team, they lose **health**.

11) Correctly answering a question from a teammate heals lost health.

12) If a player loses all their health, they '**die**': the player is removed from the map, their health resets, and after a brief period of self-reflection they re-appear at their home node.

Fig. 1 A summary of the goal of They Know, the basic rules of play and the standard number of participants per game

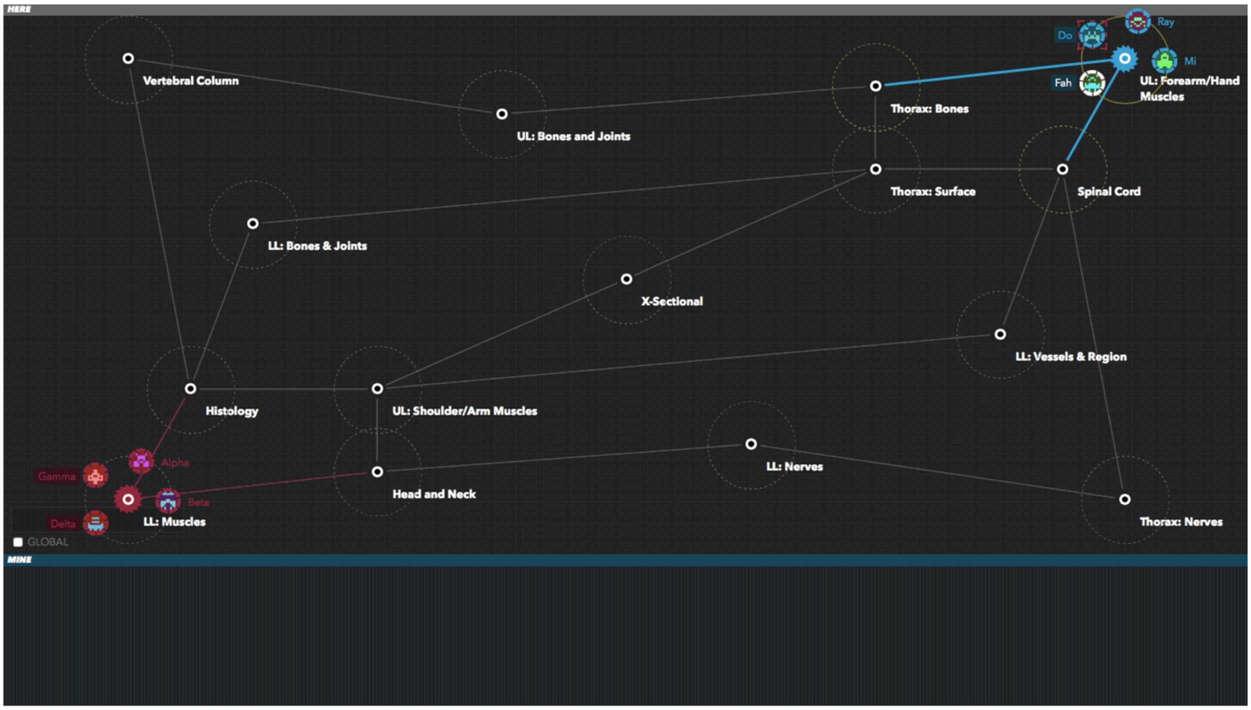


Fig. 2 Starting screen of the game showing both teams avatars in their respective home bases. One team is represented by the blue indicator in the upper right corner, and the other as the red avatars in the lower left corner. As neither team controls any nodes on the map they all appear as white, meaning they are neutral

the game platform and how it could be used effectively for developing the anatomy game. These meetings also provided opportunities for researchers to give pedagogical input into the game platform design during the development process.

Although the game can be populated with any educational topic the research team focused on anatomy. Content developers were identified from within the medical faculty at The University of Sydney to develop anatomy content for the digital game. Based on their advice, it was decided that game content would cover first year anatomy and histology knowledge in order to help students revise for their examinations in mid 2014. All content was developed, reviewed and input into the digital game They Know: Anatomy by the end of February 2014, with the aim of piloting the game by the end of March 2014. Fifteen curriculum nodes were included in the game and the content experts created ten to twenty multiple choice questions for each curriculum node. There were 240 questions in total across all nodes. [Please refer to Figs. 2, 3 and 4 for screenshots of the game].

Once the game was designed and the content had been finalized the research team decided on the placement of the curriculum nodes for the final anatomy game map. The development of this map was undertaken over several weeks and required multiple revisions to determine a layout that would encourage players to explore the maximum amount of curriculum nodes.

Piloting the game

Second year medical students were recruited in February 2014 to participate in the study. Prior to completing a session with the game pilot participants were asked to complete a brief online survey to obtain baseline data on their level of experience with commercial video and computer games, as well as exposure and experience with educational games.

After completing the baseline survey, the participants were asked to play a game session. Each session consisted of three one-hour matches of They Know: Anatomy at spaced intervals of at least three days. Participants were allocated to play in a team of four, which remained the same across all three sessions. The matches were spaced an repeated at the specified interval to increase the likelihood of co-operation between the four player teams. The first match was designed to give players an opportunity to familiarise themselves with the rules of play and the game system. The second match was designed to increase team interaction as they players got to know each other. Finally, the third match

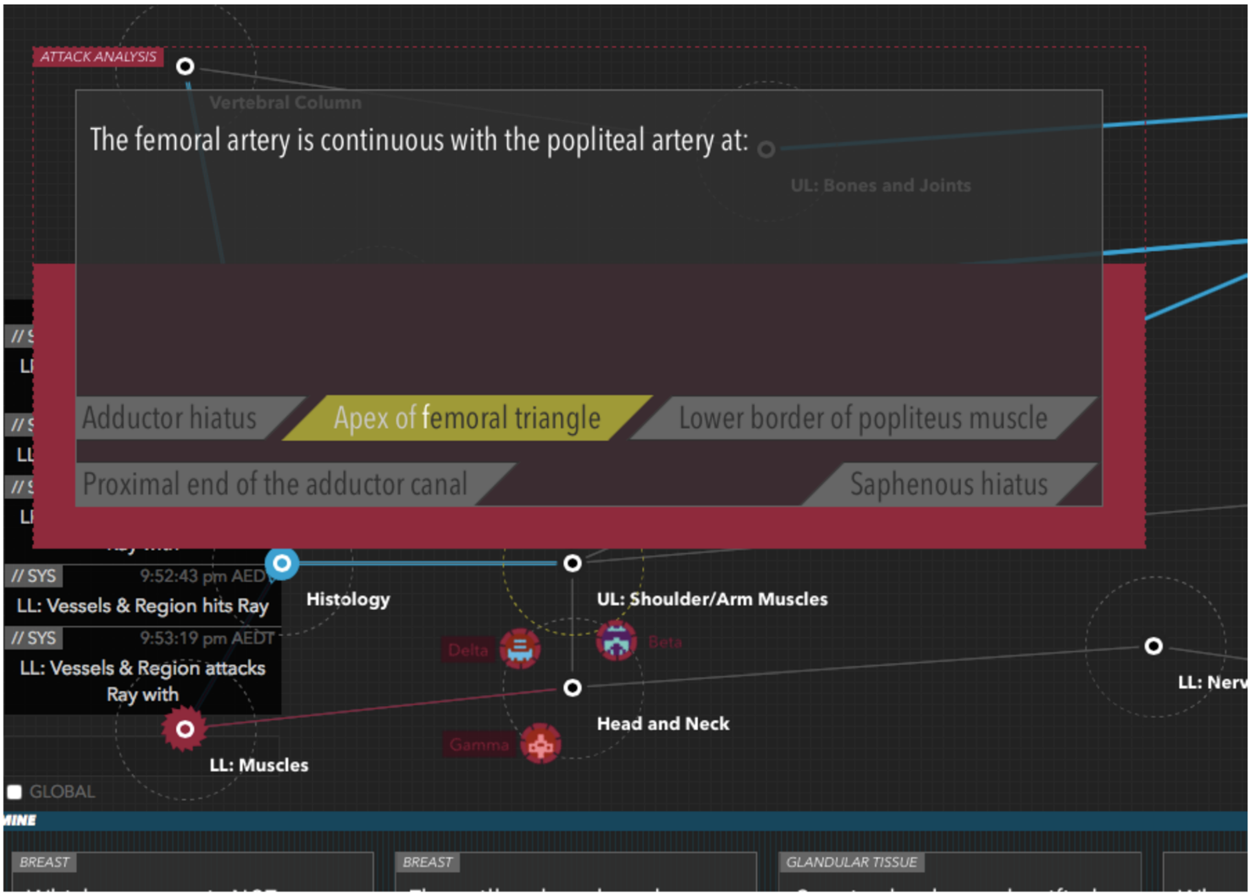


Fig. 3 Players answer multiple choice questions on a learning objectives at each node. This figure shows the question interface for text-based questions. The red timer fills in the background whilst the player chooses a response. As they type their response the answer they have selected will begin to highlight

was designed to have optimal balance of player familiarity with the game system and with team mates, resulting in collaborative team play.

During the pilot period, two game sessions consisting of three matches each were run: session A (March) and session B (August). Session A (March) was assigned a random cohort of eight participants who were then divided into two four player teams. A different group of eight participants was assigned to participate in Session B (August) and divided into two even teams as had been done during the prior session.

Participants undertook the sessions in computer labs on the University of Sydney campus, which were equipped with iMac desktop computers. Each player was given access to their own iMac computer in the computer lab which was equipped with an internet connection and a web browser, allowing participants access to the digital game which was hosted online. Each team was in the same computer lab as their other teammates but in a different computer lab to the opposing team. Players could move as individuals, controlling their own player avatar using a computer mouse to interact with nodes and access the multiple choice questions. However, in order to effectively cross the whole game map team mates had to work co-operatively and verbally communicate to coordinate their individual movements to achieve the shared goal of capturing the opposing team's base.

Data collection and analysis

During the matches, a video camera was set up in each of the two computer labs to record player-player interactions. Additionally screen capture software was running on each participants computer to recorded individual player-computer interaction. A session coordinator was present in both computer labs whose primary role was to provide technical support, but also to take field notes.

At the end of each match, participants were asked to complete a paper-based Likert ranking of the match.

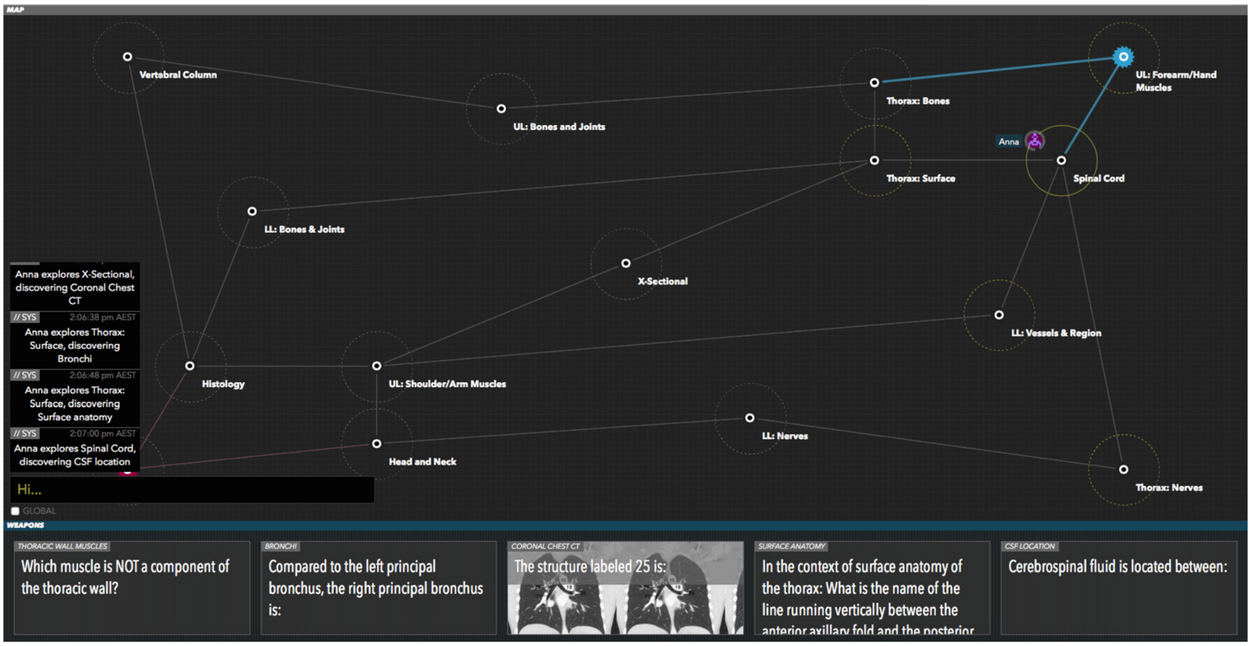


Fig. 4 The player 'Anna' is exploring the Spinal Cord node. The blue lines show the line of control from the player's home base to the node being explored. At the bottom of screen the player's hand can be seen, made up of five random cards they have collected across from the map

The Likert ranking asked participants to score their gameplay experience after each match across five domains: challenge, competitiveness, engagement, enjoyment, and replay likelihood. The Likert ranking ran from 1 to 6, with 6 indicating the most positive response and 1 the least positive. Scores from 1–2 were aggregated to determine the level of negative response to the game, scores from 3–4 were aggregated to determine a neutral response and scores from 5–6 were aggregated to determine positive response toward the game. Responses from all the pilot sessions were aggregated and compared across all matches in order to evaluate whether attitudes towards the domains varied across matches.

Within four weeks of completing the pilot sessions all participants were asked to participate in semi-structured interviews about their experiences with They Know: Anatomy. The semi-structured interview questions schema consisted of the following ten prompts:

1. Would you describe yourself as an experienced video game player?
2. Do you have any experience playing games you would consider educational at all? What was your view of them?
3. To what extent do you find anatomy a challenging subject?
4. How would you describe your experiences with the anatomy game you played?
5. What about this game did you find the most engaging?
6. Could you describe anything you disliked about the game?
7. How did you find the collaborative aspect of this game?
8. Did you seek advice from team mates when you were unsure how to answer a question/did you support them when they were trying to decide where to go?
9. Has playing the game impacted on how confident you feel in your understanding of anatomy?
10. Would you recommend playing the game to one of your peers?

All interviews were transcribed, de-identified, and then thematically reviewed. The review was structured to determine level of engagement participants felt playing the game and their perceived value of it as a knowledge dissemination tool.

Metrics collected by the game platform were analysed to determine the number of questions participants answered correctly across at least two matches. The number of correct answers was compared across the matches to determine a percentage change in the number or correct answers for each participant. An average was taken of the percentage change for all participants across the two matches to determine if participants increased the number of correct responses, decreased them or if response accuracy remained neutral between matches. Data was compared across only two of three matches to comply with ethics, which required participants to be given the opportunity to withdraw from the sessions early without feeling coerced. By comparing data across only two matches it was possible to comply with this requirement and still be able to use the comparison data.

Permission to conduct this study was received from the University of Sydney's Human Research and Ethics Committee.

Results

The demographic breakdown for the 16 participants was 13 male (81 %) and 3 female (19 %). A total of 15 participants responded to the preliminary survey with 7 (47 %) indicating they identified as experienced video game players, 4 (27 %) indicating the considered themselves occasional video game players and 4 (27 %) indicating no video game experience. In regards to exposure to educational games 6 (40 %) respondents indicated exposure to a small number of educational video games in primary and high school, and 9 (60 %) respondents did not recall ever playing an educational video game.

The first match of pilot session A (March) ran for just under two hours, so almost a whole hour over the one our time allotted, which was an unexpected outcome. When prompted by the session coordinator to end the session at the allotted time participants commented they were having so much fun playing they did not wish to end the session, noting that they wanted to wait until someone won the game. Participant reluctance to leave the session at the end of the hour was considered a demonstration of their engagement with the game system. As a result of this outcome a change was made to the system for subsequent matches: a timer function was added which declared a winner after a set time based on which team controlled the most territory. This was a significant change to the win conditions for the digital game.

In spite of the changed win conditions there was no observed decline in player engagement during subsequent pilot matches, as measured by observed verbal interactions between team mates. However, these same observations suggested participants seemed to find it less satisfying to win based on territorial control at the end of a timed period than by capturing the opposing team's home base. Interestingly, the changed win condition did result in the players spreading out across the map more and covering more curriculum nodes, as the number of nodes they controlled would now determine if they won or lost.

At the conclusion of each match participants were asked to complete a Likert rating of various aspects of the game, with the scale using 1 to represent least agree and 6 to represent most agree. Responses from all three matches of Session A (March) and Session B (August) were combined in order to get an overall impression of how players found the game. The ranking looked at how challenging the participants found the game content, how competitive they found the game, how engaging, how enjoyable and finally their desire to play the game again.

The vast majority of participants rated the game extremely positively, with 93 % agreeing the game was challenging, 89 % agreeing the game was competitive, 89 % agreeing the game was engaging, 73 % agreeing the game was enjoyable and 74 % indicating they would like to play the game again if given the opportunity. Although there was no comment section on the evaluation page several participants who rated the game at the lower end of enjoyment or engagement stated at the end of the match this was due to technical difficulties with the computers. Technical difficulties occurred due to the age of the computers, meaning that some computers created a 'lagging' effect which delayed the timers on multiple choice questions. This issue resulted in some questions being answered incorrectly due to the timer malfunctioning, but these questions were removed from the data set prior to analysis. [Please refer to Fig. 5 for visualization of Likert responses].

In addition to collecting data on how participants perceived the game, the research team also wanted to collate more objective data on the games impact on player knowledge retention across a spaced interval. In order to do this participant data collected by the game system across two matches was analyzed, to determine if there was a change in the number of questions participants answered correctly between the first and second match. When the number of questions players answered correctly across two matches was compared it was shown that, on average, players answered 11 % more questions correctly during the second match than the first. The standard deviation for this comparison was 11, with a range of −5 % to 30 %.

Three participants answered fewer questions correctly during the second match, with a decrease in accuracy of 5, 4 and 3 % in this group. However, the majority of participants ($n = 12$) showed an increase in response accuracy, with a minimum improvement of 3 % and a maximum of 30 %.

On average players visited 6.3 nodes in each match, revisiting an average of 4.8 nodes on subsequent replays. Participants encountered an average of 65 questions in a match, with a range from 20–115 questions encountered by each participant.

Data was also collected on the proportion of the match participants spent at each node. Matches were forty minutes in duration, with participants spending 2 min and 21 s of each match at a node (6 %). The

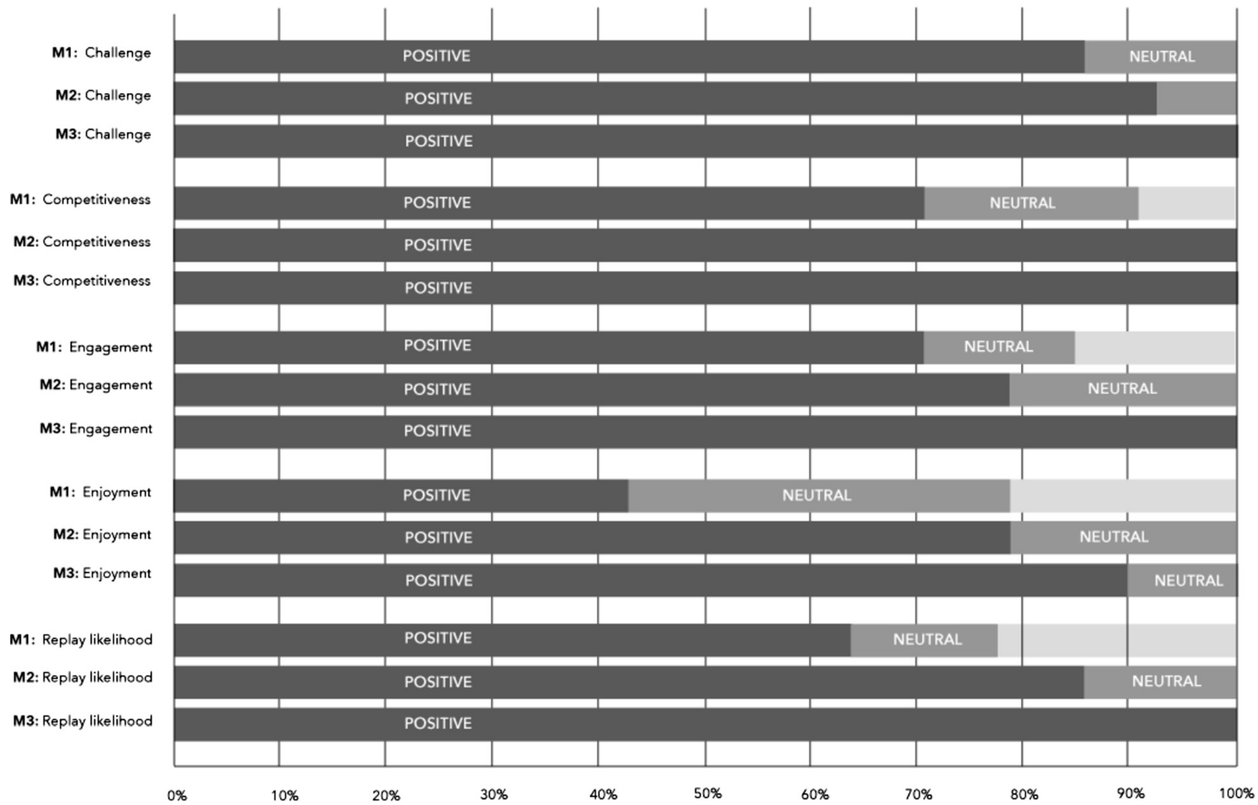


Fig. 5 Details of the Likert scale responses compared three matches, aggregated across both sessions. Participants were asked to rate their experience of each gameplay session across the five domains shown ($n = 16$)

minimum average time spent on a node was 39 s (1 %) and the maximum was 4 min and 33 s (11 %).

A total of 14 participants agreed to be interviewed after playing the game. Each interview was de-identified and then thematically reviewed. The final thematic analysis revealed several key themes including engagement with the game platform, using digital games as a tool for exploring the limits of knowledge and peer collaboration as vehicle for knowledge retention.

In regards to their general experiences playing the digital game, all participants indicated they found the game engaging and enjoyable. Participants particularly emphasized the impact having a challenge had in helping them engage with the game, both the challenge of playing against peers they considered their equals and the challenge level of the questions encountered in the game.

> "It was fun, especially since we got to verse each other in teams. The competitive aspect of it was really entertaining… and, I think, because we all want to do well it was good motivation."

Participants were specifically asked about the collaborative aspect of the game. Several aspects of the collaboration appealed to participants, including how the team based game created common ground for interactions with fellow students after the game. In addition players suggested that collaboration made the game more exciting and rewarding. Finally collaboration provided players with an opportunity to expand their knowledge by drawing on the knowledge of their peers to move forward in the game.

> "We didn't know certain questions and we'd consult with each other. And that came up spontaneously and it was quite fun. The sharing of knowledge… when someone helps you to clarify content, I thought that was quite fulfilling."

Finally, participants were asked about whether they perceived playing the game impacted on their knowledge around anatomy. Almost all participants felt that playing the game impacted on their knowledge of anatomy, with several interviewees suggesting the game gave them a better understanding of their knowledge strengths and deficits. Generally participants felt that playing the game improved their confidence around the aspects of anatomy covered by the game.

> "I thought it was really good in that it helped me to um, get more of a breadth of revision rather than just

focusing on one thing at a time. And it was a good test as well."

Discussion

The results of this study suggest using a digital game can be a valuable tool to support medical student engagement with anatomy and histology content. This finding is consistent with the literature on digital games and their use as a tool for fun and engagement in education [1], as well as a valuable tool for medical education [2]. In the context of this study participants indicated they particularly enjoyed collaborating with their peers in teams. Additionally, the opportunity to compete against other medical students to win the game added an element of challenge that participants found rewarding and a motivating way to cover anatomy content. These findings build on previous research regarding the value of games to motivate medical students learning anatomy [10], by demonstrating engagement can be achieved not just with a real-world game but with a digital game.

Many studies have demonstrated digital games can disseminate knowledge as effectively as other formats and in some instances better [2, 3]. Some studies with medical students suggest that an online spaced education game can support knowledge gains [18]. In this study the data suggests that team based strategy games may help students to reinforce or increase their knowledge in the area of anatomy across two sessions. Although preliminary data from this study appears promising, the sample size of sixteen only allows us to draw preliminary conclusions. A larger study population would be required to evaluate the impact of the anatomy game on reinforcing player knowledge.

Feedback from the semi-structured interviews suggests that the game may offer learners and educators a unique means of gaining insight into the knowledge strengths and deficits of their students. This outcome was not anticipated by the research team, particularly the finding that participants found the game an unexpected tool for reflecting on the limits of their anatomy knowledge. This finding would benefit from further research into how learners might effectively integrate such a tool to enhance their revision schedules. Finally, future research is warranted into how the data collected by this style of game system could be used to impact on a curriculum.

Digital games may provide a valuable tool for educators to cost effectively integrate a novel teaching approach into their classroom to engage with learners. More research is needed to explore how digital games can be incorporated effectively into an educational curriculum, but growing data suggests they are an effective tool for engaging with learners and effectively disseminating new knowledge and will become more so in the future. Comments by participants that the digital game encouraged team work and collaboration outside of the game itself also warrants further investigation.

Limitations

This study demonstrates that digital games can offer learners a unique means of exploring their own knowledge deficits and strengths in a timely manner. It appears that the medium is an appealing and engaging tool for many learners, especially when players can work in teams to achieve shared goals. Finally, there are traits inherent to digital games that may offer a tool for medical educators to motivate students to engage with complex curriculum areas such as anatomy.

Conclusion

This study demonstrates that digital games may offer learners a unique means of exploring their own knowledge deficits and strengths in a timely manner. Additionally, it appears the medium is an appealing and engaging tool for many learners, especially when players can work in teams to achieve shared goals. Finally, there are traits inherent to digital games that may offer a tool for medical educators to engage students with complex curriculum areas such as anatomy.

Competing interests

The authors have no competing interests to declare.

Authors' contributions

AJ made a substantial contribution to study design, data collection and analysis and manuscript preparation. TS and PG contributed to study design and manuscript preparation. PK contributed to data analysis and manuscript preparation. DB contributed to content development for the game platform and manuscript preparation. All authors read and approved the final manuscript.

Acknowledgments

Thank you to Leon Spencer who designed and developed the platform They Know. Leon provided ongoing technical assistance to the research team throughout the pilot study period, as well as providing considerable technical detail on the platform for inclusion into the final manuscript. Additional thanks go to Michelle Gerke, John Mitrofanis, and Suzanne Ollerenshaw for volunteering their time to develop the content. In addition thank you to Charlotte Pointeaux for assisting in the coordination of study sessions and to Tracy Robinson for ongoing support and advice. Finally, thank you to all the study participants for giving up their time.

Author details

[1]Research in Implementation Science and e-Health Group (RISe), Faculty of Health Sciences, The University of Sydney, Sydney, NSW 2006, Australia. [2]Centre for Research on Computer Supported Learning and Cognition (CoCo), Faculty of Education and Social Work, The University of Sydney, Sydney, NSW 2006, Australia. [3]Surgical Service, Veterans Affairs Boston Healthcare System, Harvard Medical School, Boston, MA, USA. [4]Discipline of Anatomy, Sydney Medical School, The University of Sydney, Sydney, NSW 2006, Australia.

Received: 16 June 2015 Accepted: 30 September 2015
Published online: 12 October 2015

References

1. Griffiths M. The educational benefits of videogames. Educ Health. 2002;20(3):47–51.

2. Tsai CW, Fan YT. Research trends in game-based learning research in online learning environments: A review of studies published in SSCI-indexed journals from 2003 to 2012. Br J Educ Technol. 2013;44(5):E115–9.
3. Egenfeldt-Nielsen S. Overview of research on the educational use of video games. Digital kompetanse. 2006;1(3):184–213.
4. De Aguilera M, Mendiz A. Video games and education - Education in the face of a "Parallel School". Computers in Entertainment. 2003;1(1):1-14.
5. Squire K. Changing the game: What happens when video games enter the classroom. Innovate: J Online Educ. 2005;1(6).
6. Sward KA, Richardson S, Kendrick J, Maloney C. Use of a web-based game to teach pediatric content to medical students. Ambul Pediatr. 2009;8(6):354–9.
7. Mann BD, Eidelson BM, Fukuchi SG, Nissman SA, Robertson S, Jardines L. The development of an interactive game-based tool for learning surgical management algorithms via computer. Am J Surg. 2002;183(3):305–8.
8. Hedman L, Schlickum M, Felländer-Tsai L. Surgical novices randomized to train in two video games become more motivated during training in MIST-VR and GI Mentor II than students with no video game training. Stud Health Technol Inform. 2012;184:189–94.
9. Lin CC, Li YC, Bai YM, Chen JY, Hsu CY, Wang CH, et al. The evaluation of game-based e-learning for medical education: a preliminary survey. In: AMIA Annual Symposium Proceedings. Bethesda, USA: American Medical Informatics Association; 2005. p. 1032.
10. Anyanwu EG. Anatomy adventure: a board game for enhancing understanding of anatomy. Anat Sci Educ. 2014;7(2):153–60.
11. Ellis H. Teaching in the dissecting room. Clin Anat. 2001;14(2):149–51.
12. McKeown PP, Heylings DJA, Stevenson M, McKelvey KJ, Nixon JR, McCluskey D. The impact of curricular change on medical students' knowledge of anatomy. Med Educ. 2003;37(11):954–61.
13. Jones DG, Harris RJ. Curriculum developments in Australasian anatomy departments. Clin Anat. 1998;11(6):401–9.
14. Choudhury B, Gouldsborough I, Gabriel S. Use of interactive sessions and e-learning in teaching anatomy to first year optometry students. Anat Sci Educ. 2010;3(1):39–45.
15. Guo Y, Shen S, Visser O, and Iosup A. (2012, October). An analysis of online match-based games. Haptic Audio Visual Environments and Games. 2012 IEEE International Workshop.
16. Siu K, Zook A, Riedl MO. Collaboration versus competition: design and evaluation of mechanics for games with a purpose. In: Proceedings of the 9th International Conference on the Foundations of Digital Games. 2014.
17. Pobiedina N, Neidhardt J, Del Carmen Calatrava Moreno M, Grad-Gyenge L, Werthner H. On Successful Team Formation: Statistical Analysis of a Multiplayer Online Game. In Business Informatics (CBI). 2013 IEEE 15th Conference.
18. Kerfoot BP, Baker H, Pangaro L, Agarwal K, Taffet G, Mechaber AJ, et al. An online spaced-education game to teach and assess medical students: a multi-institutional prospective trial. Acad Med. 2012;87(10):1443–9.

Protocol

Using Video Games to Enhance Motivation States in Online Education: Protocol for a Team-Based Digital Game

Anna Janssen[1], BA, MA; Tim Shaw[2], BSc (Hons), PhD; Peter Goodyear[3], BSc, DPhil, FCIPD

[1]Sydney Medical School, University of Sydney, Sydney, Australia

[2]Research in Implementation Science and eHealth Group, Faculty of Health Sciences, University of Sydney, Sydney, Australia

[3]Centre for Research on Computer Supported Learning and Cognition, Faculty of Education and Social Work, University of Sydney, Sydney, Australia

Corresponding Author:
Anna Janssen, BA, MA
Sydney Medical School
University of Sydney
Level 2, Charles Perkins Centre D17
University of Sydney
Sydney, 2006
Australia
Phone: 61 02 9036 9406
Fax: 61 02 9351 6646
Email: anna.janssen@sydney.edu.au

Abstract

Background: Video and computer games for education have been of interest to researchers for several decades. Over the last half decade, researchers in the health sector have also begun exploring the value of this medium. However, there are still many gaps in the literature regarding the effective use of video and computer games in medical education, particularly in relation to how learners interact with the platform, and how the games can be used to enhance collaboration.

Objective: The objective of the study is to evaluate a team-based digital game as an educational tool for engaging learners and supporting knowledge consolidation in postgraduate medical education.

Methods: A mixed methodology will be used in order to establish efficacy and level of motivation provided by a team-based digital game. Second-year medical students will be recruited as participants to complete 3 matches of the game at spaced intervals, in 2 evenly distributed teams. Prior to playing the game, participants will complete an Internet survey to establish baseline data. After playing the game, participants will voluntarily complete a semistructured interview to establish motivation and player engagement. Additionally, metrics collected from the game platform will be analyzed to determine efficacy.

Results: The research is in the preliminary stages, but thus far a total of 54 participants have been recruited into the study. Additionally, a content development group has been convened to develop appropriate content for the platform.

Conclusions: Video and computer games have been demonstrated to have value for educational purposes. Significantly less research has addressed how the medium can be effectively utilized in the health sector. Preliminary data from this study would suggest there is an interest in games for learning in the medical student body. As such, it is beneficial to undertake further research into how these games teach and engage learners in order to evaluate their role in tertiary and postgraduate medical education in the future.

(JMIR Res Protoc 2015;4(3):e114) doi:10.2196/resprot.4016

KEYWORDS

digital games; medical education; online learning

Introduction

Video and Computer Games for Educational Purposes

Over the last three decades, researchers have begun investigating how video and computer games can be utilized for nonrecreational activities such as rehabilitation, memory retention, and education [1]. The growing research interest into serious applications for digital games coincides with the rise of the "digital age," from the mid to late 1980s onward, during which time video and computer games have evolved from existing predominantly in the domain of hobbyists into a widespread activity in contemporary society [2].

Within the field of digital game studies, a considerable amount of research has been conducted into the use of games in education [3,4]. This research has often focused on demonstrating whether games can be used for educational purposes for primary and secondary learners, with considerably less research into their use for tertiary and postgraduate education. The literature is sparser in relation to the application of digital games for continuing professional development and lifelong learning.

Current research suggests that digital games can be used effectively for educational purposes, but whether they can be tailored to teaching specific learning objectives, and the type of games best suited to doing so, remains unanswered. However, the 2014 Horizon Report [5] identified game-based learning as an area that is likely to have a major impact on learning in the next 2 years. The finding of this report is indicative of the growing interest in using digital game technology more effectively in education.

Using Digital Games for Education Effectively

As research in this area moves forward, it is important to begin exploring what is unique about the educational experience provided by digital games compared to other educational approaches, and when and how they can be effectively utilized within a curriculum. This gap has been identified in the literature and there is a suggestion that to address it in the future, researchers need to explore the nature of the game play experience and how the player and platform interact, rather than focusing on one or the other [6].

In the area of medical education, digital games have been applied in certain formats for several decades [7]. The health sector, alongside the fields of aviation and military training, was one of the first fields to adopt a specific type of digital game for education training simulators, which began being used in health in the mid-1990s [8]. More recent research has explored the use of digital games as tools for patient education in areas such as childhood diabetes management [9]. Researchers have also demonstrated that digital games can have a positive effect for training health professionals, with a considerable interest in the medium as a tool for reducing the learning curve for surgeons [10].

There is also some suggestion in the literature that digital game-based learning may compliment the problem-based learning approach currently utilized in medical education [4]. This finding suggests there may be a role for digital games to play in postgraduate medical education in some areas. Digital games may also prove a useful tool for engaging learners in subjects that prove time intensive or contain unique concepts, terminology, or are difficult to recall. Anatomy and histology education is one such subject, with the literature indicating that retaining knowledge is considered a significant challenge for learners of the subject [11]. Additionally, anatomy content can be difficult to internalize and contain terminology learners find hard to retain [12]. Although few digital games have been utilized to teach anatomy, a nondigital card game was used to help reinforce content from lectures for optometry students learning anatomy [13]. Additionally, a study evaluated the use of a board game in a cohort of medical and dental students, and successfully demonstrated improved attitudes and perceptions toward their learning of anatomy, as well as anatomy test scores of study participants [14].

This protocol describes a study into the use of a team-based strategy game for medical education, with a particular emphasis on tertiary and postgraduate level training. The study aims to explore the player-platform and player-player interaction of an online, team-based, digital game, with the aim of identifying how digital games can be used as effective educational tools for maximum knowledge coverage. A secondary goal of the study is to evaluate the role of digital games as revision aids for adult learners and to help them assess the limits and strengths of their existing knowledge.

The use of digital games to teach adult learners is an important area for study, as the demographic has largely been overlooked in the literature thus far. In the context of adult education, there are several aspects of video and computer games that may prove valuable, but are as yet unexplored. A core element that has been researched in the field of games studies, but not significantly in educational game studies, is how players interact when playing collaborative video and computer games, a mode which has become popular in the last decade, and its impact on player engagement [15]. Educational researchers have yet to thoroughly explore these collaborative game interactions in the context of educational engagement, or in the context of existing research conducted into collaboration in education [16], but such research suggests that the collaborative and competitive elements of video games may be a core engagement element.

Methods

Primary and Secondary Study Outcomes

This research study uses a mixed methodology to explore the way player-player and player-platform interaction occurs in the context of educational digital games. The primary outcome of the study is to evaluate how a digital game supports player engagement, particularly its value for encouraging cooperative review of player knowledge in a specific content domain. The secondary outcome is to evaluate the impact of the game platform as a tool for adult learners to individually assess their knowledge strengths and deficits, to target revision accordingly. Additionally, the research team aims to obtain preliminary data on how digital games might be integrated into unit of study curriculums in the future.

Game Platform of "They Know"

The game platform "They Know" is a team-based strategy game that was designed for use in a range of educational curriculums. In the context of this study, the platform will be used to develop a game for the study of anatomy and histology for medical students. The game platform distributes anatomy knowledge across a game map, using interconnected nodes that represent key learning categories. Players are divided into 2 teams and allocated to a home base at opposite sides of the map. The aim of the game is to work cooperatively with teammates in order to take control of an opposing team's home base by crossing the map. In order to cross the map, players must answer multiple choice questions at each node they pass, related to its specific learning category.

The primary population group involved in this research will be second-year medical students studying anatomy at the University of Sydney, Australia. A minimum sample size of 8 participants is required in order to complete the game session. Participation in the study is entirely voluntary (Figure 1).

In order to develop the anatomy game for the platform, an expert development group will be convened. This group will consist of subject matter experts in the area of anatomy, who are also familiar with a curriculum of relevance to the study population. The expert development group will also include educational designers who will be involved in the design of the game map and the coordination of game play sessions.

In order to obtain baseline data, participants will be asked to complete a brief Internet survey after they have consented to be involved in the study, but before they access the educational digital game. This survey will provide basic demographic information, along with data on the level of experience study participants have had with either commercial or educational video games and other online educational activities previously. Additionally, the survey will ask players to provide information on how they currently revise anatomy content, with a specific focus on collaborative approaches.

Participants will then be asked to participate in a game session. Each game session will consist of three 1-hour matches of the game, at spaced intervals. These spaced intervals will be a minimum of 2 days apart, a spacing that has been chosen to provide participants with an opportunity to do relevant revision between matches or have intermatch discussions with their teammates if they desire. Metrics collected by the game platform across the session will also be collected and analyzed to measure the impact of the game on player knowledge. Game metrics collected will include information regarding how quickly participants answered questions and how accurately.

During the game matches, players will be observed by a study coordinator and will be filmed so that the research team can review how players interact with their teammates. Filmed sessions will be analyzed retrospectively in a structured manner in order to observe incidence of player cooperation, as well as to evaluate whether this interaction was social (general chit-chat), strategic (discussion about how to navigate the map, or specific game mechanics), or educational (discussion about a players knowledge, or requests for assistance answering questions).

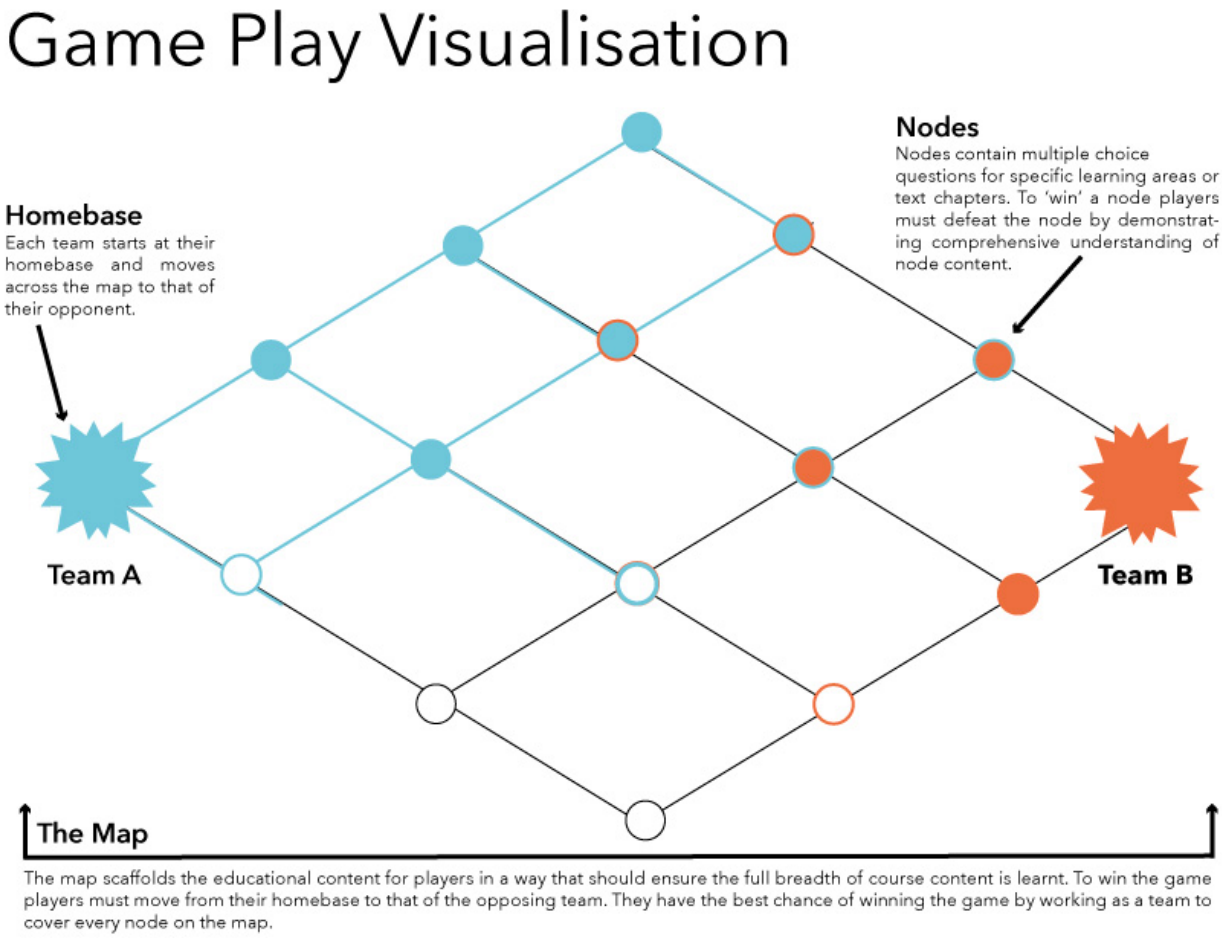
At the end of each match, participants will be asked to complete a Likert ranking of the match. This ranking will ask participants to rate 5 domains on a scale of 1-6: challenge, competitiveness, engagement, enjoyment, and replay likelihood. The postmatch ratings will be used to evaluate how participant engagement and enjoyment varied across the whole session.

After the conclusion of the session, participants will be asked to undertake semistructured interviews to explore their experiences with the game. The semistructured interviews will provide an opportunity to begin distinguishing how players interacted with the educational content in a unique manner as a result of using the game format. Semistructured interviews will include discussion of how cooperative game play impacted on the learning experience, as well as the value of the technology as a tool for shaping revision and review of a set curriculum. The research team will also be working with the study participants to explore the ways in which their knowledge has been structured as a result of playing the educational video game.

By conducting this study, the research team hopes to make contributions to the current understanding of video games and their use for educational purposes. In particular, it is hoped that undertaking this study will develop a more comprehensive understanding of the use of video games for educating adult learners, a group currently not significantly researched in the field of game studies. Finally, this study is researching the use of a genre of games that has never been utilized in medical education, and has only had minimal research interest in the broader educational research.

Permission to conduct this study was received from the University of Sydney's Human Research and Ethics Committee.

Figure 1. Game play diagram.



Results

This protocol describes a research study in its preliminary stages. However, several research outcomes have been achieved. First, after consultation with the medical faculty, a specific content area, first- and second-year anatomy and histology, has been chosen as the focus of the game. Additionally, an expert content development group has been convened to begin development of content for the digital game platform suitable for second-year medical anatomy students. This content group consisted of 6 subject matter experts and educational designers.

Additionally, development of the game platform has been finalized and tested by small groups of experienced commercial game players. These early tests have been used to ensure the stability of the game platform prior to being utilized by the medical students, as well as to determine expected match times for playing each game map.

Finally, second-year medical students have been recruited to participate in the study. A total of 54 second-year medical students expressed their interest in participating in the study. These individuals will be contacted to participate in small group sessions of the digital game containing the anatomy content. It is anticipated that with 54 participants it will be possible to run up to 6 sessions with 8 participants per session.

Discussion

Preliminary Findings

The literature on the use of educational digital games has repeatedly shown them to have a positive effect on learners [3]. In the context of medical education, there has been significant research interest in the use of digital games in clinical training, such as for surgical skills training [17]. There has also been a small amount of research into the use of digital games for continuing education, including one study into their usability for resuscitation skills retraining [18]. Far less research has been undertaken around applying digital games in the tertiary and postgraduate context, though there is some literature to suggest there is interest from students toward the use of digital games to enhance health education [19]. Although this protocol can only describe preliminary outcomes of the research study, recruitment data for the study would suggest there is some level of interest from students within the study population toward the use of a digital game to teach anatomy. This preliminary finding appears to support the existing research in this area, and has the potential to add data to an area of research that is underexplored.

At the postgraduate level, there are numerous units of study that are considered challenging for learners, but integral components of medical education. Anatomy is a good example of this phenomenon, as it is a necessary foundational subject for this student group, but learners often find it complex and difficult to learn [12]. In order to continue to offer high-quality educational experiences to learners, it is important for educators to explore tools that may enhance the educational impact of curriculums. The team-based strategy game described in this research protocol may prove a valuable tool for imparting such information, due to mechanics that make games highly engaging and the networked structure of the game map used in this genre of game, which is anticipated to align well with an anatomic curriculum.

Developing methodologies that can effectively capture how a learner interacts with a technological medium and not just the end result of that interaction is a challenge for researchers of many disciplines. In medical education digital game research, randomized controlled trials are the dominant methodology used, which are a very effective means of demonstrating a knowledge change [20]. However, they are less valuable for capturing what about the medium is unique and effective. This protocol has explored a mixed methodological approach, which may be of benefit to other health researchers interested in evaluating digital games for use on a large scale, such as in a postgraduate unit of study curriculum. The use of structured observation provided a powerful tool for developing understanding of player-player and player-platform interaction. Paired with semistructured interviews, this approach should provide a holistic perspective of how digital games can be uniquely utilized for knowledge retention and consolidation.

In all areas of digital games studies, there is a shortage of research investigating how the medium teaches effectively, particularly how various game mechanics work [21]. It is important that a better understanding of this technology's strengths and weaknesses is developed in order to effectively utilize it in the context of medical education.

Conclusions

Digital games are a common recreational medium in contemporary society. They have also been shown to be effective for serious applications, such as education or memory retention. In medical education, they have great potential to engage with adult learners, but there is minimal research exploring how to effectively use them for this purpose. Further research in this area would be of benefit to both learners and educators alike.

Acknowledgments

The authors would like to thank the Department of Anatomy, Sydney Medical School for their ongoing support of this study.

Conflicts of Interest

None declared.

References

1. Griffiths M. Education and Health. 2002. The educational benefits of video games URL: http://sheu.org.uk/sites/sheu.org.uk/files/imagepicker/1/eh203mg.pdf [accessed 2015-09-21] [WebCite Cache ID 6biNfhrwH]
2. Bennett S, Maton K, Kervin L. The 'digital natives' debate: A critical review of the evidence. Br J Educ Technol 2008:775-786 [FREE Full text] [doi: 10.1111/j.1467-8535.2007.00793.x]
3. de Aguilera M, Mendiz A. Video games and education. Comput Entertain 2003 Oct 01;1(1):10. [doi: 10.1145/950566.950583]
4. Tsai CY, Fan Y. Research trends in game-based learning research in online learning environments: A review of studies published in SSCI-indexed journals from 2003 to 2012. Br J Educ Technol 2013 Aug 13;44(5):E115-E119. [doi: 10.1111/bjet.12031]
5. Johnson, Adams BS, Estrada VA. Austin, Texas: The New Media Consortium. 2014. NMC Horizon report: Higher education edition URL: http://www.nmc.org/publication/nmc-horizon-report-2014-higher-education-edition/ [accessed 2015-09-21] [WebCite Cache ID 6biP6mcCx]
6. Johnson D, Johnson R T, Stanne MB. Meta Analysis. 2000. Cooperative learning methods: A meta-analysis URL: http://www.researchgate.net/publication/220040324_Cooperative_Learning_Methods_A_Meta-Analysis [accessed 2015-09-21] [WebCite Cache ID 6biPJrczx]
7. Yunyongying P. Gamification: Implications for curricular design. J Grad Med Educ 2014 Sep;6(3):410-412 [FREE Full text] [doi: 10.4300/JGME-D-13-00406.1] [Medline: 26279763]
8. Egenfeldt-Nielsen S. Digital kompetanse. 2006. Overview of research on the educational use of video games URL: http://egenfeldt.eu/papers/game-overview.pdf [accessed 2015-09-21] [WebCite Cache ID 6biPTzoSU]
9. DeShazo J, Harris L, Pratt W. Effective intervention or child's play? A review of video games for diabetes education. Diabetes Technol Ther 2010 Oct;12(10):815-822. [doi: 10.1089/dia.2010.0030] [Medline: 20807119]
10. Rosser JC, Lynch PJ, Cuddihy L, Gentile DA, Klonsky J, Merrell R. The impact of video games on training surgeons in the 21st century. Arch Surg 2007 Feb;142(2):181-186; discusssion 186. [doi: 10.1001/archsurg.142.2.181] [Medline: 17309970]
11. Ellis H. Teaching in the dissecting room. Clin Anat 2001;14(2):149-151. [doi: 10.1002/1098-2353(200103)14:2<149::AID-CA1023>3.0.CO;2-U] [Medline: 11241750]
12. Jones DG, Harris RJ. Curriculum developments in Australasian anatomy departments. Clin Anat 1998;11(6):401-409. [doi: 10.1002/(SICI)1098-2353(1998)11:6<401::AID-CA6>3.0.CO;2-#] [Medline: 9800920]

13. Choudhury B, Gouldsborough I, Gabriel S. Use of interactive sessions and e-learning in teaching anatomy to first-year optometry students. Anat Sci Educ 2010;3(1):39-45. [doi: 10.1002/ase.123] [Medline: 20014300]
14. Anyanwu EG. Anatomy adventure: A board game for enhancing understanding of anatomy. Anat Sci Educ 2014;7(2):153-160. [doi: 10.1002/ase.1389] [Medline: 23878076]
15. Jansz JL. Gaming at a LAN event: The social context of playing video games. New Media Soc 2005 Jun 01;7(3):333-355. [doi: 10.1177/1461444805052280]
16. Squire K. Game studies. 2002. Cultural framing of computer/video games URL: http://www.gamestudies.org/0102/squire/ [accessed 2015-09-21] [WebCite Cache ID 6biPntKfK]
17. Hedman L, Schlickum M, Felländer-Tsai L. Surgical novices randomized to train in two video games become more motivated during training in MIST-VR and GI Mentor II than students with no video game training. Stud Health Technol Inform 2013;184:189-194. [Medline: 23400154]
18. Buttussi F, Pellis T, Cabas VA, Pausler D, Carchietti E, Chittaro L. Evaluation of a 3D serious game for advanced life support retraining. Int J Med Inform 2013 Sep;82(9):798-809. [doi: 10.1016/j.ijmedinf.2013.05.007] [Medline: 23763908]
19. Kron FW, Gjerde CL, Sen A, Fetters MD. Medical student attitudes toward video games and related new media technologies in medical education. BMC Med Educ 2010;10:50 [FREE Full text] [doi: 10.1186/1472-6920-10-50] [Medline: 20576125]
20. Boeker M, Andel P, Vach W, Frankenschmidt A. Game-based e-learning is more effective than a conventional instructional method: A randomized controlled trial with third-year medical students. PLoS One 2013;8(12):e82328 [FREE Full text] [doi: 10.1371/journal.pone.0082328] [Medline: 24349257]
21. Gee J. What video games have to teach us about learning and literacy. Comput. Entertain 2003 Oct 01;1(1):20-20. [doi: 10.1145/950566.950595]

Edited by G Eysenbach; submitted 12.11.14; peer-reviewed by J Huh; comments to author 19.07.15; revised version received 21.07.15; accepted 18.08.15; published 28.09.15

Please cite as:
Janssen A, Shaw T, Goodyear P
Using Video Games to Enhance Motivation States in Online Education: Protocol for a Team-Based Digital Game
JMIR Res Protoc 2015;4(3):e114
URL: http://www.researchprotocols.org/2002/3/e114/
doi:10.2196/resprot.4016
PMID:26416522

Original Paper

The Evolution of a Professional Practice Forum: Balancing Peer-to-Peer Learning With Course Objectives

Anna Janssen, BA, MA; Tracy Robinson, BA (Hons), RN, PhD; Tim Shaw, BSc (Hons), PhD

Workforce Education and Development Group, Sydney Medical School, University of Sydney, Sydney, Australia

Corresponding Author:
Anna Janssen, BA, MA
Workforce Education and Development Group
Sydney Medical School
University of Sydney
Level 2, Mackie Building K01
University of Sydney
Sydney, 2009
Australia
Phone: 61 02 9036 9406
Fax: 61 02 9351 6646
Email: anna.janssen@sydney.edu.au

Abstract

Background: The Opioid Treatment Accreditation Course (OTAC) is a mandatory accreditation requirement in New South Wales, Australia, and aims to prepare medical practitioners for the provision of safe and effective Opioid Substitution Treatment to people with opioid dependence. The course has a strong focus on safe prescribing practices and the course design includes a Professional Practice Forum that is engaging for participants and effective at imparting complex ideas and concepts that do not place additional time constraints on already time-poor health professionals.

Objective: The study aimed to use participatory action research methods to develop and evaluate an online Professional Practice Forum that is a key component of the OTAC teaching and learning experience.

Methods: Three evaluation cycles were implemented with three cohorts of participants (N=40) to inform the design and review of the updated OTAC course. Overall, the study relied on participatory action research methods to enhance a sense of online community and to revise the Professional Practice Forum component of the course. Findings from survey feedback and an examination of Web metrics were used to monitor participant learning and were subsequently subject to thematic analysis in order to identify key themes.

Results: The use of participatory action techniques in the redesign of the OTAC course was a successful means of engaging with participants and resulted in four revisions based on feedback from facilitators and participants. The Professional Practice Forum was rated highly and received positive feedback from both moderators and participants.

Conclusions: The use of interactive forums in online learning in an educational module for adult learners can prove extremely valuable as a means for participants to share their expertise and improve their learning outcomes. In particular, the use of sticky and welcome threads were significant features that enhanced interactions between participants and facilitators and resulted in increased quantity and quality of postings. These findings can help inform future researchers on how to develop peer engagement modules that are amenable to assessment and that build an online sense of community.

(JMIR Res Protoc 2014;3(4):e58) doi:10.2196/resprot.3287

KEYWORDS

medical education; peer-to-peer; online learning; formative assessment

Introduction

Overview

Over the last decade, there has been increasing demand for continuing medical education programs that enhance the clinical skills and knowledge of medical specialists and general practitioners [1,2]. This is particularly the case in relation to providing safe treatment for people with opioid dependence because of the widespread stigma associated with opioid use in Australia. At the same time, medical practitioners have high-volume work environments and are often time-poor. Hence, educators need to develop high-quality learning environments and to identify and evaluate learning outcomes to ensure they have utility for participants and can be readily applied into their own practice [3,4]. The current Opioid Treatment Accreditation Course (OTAC) is designed around the core principles of both adult learning and situated learning [5-7]. This approach recognizes the knowledge and experience that participants bring to learning environments, and the literature confirms that this approach contributes to the creation of authentic and "real life" activities and contexts to promote learning [8].

The use of online forums and peer-to-peer learning approaches are now commonplace in e-learning because of their capacity to engage participants and to promote interactive learning environments [9,10]. In addition, the literature confirms that peer-to-peer learning approaches are particularly appealing in online medical education because they emphasize individual autonomy and participants are able to take responsibility for their own learning experiences [11]. Furthermore, collaborative educational environments allow adult learners to identify their existing knowledge and determine their future educational needs [12].

Nevertheless, the literature identifies high rates of attrition from online courses and that educators need to ensure the online environment is engaging and promotes a sense of community between participants [13]. Although challenging, a systematic review of 57 studies on e-learning for health professionals and students demonstrated that well-designed e-learning packages are learner centric and share responsibility between trainers and learners [14]. A significant challenge to building a thriving online community is the time and effort required to build a sense of community that requires enabling efforts more than moderation of participant activity [15]. This paper describes the development and review of an online course and Professional Practice Forum for clinicians who wish to be accredited to dispense Opioid Substitution Treatment in New South Wales (NSW), Australia.

Background to the Opioid Treatment Accreditation Course

The treatment of opioid dependence is often challenging for medical practitioners and prescribing opioids in NSW occurs within a regulatory framework that requires clinicians to have approval from the NSW Health Department to prescribe to each patient [16]. The OTAC can be completed as either an online course or as a 1-day face-to-face workshop. In 2009, addiction medicine was formally recognized by the Australian government as a medical specialty. Given the complex mental and physical health needs experienced by people recovering from opioid dependence, it is anticipated that this recognition will improve the safety and standards of health care for this cohort. It is noteworthy, however, that not all practitioners who complete the OTAC course go on to be active prescribers.

The OTAC course primarily targets general practitioners, who are already heavily targeted for continuing medical education, much of which is online. Hence, medical practitioners have high expectations in relation to the quality of online materials and are well placed as informants for the design and application of online learning programs [2]. In 2011, the Workforce Education and Development Group at the University of Sydney undertook a content and design review of the OTAC and subsequently piloted the program with medical practitioners (N=14) from diverse locations, including regional and rural centers. The aim of the review was to realign the course with the latest approaches in online learning in the medical sector and to ensure that the program was consistent with the principles of adult education that include self-directed learning and knowledge acquisition [14,15]. Subsequently, the OTAC was implemented and evaluated with two more cohorts to further develop and refine the course components and, in particular, the Professional Practice Forum.

Providing participants with opportunities to consult experts and collaborate with their peers was seen as instrumental in exploring their attitudes to prescribing and in developing support and knowledge networks that could be sustained subsequent to their participation in the course. Hence, the updated OTAC consisted of three modules that allowed participants to be self-directed in attaining their learning objectives over the 4-week course duration and a Professional Practice Forum (the third module) that was a mandatory component for satisfactory course completion. This forum was designed to enable participants to be assessed by experienced prescribers (referred to as facilitators) to ensure they had achieved key learning outcomes and to allow participants an opportunity to reflect on and demonstrate the knowledge they had acquired.

The forum provided a platform for participants to collaborate and to reflect on their learning in an online community environment. Two experienced facilitators were recruited to moderate the forum and to formatively assess the extent to which participants had developed their knowledge and skills in line with the core learning principles of the wider course. Given the challenges involved in recruiting busy practitioners for lengthy periods of time, participants were only required to interact with peers and moderators for a maximum of 4 hours. The forum was a largely asynchronous activity, and this allowed participants to access the discussion at a time of their convenience. The forum was made available for a 4-week period and participants had a 5-day period in which they could interact with, and be assessed by, the moderators.

This paper reports on the modification and evaluation of the Professional Practice Forum designed to increase the knowledge and confidence of medical practitioners to become accredited prescribers in the OTAC program. In addition to reviewing and redesigning the course, the study used participatory action research (PAR) approaches in order to identify the salient factors for sustaining an online collaborative network in the field of opioid substitution. The study hypothesized that the use of PAR to design the Professional Practice Forum would enhance the learning experience and retention of participants in the course. PAR has been described as a collective and self-reflective inquiry that researchers and participants undertake in order to understand and improve on the practices in which they participate and the situations in which they find themselves [17]. In the current study, PAR methods were used to inform the development and refinement of the Professional Practice Forum.

Methods

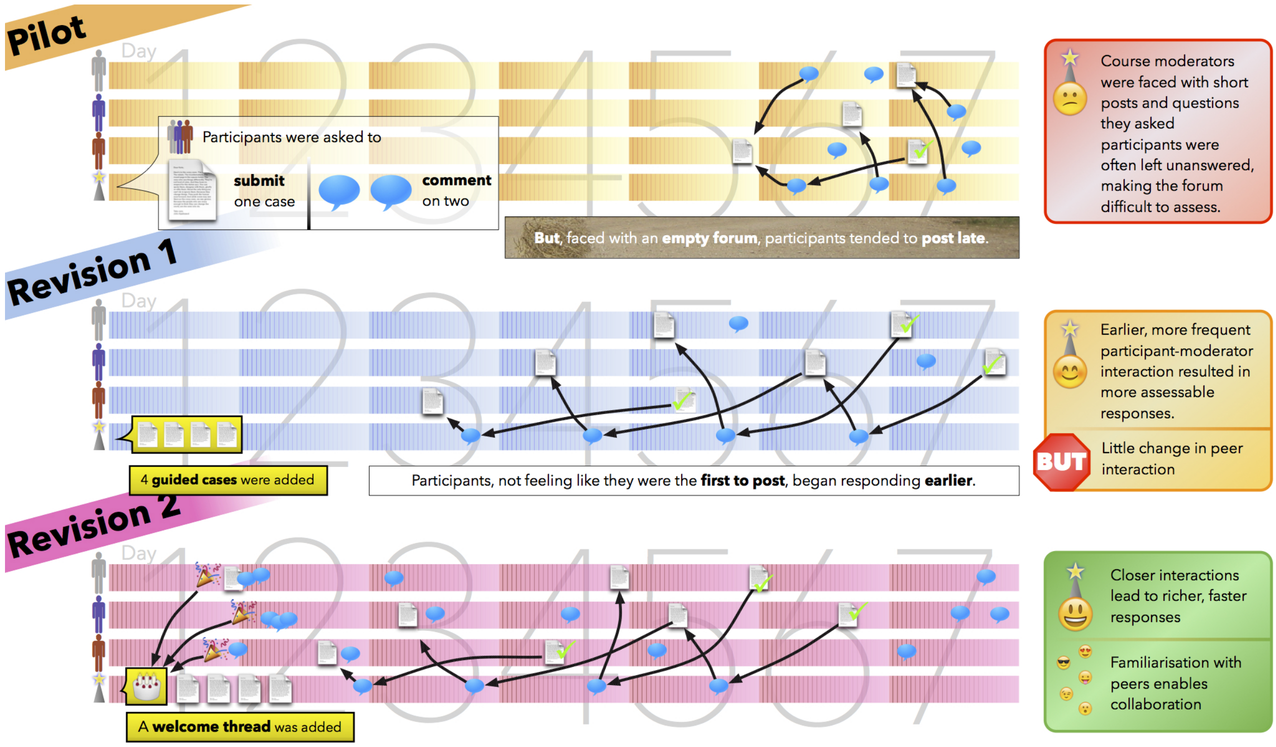
The current study involved three evaluation cycles of the OTAC with three cohorts of participants (N=40) and two facilitators who were also accredited and experienced prescribers. Participants were recruited primarily via email mail-out of course flyers, but some promotion was done via phone. Process and impact evaluations were undertaken after each of the three course iterations. In particular, observational techniques were used to assess processes such as peer interaction and the use of online resources. Analysis of website metrics was also undertaken, including the time that elapsed between the commencement of the forum module and when participants posted their first response. Interactions on the Professional Practice Forum were observed and recorded by the course coordinator in order to review the extent of interaction between participants and between participants and facilitators. Outcome measures were assessed using self-report surveys that asked participants to rate their learning experiences and to comment on their online sense of community. Permission to conduct this study was received from the University of Sydney's Human Research and Ethics Committee.

The Professional Practice Forum was piloted during 2011. At the completion of the first two modules, all participants were emailed by the course coordinator and invited to submit a short scenario to the forum that demonstrated their understanding and application of the previous course modules. In addition, participants were asked to comment on the scenarios of at least 2 peers in order to foster engagement and team problem solving. Subsequent to their completion of the OTAC, participants were asked to respond to an evaluation on their experiences with the forum via an online survey. The survey measured their interest in the Professional Practice Forum format as well as the ease of use and any changes they would recommend. In addition, the forum facilitators were asked to provide feedback on the challenges and benefits of the forum in relation to its utility and how effective it was for enhancing participant knowledge and confidence.

The findings from the pilot study informed revisions to the Professional Practice Forum and the revised OTAC was subsequently implemented with (N=13) participants. This iteration of the course included four "sticky" threads that linked to exemplars of case scenarios, and participants were invited to respond to at least one scenario prior to submitting their own case studies. All other evaluation methods were consistent with the pilot study. A final iteration of the OTAC course was developed and tested in mid-2011 (N=13) This version of the course included a welcome thread that provided participants with an opportunity to access information on the backgrounds and expertise of course facilitators and to post their own biographical information. In addition, a feedback thread was included to enable an accessible and ongoing evaluation tool for future OTAC participants.

Overall, the study used PAR methods to identify strategies for creating a sense of community and to revise the Professional Practice Forum. Feedback from each of the three course iterations was subject to thematic analysis that was undertaken until saturation was reached and clear themes emerged. See Figure 1.

Figure 1. Visualization of the three evaluation phases, which resulted in revisions to improve the educational impact of the Professional Practice Forum.



Results

A total of 40 participants completed all aspects of the OTAC and provided process and impact feedback. Course participants included 14 general practitioners, 6 registrars, 1 psychiatrist, and 2 chief medical officers; 15 participants indicated they were from rural and regional NSW and the remainder were based in urban centers. Findings that emerged from the feedback (surveys and Web metrics) demonstrate that the use of participatory action techniques in the re-design of the OTAC program was a successful means of engaging with participants and resulted in four revisions based on feedback from both facilitators and participants.

In the pilot OTAC, the open-interfaced design of the Professional Practice Forum appeared to discourage participants from making initial posts, which meant the course coordinator had to repeatedly email instructions and reminders to participants. The inclusion of four "sticky" threads in the second iteration of the course reduced the time participants took between commencing the course and posting their first discussion thread. It also allowed more discussion time for moderators and participants and a longer timeframe for peer interaction. In addition, the guidance provided by the sticky cases resulted in more pertinent responses and content between participants as well as lengthier posts that contained more detailed information about treatment options and management.

Feedback from facilitators' observations of the Professional Practice forum indicated that some participants remained hesitant about fully engaging with their peers. This resulted in a third iteration of the OTAC that included a welcome thread. Participants reported that this had a notable impact on their engagement and sense of online community, which was demonstrated by their increased number of posts as well as the frequency and depth of their interactions with each other. The welcome thread allowed participants to introduce themselves and build rapport with their peers. As one participant stated, "I enjoyed this component and it was interesting to see the various challenges that all clinicians have at their point of treatment or engagement".

Overall, participants reported that they enjoyed the OTAC course and that it resulted in improved knowledge about prescribing and managing people with opioid dependence. In particular, they enjoyed the opportunity of engaging with facilitators who had extensive experience in the field. As one participant stated, "It is an excellent teaching session, I learned a lot from seniors". Nevertheless, facilitators did report that their engagement with and observations of the Professional Practice Forum were time consuming and that some participants required considerable encouragement to complete all forum activities. The use of PAR methods resulted in three changes to the OTAC and provided important information on the factors that enabled participation in the forum.

Discussion

Principal Findings

The re-design of the OTAC Professional Practice Forum was informed by literature on autonomous learning [1,2] and collaborative peer learning [11,14]. Most participants were able to commit approximately 4 hours of their time over the 7-day period to engage with forum activities. Nevertheless, facilitators and the course coordinator reported that they had to be proactive to ensure that all participants engaged fully with the course. This highlights the challenges involved in creating an evolving online community rather than choreographing participation. It also highlights the important role of "enabling" rather than moderating online facilitation. The use of current prescribers as facilitators was an important strategy for engaging participants and for enabling them to actively join the forum.

At the same time, facilitators reported challenges in facilitating the forum, particularly in relation to the administration burden of following up with participants in the first two iterations of the OTAC. Previously, participants had a tendency to post only what was required and to post directly to facilitators, without drawing on the expertise of their peers. The fact that participants increased their engagement with each other in the final OTAC demonstrates that when they are able to familiarize themselves with each other and when they are provided with exemplars of the work that is required, they are much more likely to actively contribute to the forum.

Another challenge with the creation of online forums is ensuring that participants post enough detail in their responses to make them amenable to both formative and summative assessment processes. The incorporation of the four sticky cases into the Professional Practice Forum after the initial pilot was an effective tool for encouraging participants to post comments on the forum with sufficiently detailed responses. This allowed facilitators to more accurately assess participant knowledge and meant there was more time for them to interact with participants and to request additional information. In the first iteration of the OTAC, participants were disinclined to post to the forum and this challenge is consistent with the literature that identifies participant engagement as a significant challenge in online learning [9].

In subsequent revisions of the OTAC that used guided and exemplar cases, participants were observed to make earlier postings and provided more detailed answers, which were noticeably longer and contained more detailed information on patient history and other diagnostic criteria. This demonstrated their depth of knowledge in regard to symptoms, treatment planning, and management. In the final revision of the Professional Practice Forum, the inclusion of a welcome thread had a noticeable impact on peer interaction. The use of the welcome thread provided participants with immediate access to the Professional Practice Forum and enhanced the growth of an online community. This highlights the importance of encouraging early online interaction between participants and recognizing that learning is also a social process. This is consistent with learner- and community-centered approaches to teaching and learning that emphasize the importance of building on participant knowledge, providing and receiving feedback, and self-evaluation.

Limitations

Several limitations to the current study must be acknowledged. The use of purposive sampling and the diverse discipline backgrounds of participants means that the findings are not generalizable and further dissemination and evaluation of the OTAC course is warranted. In particular, future evaluations of the course should include follow-up information on whether participants go on to become active prescribers. At the same time, the sample was sufficient for the development and piloting of the Professional Practice Forum. The reliance on qualitative feedback from participants is another limitation, and the use of validated measures for online sense of community would be beneficial for quantifying the sense of connection between and within participants and facilitators. Furthermore, future evaluations of OTAC should include long-term follow-up with participants to ascertain if changes in their knowledge are sustained.

The use of PAR methods did, however, provide rich feedback on modifications that were required of the OTAC and resulted in an increased number and quality of interactions in the Professional Practice Forum. Given that the study aimed to build and sustain an online learning community and to enhance retention of busy clinicians, the methods used were adequate for the pilot implementation and refinement of the OTAC.

Conclusions

The challenges of developing and sustaining a sense of community in online learning environments are well documented in the literature. However the literature has a particular focus on strategies for enhancing the sense of connection between participants and facilitators. There is still limited research on how to generate peer-to-peer interactions and harness them as a vehicle for developing and implementing online forums. The findings from this study contribute to better understanding of the factors that encourage peer-to-peer learning.

Peer-to-peer engagement in an educational module for adult learners can prove extremely valuable as a means for participants to share their expertise and improve their learning outcomes. The use of a forum module allowed the course designers to use both formative and summative assessment and evaluation processes. Given the relatively small number of participants, however, it is important that the OTAC is tested with a larger cohort of participants to further explore its utility across different geographical contexts where the use of online education may be less familiar. The use of participatory action approaches in the conduct of the current study was highly effective for allowing participants to engage actively in the construction of the Professional Practice Forum.

Acknowledgments

The authors would like to acknowledge NSW Health who fund the Opioid Treatment Accreditation Course, with particular mention of the dedicated NSW employees who had day-to-day involvement with the course. In addition, the research team would like to thank and acknowledge the OTAC facilitators who were involved in the review of the forums and all the OTAC participants.

Additionally, the authors would like to thank and acknowledge Leon Spencer for the design of the figure used in this paper.

Authors' Contributions

Anna Janssen made a substantial contribution to program development, data collection and analysis, and manuscript preparation. Tracy Robinson made a substantial contribution to manuscript preparation. Tim Shaw made a significant contribution to program design and manuscript preparation.

Conflicts of Interest

None declared.

References

1. Mansouri M, Lockyer J. A meta-analysis of continuing medical education effectiveness. J Contin Educ Health Prof 2007;27(1):6-15. [doi: 10.1002/chp.88] [Medline: 17385735]
2. Daniels AS, Walter DA. Current issues in continuing education for contemporary behavioral health practice. Administration and Policy in Mental Health and Mental Health Services Research 2002;29(4):359-376.
3. Mazmanian PE, Davis DA. Continuing medical education and the physician as a learner: guide to the evidence. JAMA 2002 Sep 4;288(9):1057-1060. [Medline: 12204068]
4. Henwood SM, Yielder J, Flinton D. Radiographers attitudes to mandatory CPD: a comparative study in the United Kingdom and New Zealand. Radiography 2004 Nov;10(4):251-258. [doi: 10.1016/j.radi.2004.05.008]
5. Brown JS, Collins A, Duguid P. Situated cognition and the culture of learning. Educational researcher 1989;18(1):32-42.
6. Ellis A, Phelps R. Staff development for online delivery: A collaborative, team based action learning model. Australian Journal of Educational Technology 2000;16(1):26-44 [FREE Full text] [WebCite Cache]
7. Mongoose Technology Inc. Digital Places. 2001. The twelve principles of collaboration - guidelines for designing internet services that support group collaboration (White Paper) URL: http://www.digitalplaces.biz/pages/12Principles-Collaboration.pdf [accessed 2014-01-30] [WebCite Cache ID 6N0jRZ2gh]
8. Oliver R. Developing e-learning environments that support knowledge construction in higher education. 2001 Presented at: International We-B Conference; 2001; Perth, Western Australia p. 407-416.
9. Richardson JC, Swan K. Examining social presence in online courses in relation to students' perceived learning and satisfaction. Journal of Asynchronous Learning Networks 2003;7(1):68-88.
10. Swan K. Building Learning Communities in Online Courses: the importance of interaction. Education, Communication & Information 2010 Oct 14;2(1):23-49. [doi: 10.1080/1463631022000005016]
11. Haidet P, Stein HF. The Role of the Student - Teacher Relationship in the Formation of Physicians. Journal of General Internal Medicine 2006;21(1):16-20. [doi: 10.1111/j.1525-1497.2006.00304.x]
12. Higgs J, Titchen A. Rethinking the Practice-Knowledge Interface in an uncertain world: a model for practice development. The British Journal of Occupational Therapy 2001;64(11):526-533.
13. Lin H. The role of online and offline features in sustaining virtual communities: an empirical study. Internet Research 2007;17(2):119-138. [doi: 10.1108/10662240710736997]
14. Childs S, Blenkinsopp E, Hall A, Walton G. Effective e-learning for health professionals and students--barriers and their solutions. A systematic review of the literature--findings from the HeXL project. Health Info Libr J 2005 Dec;22 Suppl 2:20-32. [doi: 10.1111/j.1470-3327.2005.00614.x] [Medline: 16279973]
15. Young C. Community management that works: how to build and sustain a thriving online health community. J Med Internet Res 2013;15(6):e119 [FREE Full text] [doi: 10.2196/jmir.2501] [Medline: 23759312]
16. Baum F, MacDougall C, Smith D. Participatory action research. J Epidemiol Community Health 2006 Oct;60(10):854-857 [FREE Full text] [doi: 10.1136/jech.2004.028662] [Medline: 16973531]
17. Nicol DJ, Macfarlane-Dick D. Formative assessment and self - regulated learning: a model and seven principles of good feedback practice. Studies in higher education 2006;31(2):199-218.

Abbreviations

NSW: New South Wales
OTAC: Opioid Treatment Accreditation Course
PAR: participatory action research

Edited by G Eysenbach; submitted 30.01.14; peer-reviewed by J Phillips, L Sherman, AM Auvinen; comments to author 27.08.14; revised version received 10.09.14; accepted 13.09.14; published 31.10.14

Please cite as:
Janssen A, Robinson T, Shaw T
The Evolution of a Professional Practice Forum: Balancing Peer-to-Peer Learning With Course Objectives
JMIR Res Protoc 2014;3(4):e58
URL: http://www.researchprotocols.org/2014/4/e58/
doi:10.2196/resprot.3287
PMID:25363273