Journal of Education, Teaching and Social Studies
ISSN 2642-2336 (Print) ISSN 2642-2328 (Online)
Vol. 1, No. 2, 2019
www.scholink.org/ojs/index.php/jetss

Original Paper

Anatomically Correct: Implementing and Evaluating an Educational Digital Game for Applied Sciences Students

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Received: October 17, 2019 Accepted: October 28, 2019 Online Published: November 13, 2019

doi:10.22158/jetss.v1n2p75 URL: http://dx.doi.org/10.22158/jetss.v1n2p75

Abstract

Digital games are a common form of entertainment in modern society and are increasingly prevalent in health education. However, little research has been conducted into their use for delivering anatomy and histology education for health students. This is surprising considering the difficulty many health students have learning anatomy and histology. The study used a mixed methodology, consisting of a controlled trial and qualitative evaluation of learner attitudes towards the digital game. The trial stratified learners into two groups: a digital game group and a multiple-choice quiz group, for one semester. At the end of semester final examination results from the two groups were compared to see if the digital game was a comparable means of revising anatomy and histology subject matter. Additionally, an online survey and semi-structured interviews were used to explore student attitudes towards the digital game. Findings demonstrated that a digital game could be as effective as alternative methods to support revision of anatomy subject matter. Further, results post-intervention survey (n=10) and semi-structured interviews (n=6) showed that students were interested in the use of digital games to support revision and enjoyed their experiences using the digital game during their studies.

Keywords

Digital games, digital health, health education, anatomy, collaboration

1. Introduction

Digital games have great potential as innovative learning tools due to their demonstrated ability to motivate, challenge and engage learners (Prensky, 2003). They have been shown to have a positive effect on knowledge acquisition and concept learning in health education (Akl et al., 2008; Akl et al., 2010), a well as in science learning (Li & Tsai, 2013). Digital games have also been shown to improve content understanding and learner motivation (Connolly, Boyle, MacArthur, Hainey, & Boyle, 2012; Wouters, Van Nimwegen, Van Oostendorp, & Van Der Spek, 2013) and in some instances skills acquisition and development (Graafland, Schraagen, & Schijven, 2012; Khatri, Sugand, Anjum, Vivekanantham, Akhtar, & Gupte, 2014). A meta-analysis on digital simulation games demonstrated that medical trainees taught with simulation games learned more than those that were in a comparison group (Sitzmann, 2011). This difference is likely attributed to the trainees' engagement with the learning material through more active learning processes rather than passive didactic learning methods (Sitzmann, 2011). However, it is also noted that there is strong evidence of publication bias in the literature on the use of these types of simulation games (Sitzmann, 2011). Furthermore, there is a notable gap in understanding regarding the interrelationship between sound pedagogical approaches and game designs (Gorbanev et al., 2018).

There is increasing evidence suggesting that medical and allied health students like the concept of using technology to enhance healthcare education and that digital games add value to student learning (Kron, Gjerde, Sen, & Fetters, 2010). A survey of nursing students showed they were supportive of the use of new media such as video games to augment education and training (Lynch-Sauer, VandenBosch, Kron, Gjerde, Arato, Sen, & Fetters, 2011). Further, it has been shown that there is enthusiasm for the development of video-based simulation games for use in nursing education (Johnsen, Fossum, Vivekananda-Schmidt, Fruhling, & Slettebø, 2018). However, there is currently a gap in anatomy education literature regarding how digital games can facilitate and enhance scholarly learning.

Anatomy is a basic science that underpins all medical and paramedical education. It is commonly perceived as content-heavy and complex to internalize (Pandey & Zimitat, 2007). Students report that the subject is stressful and daunting (Jones & Harris, 1998; Smith & Mathias, 2010), as well as low self-confidence in learning and revising anatomy (Nicholson, Reed, & Chan, 2016). Consequently, many learners adopt a surface-approach to learning, failing to retain content for future use both during their courses and in their subsequent careers. The pedagogical literature demonstrates that anatomy has been taught much the same way since the early 20th century with educators particularly resistant to changes in teaching practice (Sugand, Abrahams, & Khurana, 2010). This is not surprising since functional content-heavy anatomy units of study require students to learn a new medical Latin-based language, while integrating new content and concepts into real-life functional applications. For these reasons, there is a need to explore the use of new and innovative tools to facilitate the learning and teaching of anatomy.

The objective of the study described in this article was to explore the acceptability of using a series of digital games to engage first-year university students in anatomy learning and revision. Due to their highly engaging nature, low barrier to entry and demonstrated ability to be used for knowledge transfer, there is reason to believe digital games may be a beneficial tool to support learners of anatomy and histology. The study evaluates the extent to which university students felt they engaged with a digital game to support their revision of anatomy subject matter. A secondary aim of the study was to determine whether a digital game could support an equivalent level of academic performance as other existing revision methods.

2. Method

2.1 Recruitment and Study Setting

Participants were eligible to participate in the study if they were enrolled in a specific undergraduate anatomy course within the University the study was taking place in. Full-time students, over the age of 18, enrolled in a first-year unit of study on functional musculoskeletal anatomy were recruited. Participants were recruited via a five-minute oral presentation during their first lecture of the semester for the unit. This presentation explained the project to the students so that they could decide if they were interested in participating. All potential participants who expressed interest in the study provided email addresses to receive further information about the study and a link to consent to participate.

2.2 Study Design

The study used a mixed methodology, consisting of a controlled trial and qualitative evaluation of learner attitudes towards the digital game. In order to determine whether the digital game was comparable to other methods for revising anatomy, a controlled trial was used. For the controlled trial a minimum sample size of 80 participants was needed to detect a significant difference, factoring in possible attrition or withdrawal. Once participants were recruited, they were stratified into one of two groups: one group to play the online digital game (Intervention), and another to complete the online multiple-choice questions (Control). Stratification was based on prior academic performance to optimize between-groups equivalence and minimize the confounding effect of academic capacity. Academic performance was determined first using participants' high school leaving mark (Australian Tertiary Admission Rank or equivalent) or, if that was unavailable, their weighted average mark for completed tertiary studies. Additionally, participants were stratified based on gender so that an equivalent number of male, female and unspecified gender participants were allocated to each group. Refer to Figure 1 to see a flow diagram of the stratification process.

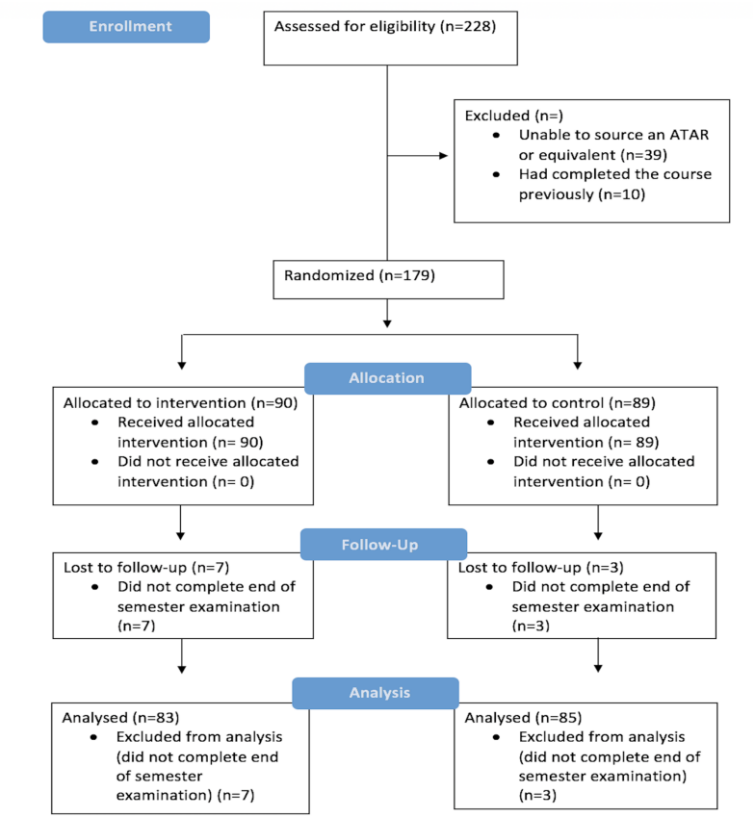

Figure 1. A Flow Chart Showing How Participants were Stratified for the Controlled Trial Component of the Research Study

Prior to receiving access to the revision questions, both the Intervention and Control group were asked to complete an online survey. The baseline survey was undertaken to ascertain any differences in experience with commercial digital games or demographic differences across the two cohorts, to identify characteristics that may lead to performance bias. Questions in the survey included Likert rankings of confidence on participant experience with and attitudes to commercial digital games and motivations for playing commercial digital games. The Likert ranking used a five-point Likert scale where 1 was equivalent to strongly disagree and 5 was equivalent to strong agreement. Participants could select more than one response to this question. The researchers developed the baseline survey questions based on a review of the literature.

Both the Intervention and Control group received the same anatomy revision multiple choice questions throughout the semester. For the Intervention group the anatomy multiple choice questions were delivered via the digital game, and for Control group the same multiple choice questions were delivered using the quiz function of the Blackboard Learning Management System. Although the multiple-choice questions content across the two platforms were the same, the digital game delivered the questions in a different manner to Blackboard. The two key differences between the digital game and Blackboard were that the digital game required participants to type the answers to the multiple-choice questions, rather than click on the correct answer, and the digital game had time limits on how long players had to

answer the questions to stimulate examination conditions.

To measure engagement with the digital games, participants in the Intervention group were invited to complete an online survey post-intervention and/or participate in a semi-structured phone interview. The online survey asked participants to respond to free-text questions about their enjoyment with the game and engagement they experienced playing it. Additionally, respondents were given the opportunity to give feedback on what they liked about the digital game and what aspects of it they would improve. Semi-structured interviews explored similar themes, but in more depth than could be achieved in an online survey.

2.3 Development and Implementation

The digital games used in this study were developed using the game platform which was licensed from the developer for this study. The platform is designed to support the creation of team-based strategy games that can be used to deliver educational experiences in any subject area. In this study, the platform was licensed from the developer and was then used to develop a suite of games on musculoskeletal anatomy for university level students enrolled in a number of health sciences degrees. The game platform was chosen because it supports the development of multiplayer digital games, where teams of players work together to take control of the opposing team's home base. It is also possible to play games in a single-player time trial mode in order to revise the content and compare the time taken to take control of the map with other players.

Developing a game in the platform involves distributing content across a game map in a network format, 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 an adjacent node connected to a node controlled by their team, the player gains more influence of this adjacent node for their team and decreases that of their opponents. When enough influence has been gained, the adjacent node becomes controlled, turning from white to fully blue. Players in that team can then continue to try to take control of a neighboring node. The first team to control their enemy's home node wins the game.

In order to develop the suite of game maps, a working group bringing together an educational designer and content experts was convened. The content experts were faculty members who delivered anatomy and histology units to health students at the University, and who were the creators of the final examinations. The content experts developed over 200 multiple-choice questions, distributed across 22 categories for dissemination by both the digital games and the multiple-choice quiz platform. The educational designer developed 8 games, each game with increasing number of nodes, from these questions to be published at time-contingent intervals. Refer to Figures 2, and 3 for examples of elements of the game. The intervention was delivered over 12 weeks. The first game was published in week four of the semester, with subsequent games being published every two weeks to align with

progression of the curriculum. Participants were free to access published games during the intervention period as often as they wished.

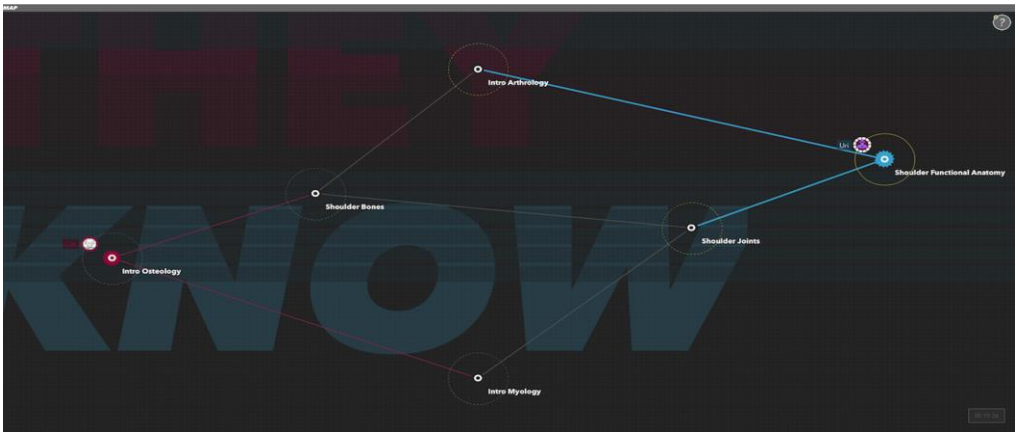

Figure 2. A Screenshot of the Starting Screen for a Game Map. Players from Opposing Teams are Shown at Their Respective Home Bases. Blue Indicates a Player is Friendly, Red Indicates Players on the Opposing Team. Players Start at Their Team's Homebase. Teams Control Their Homebase at the Start of the Game, but no Other Nodes on the Map. Blue Lines Extending out of the Team's Homebase Indicate Which Nodes They can Travel to Next

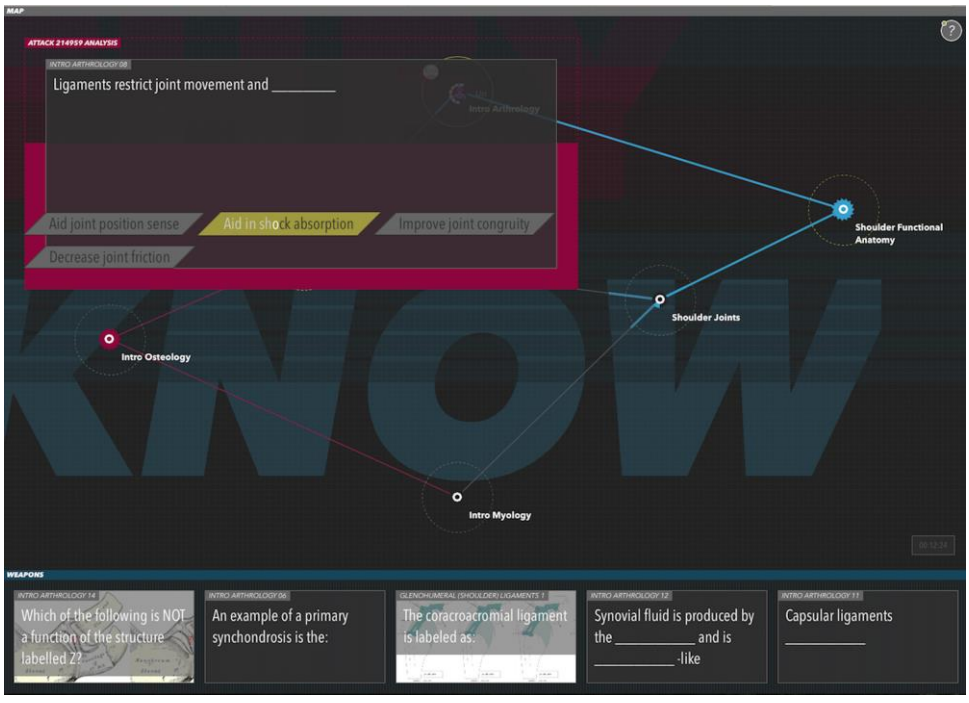

Figure 3. A Screenshot of the Game Mid-way through, Showing Some of the Elements Players Obtain During the Game. At the Bottom of the Screen the Question Cards Obtained by the Player as They Navigate the Game Map are Shown. These Cards can be Used Defensively to Slow Opposing Players Progress across the Map

2.4 Evaluation

A mixed methodology was used to evaluate the impact of the intervention. Qualitative measures were used to determine whether the digital game was an equivalent means of revising anatomy to the existing approach available to students, the online Blackboard quizzes.

Quantitative measures used were final examination results from the Intervention and Control groups. The examination is a validated tool developed by subject matter experts to ensure it consistently evaluates student understanding of anatomy and histology content in the unit of study. To ensure the validity of the exam the multiple-choice theory exam undergoes a test reliability screen each semester to ensure a high reliability using LXR.Test (V6.0, 2003). To date, the theory examination has had a reliability of between 89-93%. At the end of the intervention period, results from the final examination for the anatomy unit were compared across the two groups in order to identify between-group differences in examination performance. In order to demonstrate that the digital game was equivalent to the Blackboard quizzes for revising anatomy end semester examination results were analyzed using the TOST procedure with equivalence bounds of +7and -7. The equivalence bounds were determined based on expert assessment. Prior to analyzing the data, a Kolmogorov-Smirnov test was used to check for normality.

Qualitative measures were used to evaluate the extent to which participants engaged with the digital game, and the benefits and disadvantages of digital game-based learning in anatomy education. The survey questions used in the evaluation were informed by a scoping review of the literature evaluating other digital games used in tertiary education. The final list of questions was peer-reviewed by the researchers until agreement was reached. There was no input from students in to the development of the survey. In order to motivate students to complete the online surveys before and after they had played the digital game, participants who completed both surveys went in the draw to win a US$15 gift voucher. The tools used to collect qualitative data included online surveys and semi-structured interviews. Semi-structured interviews were audio recorded, transcribed, de-identified and then thematically analyzed, in line with recognized approaches (Braun & Clarke, 2006). Thematic analysis consisted of an initial reading of the transcripts in order to obtain an overview of their content. Once this reading had been completed the transcripts were re-read for the purpose of undertaking a structured analysis. Structured analysis involved reviewing the transcripts line by line to identify key themes across the entire transcript. These key themes were then grouped into categories and sub-categories, based on the similarity of the themes. The transcripts were read and re-read until no new themes emerged. During the thematic analysis key quotes were identified, illustrating each category and sub-category.

2.5 Ethics

Permission to conduct this study was received from The University of Sydney Human Research Ethics Committee (Protocol 2015/938).

3. Results

3.1 Participant Characteristics

A total of 179 students participated (female n = 92, male n = 79, unspecified = 8). The participants were stratified into two groups, with 90 participants in the Intervention Group and 89 in the Control Group. Data on the age of participants were not collected. However, it is known that all students enrolled in the course are either first or second year undergraduates in health science degrees at the study site. The majority of first-year and second-year undergraduates are between 18-19 years old, with a small number of mature age students. In order to enroll in an undergraduate health science degree at the University in this study, it was necessary for school leavers to have an ATAR (Australian Tertiary Admissions Rank) school leaving mark from 80-99.95/100.

Of the 179 students who participated in the study, 54.2% (n = 97) completed the baseline survey. Refer to Tables 1, 2 and 3 for an overview of the baseline characteristics of participants in both groups.

Table 1. Number of Responses for Participant Likert Rankings of Motivations for Playing Commercial Digital Games on a 1-5 Scale, for the Intervention Group and the Control Group

	Intervention Group (45.6%) n = 41	**Control Group (56.2%) n = 50**
Do you own any of the video game consoles listed below?		
Nintendo WiiU	5 (12.2%)	11 (22.0%)
PlayStation 4	7 (17.1%)	10 (20.0%)
Xbox One	3 (7.3%)	1 (2.0%)
Nintendo DS	15 (26.6.4%)	13 (26.0%)
PlayStation Vita	1 (2.4%)	1 (2.80)
None	10 (24.4%)	14 (28.0%)
How many hours per week do you play video or computer games?		
None	26 (63.4%)	27 (57.5%)
1-3 per week	12 (29.3%)	16 (34.0%)
1-3 per day	3 (7.3%)	4 (8.5%)
3-5 per day	0 (0.0%)	0 (0.0%)
6+ per day	0 (0.0%)	0 (0.0%)
Other (please specify)	0 (0.0%)	3 (6.4%)
How many years of experience do you have playing video or computer games?		
None	12 (29.3%)	11 (22.0%)
1-2 years	7 (17.1%)	11 (22.0%)
2-5 years	6 (14.6%)	8 (16.0%)
5-10 years	10 (24.4%)	9 (18.0%)
10+ years	5 (12.2%)	9 (18.0%)

Other (please specify)	1 (2.4%)	2 4.0%)
Do you believe that computer games can be used to learn in a Tertiary education environment?		
Yes	35 (85.4%)	47 (94.0%)
No	6 (14.6%)	3 (6.0%)

The rankings on the scale indicated the following levels of agreement: 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree and 5 = strongly agree.

Table 2. Number of Responses for Participant Likert Rankings of Motivations for Playing Commercial Digital Games on a 1-5 Scale, for the Intervention Group and the Control Group

	Intervention Group (45.6%) n = 41					**Control Group (56.2%) n = 50**				
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
Pleasure	2 (4.8%)	2 (4.8%)	10 (24.3%)	16 (39.0%)	11 (26.8%)	2 (4.0%)	0 (0.0%)	9 (18.0%)	24 (48.0%)	15 (30.0%)
Relaxation	1 (2.4%)	3 (7.3%)	7 (17.1%)	20 (48.8%)	10 (24.3%)	2 (4.0%)	3 (6.0%)	8 (16.0%)	25 (50.0%)	12 (24.0%)
Excitement	2 (4.8%)	5 (12.2%)	9 (21.9%)	18 (43.9%)	7 (17.1%)	4 (8.0%)	2 (4.0%)	16 (32.0%)	15 (30.0%)	13 (26.0%)
Challenge	2 (4.8%)	5 (12.2%)	8 (19.5%)	15 (36.6%)	10 (24.3%)	5 (10.0%)	3 (6.0%)	10 (20.0%)	23 (46.0%)	9 (18.0%)
Leisure	2 (4.8%)	2 (4.8%)	3 (7.3%)	24 (58.5%)	10 (24.3%)	3 (6.0%)	1 (2.0%)	10 (20.0%)	20 (20.0%)	16 (32.0%)
Prevention of boredom	3 (7.3%)	3 (7.3%)	9 (21.9%)	20 (48.8%)	6 (14.6%)	4 (8.0%)	5 (10.0%)	6 (6.0%)	20 (20.0%)	15 (30.0%)
Stress relief	4 (9.8%)	2 (4.8%)	9 (21.9%)	19 (46.3%)	7 (17.1%)	4 (8.0%)	10 (20.0%)	17 (34.0%)	10 (20.0%)	9 (18.0%)
Curiosity	2 (4.8%)	5 (12.2%)	11 (26.8%)	17 (41.4%)	6 (14.6%)	7 (14.0%)	9 (18.0%)	17 (34.0%)	12 (24.0%)	5 (10.0%)
Feeling good	3 (7.3%)	4 (9.8%)	10 (24.3%)	17 (41.4%)	7 (17.1%)	5 (10.0%)	3 (6.0%)	20 (20.0%	13 (26.0%)	9 (18.0%)
Release tension	3 (7.3%)	4 (9.8%)	13 (31.7%)	15 (36.6%)	5 (12.2%)	5 (10.0%)	12 (24.0%)	14 (28.0%)	13 (26.0%)	6 (6.0%)
Fantasy	4 (9.8%)	6 (14.6%)	16 (39.0%)	8 (19.5%)	7 (17.1%)	7 (14.0%)	9 (18.0%)	11 (22.0%)	13 (26.0%)	9 (18.0%)
Emotional stimulation	5 (12.2%)	7 (17.1%)	14 (34.1%)	10 (24.3%)	5 (12.2%)	9 (18.0%)	9 (18.0%)	17 (34.0%)	9 (18.0%)	5 (10.0%)
Competition	3 (7.3%)	8 (19.5%)	9 (21.9%)	15 (36.6%)	6 (14.6%)	7 (14.0%)	4 (8.0%)	15 (30.0%)	17 (34.0%)	7 (14.0%)

Cooperation	3 (7.3%)	9 (21.9%)	11 (26.8%)	13 (31.7%)	5 (12.2%)	6 (6.0%)	10 (20.0%)	24 (48.0%)	4 (8.0%)	6 (6.0%)
Control	3 (7.3%)	11 (26.8%)	14 (34.1%)	8 (19.5%)	4 (9.8%)	7 (14.0%)	16 (32.0%)	20 (20.0%)	6 (6.0%)	1 (2.0%)
Avoidance of other activities	8 (19.5%)	11 (26.8%)	7 (17.1%)	12 (29.3%)	3 (7.3%)	8 (16.0%)	9 (18.0%)	13 (26.0%)	15 (30.0%)	5 (10.0%)
Recognition	8 (19.5%)	12 (29.3%)	15 (36.6%)	4 (9.8%)	1 (2.4%)	12 (24.0%)	16 (32.0%)	19 (38.0%)	2 (4.0%)	1 (2.0%)

The rankings on the scale indicated the following levels of agreement: 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree and 5 = strongly agree.

Table 3. Number of Responses for Likert Rankings of Statements about Educational Use of Digital Games on a 1-5 Scale, for the Intervention Group and the Control Group

	Intervention Group (44.4%) n = 40					**Control Group 2 (55.1%) n = 49**				
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
I like the idea of using technology to enhance the current healthcare education experience.	1 (2.5%)	0 (0.0%)	1 (2.5%)	24 (60.0%)	15 (37.5%)	0 (0.0%)	1 (2.1%)	1 (2.1%)	24 (48.9%)	23 (46.9%)
I like the idea of using technology to enhance the current healthcare education experience.	1 (2.5%)	0 (0.0%)	1 (2.5%)	23 (57.5%)	16 (40%)	0 (0.0%)	1 (2.1%)	1 (2.1%)	23 (46.9%)	24 (48.9%)
I think that education should make better use of new media technologies.	1 (2.5%)	0 (0.0%)	3 (7.5%)	21 (52.5%)	16 (40.0%)	0 (0.0%)	1 (2.1%)	1 (2.1%)	22 (44.9%)	20 (40.81%)
I think real life is migrating online for many millions of people, in its personal, social, economic, educational and even political aspects.	1 (2.5%)	0 (0.0%)	1 (2.5%)	26 (65.0%)	13 (32.5%)	1 (2.1%)	0 (0.0%)	0 (0.0%)	21 (42.9%)	18 (36.7%)
I feel that video games can have educational value.	1 (2.5%)	1 (2.5%)	1 (2.5%)	25 (62.5%)	12 (30.0%)	0 (0.0%)	1 (2.1%)	1 (2.1%)	25 (51.0%)	15 (30.6%)

The rankings on the scale indicated the following levels of agreement: 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree and 5 = strongly agree.

3.2 Engagement with the Digital Game

Participant feedback indicated that some participants found the digital game an engaging means of revising anatomy subject matter, by enabling integration of anatomy knowledge during revision. However, participants indicated there were some technical barriers to engagement with the game, such as web browser compatibility issues that were barriers to engagement. Exemplar quotes in support of these findings are detailed in Table 4.

In total eleven of the 91 (12.1% of the entire unit of study cohort) participants in the intervention group provided feedback via free text on the post-intervention online survey, and an additional six of the 91 participants in the intervention group (6.6%) consented to complete a semi-structured phone interview. There were four (66.7%) female and two (33.3%) male interviewees. This broadly aligns with the intervention group, which consisted of 57 (63.3%) female and 33 (36.7%) male participants. Although participants had the opportunity to win a prize for responding to the post-intervention survey, response remained low. It is possible this was because the survey was disseminated at the end of semester when participants were preparing for examinations and going on holidays. Analysis of survey and interview feedback indicated that most participants found the digital game an engaging means of revising anatomy for their unit of study. The digital game also engaged participants by providing a complementary revision tool to textbooks and other methods. Overall, participants found the interactivity of the game and elements of the game, such as the network of subject nodes that made up a game map, engaging and enjoyable. Refer to Table 4 for exemplar quotations exploring participant engagement.

Table 4. Exemplary Quotes from Semi-structured Interviews with Intervention Participants, Group by Categorization of the Quote Content

Category	Quote	Participant
Engagement with game	"I thought it was really brilliant. Yeah, it really gave me a really good first-hand impression of the content. Even though I played alone it was enjoyable, and would want to play it again. It was a valuable learning experience." "I thought it was really brilliant. Yeah, it really gave me a really good first-hand impression of the content. Even though I played alone it was enjoyable, and would want to play it again. It was a valuable learning experience."	Male A, 22, Physiotherapy
Use for revision	"I felt like it was good, after a study session. I'd probably study for two hours and then I'd spend fifteen minutes on the game. Just to sum up what I've been doing. It was good. It put everything together to test my knowledge at the end."	Female B, 20, Exercise Physiology
	"I found that it was really good having that access to the game. It really boosted my confidence before going into exams, when I was getting all the answers right on that game. That's very helpful when you're stressing out."	Female A, 20, Exercise Physiology

Usability challenges	"we didn't have enough time to choose an answer and then write out the whole thing. I did like the time limit because it made me decide quickly and have to really think about what my answer was - what it would be in our tests and stuff - but I just never found time to write it all out. If we had to write maybe a bit less, maybe shorter answers, or like with the A-B-C-D thing, where you just hit A, hit B, hit C. I reckon it would improve it dramatically."	Female A, 20, Exercise Physiology
Barriers to team-based play	It's a bit hard to organise groups because everyone's got things going on. I think if its organised by someone other than us, I think we would have a greater chance of doing it in teams. But if it's just up to us, I think everyone would just sort of go back to their own individual studies.	Female B, 20, Exercise Physiology

Although the digital game successfully engaged participants, there were elements of the digital game that were considered challenging to use. Multiple participants found the combination of the time limit and the need to type out the correct response, which consisted of one to four words, difficult. A single participant encountered some technical issues accessing the game as they did not realize that the game was only optimized for certain web browsers. Participants understood the intent of reinforcing their knowledge and spelling by typing the answers but felt in that it complicated the process.

Although the digital game was designed to be played in teams, the majority of participants played single player time trial games throughout the semester. This trend was discussed with participants during the semi-structured interviews, in order to gain insight into why participants had predominantly used the game as a single player experience. Interview data revealed the lack of structure to support team development is a significant barrier for participants wishing to organize multiplayer games.

Analysis of interview data revealed that participants were keen to engage in team-based digital game play, in spite of the difficulty arranging multiplayer games throughout the semester. Feedback was very positive regarding using the digital games in study groups in order to add variety and promote friendly competition into sessions. Alternatively, participants suggested the game could be used as a warm-up exercise before anatomy laboratories or lectures, where groups of students were together and waiting for sessions to start.

Feedback on the intervention revealed how participants had integrated the digital game into their revision processes during the semester. The digital game was used to support short cycles of revision after lectures and practical classes progressively throughout the semester. Using the digital game in this way allowed participants to identify how much information they had gained during a lecture and identified areas in which they needed to undertake further revision. Alternatively, some participants integrated the digital game into study blocks, using it to break up textbook revision or to identify the impact of a revision session.

Finally, some participants reported that using the digital game increased their confidence in their anatomy knowledge. This increased knowledge had the potential to reduce stress about the subject.

3.3 Impact on Academic Performance

The digital game was equivalent to traditional for revising and consolidating anatomy subject matter. An independent samples t-test showed no significant differences in examination results between students in the intervention group (M = 51.91, SD ±11.16) and students in the control group (M = 50.56, SD ±12.15); t (155) = 0.73, *P* = 0.47. A Kolmogorov–Smirnov test indicated the data are normally distributed. The upper bound t= -3.03 and the lower bound t=4.48 are highly significant with 153df based on Welch's t-test and p < .001 for both one-sided t-tests, since both t-tests are statistically significant, we can declare equivalence.

4. Discussion

The study described in this article aimed to explore the acceptability of using a series of digital games to engage first-year university students in anatomy learning and revision. Findings from the study present an incremental contribution to the literature on the use of digital games in anatomy and histology revision. The findings from this study suggest that some students engaged with the game because learning anatomy through this medium was enjoyable compared to using the traditional quizzes, and that the game increased consolidation and integration of anatomy knowledge during revision. The secondary aim of this study was to determine whether a digital game could support an equivalent or higher level of academic performance as other existing revision methods. The findings of this study would support the thesis that digital games equivocally enhance academic performance compared to traditional methods of learning (online quizzes), and can be equally as effective if designed in a manner that is constructively aligned to assessment tasks as has been done in other studies (Biggs, 2003).

An emerging body of literature exists on the attitudes of faculty and students on the use of new media such as digital games to contribute to enhance health and medical education. Findings from this study contribute to the current literature by demonstrating that students enrolled in a first-year anatomy unit are supportive of the use of digital games in education. This finding reinforces existing literature reporting that nursing and medical students are supportive of the use of new media such as video games in their education and training (Kron, Gjerde, Sen, & Fetters, 2010; Lynch-Sauer, VandenBosch, Kron, Gjerde, Arato, Sen, & Fetters, 2011). However, it has also been established in the literature that students do not always know what the best way for them is to learn specific matter (Kirschner & van Merriënboer, 2013). Balancing student enjoyment with educational impact is a significant challenge with digital games, that is yet to be fully resolved, but is particularly pertinent with educational games that must balance education with entertainment (Denham, Mayben, & Boman, 2016). The research presented in this article also contributes new findings on health students' familiarity with and usage of commercial video games. These findings show that there is a low level of commercial digital game usage amongst Australian allied health students. While most have some level of familiarity with the

medium, regular game players are in the minority. Furthermore, the occasional to rare usage of commercial digital games in the study participants made it unlikely that the use of a digital game for revising course content would fuel addictive game behaviors in participants (Thomas & Martin, 2010). Interestingly, in spite of the low usage of commercial digital games, there is widespread support for the use of digital games to augment university education.

In spite of enthusiasm for the use of digital games in university education from learners, findings from this study indicate that the design of the game has a central role in uptake and engagement with the serious game by learners. There is currently little emphasis in the literature on the design of serious digital games for health education. However, research is beginning to emerge in the broader literature on the design of serious digital games (Denham, Mayben, & Boman, 2016). One of the central challenges undertaking research relating to game design is the diversity of digital games available, making comparison of design elements across different studies challenging. Some researchers have attempted to overcome this by designing studies that compare individual game mechanics to the same intervention without those mechanics, in order to explore how learners, engage with game design elements (Attali & Arieli-Attali, 2015). In this study findings indicated that certain elements in the design of the game were challenging for participants, particularly the timer mechanism. In order to overcome this additional play testing of the digital game would have been required by content experts, to ensure the time limits for answering each question aligned with the complexity of the content.

Findings from this study build on existing literature that educational digital games have the capacity to engage health learners. This literature has shown the impact of digital games on engaging learners across a range of subject areas in health, including geriatrics (van de Pol, Lagro, Fluit, Lagro-Janssen, & Olde Rikkert, 2014), diabetes management (Diehl, Gordan, Esteves, & Coelho, 2015), and pediatrics (Fonseca, Dias, Góes Fdos, Seixas, Scochi, Martins, & Rodrigues, 2014). Findings from this study demonstrated that a digital game can be an effective means of engaging learners in continuous anatomy revision for the duration of a unit of study. Specifically, digital games provide learners with a tool to embed into their existing revision structures, adding variety to study sessions. Additionally, the digital game in this study provided learners with a means of determining the impact of their revision approaches, by identifying knowledge strengths and weaknesses across the subject matter of the anatomy unit of study. Investigating new methods for supporting revision in anatomy and histology is important, due to the challenging nature of this subject area for many health students (Jones & Harris, 1998; Smith & Mathias, (2010).

Although findings indicated some learners enjoyed their experiences with the digital games, it is unclear whether this outweighs the resource and cost-effectiveness concerns of using digital games. Licensing or purchasing commercial digital games can be expensive, as is developing bespoke digital games. Furthermore, populating digital game platforms, such as the one used in this study, requires the time of content matter experts and education officers to input content into the digital game platform. Although these factors do reduce the cost-effectiveness of digital games for learning, it should be noted

that in this study a comparable amount of time was contributed by such individuals to develop and input resources for the online learning management system. While digital games in learning have implications for cost-effectiveness, it must be remembered that the literature has identified that cost-effectiveness can also be a factor in non-game based online learning resources (Bacow, Bowen, Guthrie, Long, & Lack, 2012; Hollands & Tirthali, 2014).

Finally, this study contributed new knowledge on the use of multiplayer digital games in health education. Although there is some evidence collaborative games can be effective tools for teaching science education in some contexts (Smith & Chan, 2017), there is currently minimal literature on the use of multiplayer games in health education. The research that has been undertaken on collaborative digital games has focused on the ability of these types of games to engage learners (Mann, Eidelson, Fukuchi, Nissman, Robertson, & Jardines, 2002), and assess learner attitudes towards multiplayer digital games (Sward, Richardson, Kendrick, & Maloney, 2008). Findings from this study align with literature that reports that learners are supportive of the use of multiplayer games in education, valuing collaborative approaches to learning and revision. However, this study reveals that supporting multiplayer gameplay in large cohorts can be challenging, particularly for students in their early university training who have few existing social networks. It has been established in the literature that digital games are most likely to increase learning if they are embedded in addition to other resources and structures (Dankbaar, 2017). However, there is little literature on how to facilitate collaborative digital game play in university and adult learners. Findings from this study provide some strategies for improving implementation of multiplayer digital game-based learning in health education. These strategies include embedding the use of games at the start of existing small group activities such as laboratories and clinical training groups.

4.1 Limitations

A limitation of this study is the small number of participants who provided feedback on the intervention. The feedback provided allowed the researchers to draw important insights on student experiences with the digital game, areas for improvement and enablers to implementation of multiplayer games, but a larger number of respondents would have strengthened the conclusions and generalizability of this study. Future researchers should consider designing studies which incorporate the collection and comparison of quantitative engagement data on the use of digital games. Such data could include user metrics such as time spent playing digital game compared to time spent using multiple choice questions, participant ranking of replay value and changes in participant attitudes towards digital games for anatomy and histology revision. Additionally, future research should consider exploring questions about aspects of the design of digital games, such as whether time restriction inhibit or stimulate learning and whether a team-based strategy games are better than other forms of game to enhance learning. This could best be determined using questionnaires of proven reliability and validity. Finally, the collection and analysis of metrics collected by game platforms such as time-on-task would benefit from additional research.

5. Conclusion

The use of digital games, particularly those designed to support collaboration, to supplement the delivery of education and training has appeal to university level health students. Digital games have the capacity to engage learners in ongoing revision, which is important for long-term retention of knowledge. When and how digital games are embedded in to university curriculums has a central role in the likelihood students will engage with the digital game. A key implication for educational practice is ensuring supports are integrated into curriculums to facilitate game-play experiences, particularly with team-based games. The use of digital games should support collaborative game-play experiences for learners, especially those in large cohorts early in their study who may have less familiarity with their peers. However, it remains to be seen whether the resource commitment, in the form of time and cost-effectiveness, outweighs the benefits of alternative methods for supporting learner revision of anatomy and histology subject matter.

Acknowledgements

The authors wish to thank Darren Reed for contributing to the development of content for the multiple-choice questions used in both the digital game and blackboard revision tools used in this study. The authors also wish to thank Janny Chen for her ongoing administrative support over the course of this project. Additionally, the authors wish to thank The University of Sydney for funding this research, through the award of a Strategic Education Grant. Finally, the authors wish to thank all the participants in this study for volunteering their time to support this project and further understanding on the use of digital games in health education.

Funding Sources

This work was supported by a Strategic Education Grant from The Office of Teaching and Learning, The University of Sydney.

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