Investigating the use of Serious Games for teaching anatomy and physiology to higher education students

Research into Serious Games

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Copyright Statement

Abstract

This report gives a case study account of an investigation into the use of serious games for teaching anatomy and physiology to higher education students. The investigation attempts to show how such technologies can be used as effective learning solutions to problems faced in education today. Two types of serious game were designed and developed for the project, namely an educational game and simulation which aimed to teach the cardiovascular system to foundation level students in the School of Human Health Sciences at the University of Huddersfield. Informal discussions and formal tests were conducted over the course of the year, providing valuable feedback regarding the project objectives. Both products were met with student approval, who felt them to be effective learning tools in their own right and compared to traditional methods of teaching and learning.

Acknowledgements

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Chapter 2. Introduction

This research project addresses theories which suggest the education system is faced with a new generation of digital learners, which Prensky (2001) and Tapscott (2009) label as 'digital natives' and the 'net-generation' respectively. There is a need for more effective methods of educating which not only appeal to these new learners but which address some of the shortcomings of traditional teaching methods. The background of this research suggests such shortcomings as the difficulties experienced when trying to teach heavily visual and tactile reliant topics, in typically static and passive manners.

The overall goal of this research is to show that serious games can be an effective solution to such problems, with the aim of investigating a hypothesis which states that if two types of serious games (simulations and educational games) were to be applied to a single topic, it would be the educational game that would prove to be the more effective learning tool. Initial literary research will be undertaken to clarify many of the definitions surrounding the field of serious games and also to give evidence for the use of serious games as effective educational solutions. To investigate the problem and hypothesis, two products will be made with the aim of teaching foundation level students studying on the *Foundation Course for the Health Professionals* pathway, and specifically those studying the *Introduction to Anatomy and Physiology* module at the University of Huddersfield, the topic of the cardiovascular system. The project's researcher will work with Dr Jenny Killey of the School of Human and Health Sciences, who will act as the subject matter expert and client of the software to be developed.

The developed software will be tested over the course of the year using a mixture of quantitative and qualitative methods. As will be shown while the original methodology only included the specific target audience as the test subjects, circumstances during the project required the expansion to include a second set of participants. The teaching and learning experiences of students in higher education will be analysed and the applicability of Prensky (2001) and Tapscott's (2009) theories will be commented on. Furthermore the effectiveness of each piece of software and which software is deemed to be most effective overall will be stated.

This report will begin by introducing literary research surrounding the background of the field being investigated. The remainder of the report will act as a case study for the process of developing educational software for a specific topic. The following will be covered:

- Methodology for the carrying out the project, including the project objectives, outcomes and outputs.

- Initial research into the client, target audience and subject matter.
- The design process for each piece of software developed.
- The development process for each piece of software developed.
- Project management of the development.
- Testing methodologies.
- Result analysis.
- Evaluation of project objectives.

Chapter 3. Literature Review

3.1. Investigating the term 'Serious Games'

3.1.1. 'Serious Games' at a glance

The use of the term 'Serious Games' is becoming ever more prevalent in research and development communities (Susi, Johannesson and Backlund 2007); a term which the Serious Games Initiative has been supporting since 2002 (Carriker 2011; Serious Games Initiative 2011). With a market value estimated at being worth $1.5 – 2 billion in 2008, such applications are a valuable and important form of digital learning solution (Alhadeff 2008). What is perhaps less clear is what the concept itself actually means.

Following a brief survey of literature relating to the field it is obvious that there is no single definitive definition of the term. A common finding seems to be that serious games are simply games in which education is the primary goal rather than entertainment (Michael and Chen 2005; Susi, Johannesson and Backlund 2007; Gelperin and Enterprises 2011); a view which is supported in more detail by de Freitas (2006), who describes them as software which uses the qualities of traditional computer games to create learning tools which have the potential to be both engaging and immersive.

Further investigation however reveals other more ambiguous definitions of the terms. Raybourn and Bos (2005) quote the Serious Games Initiative (2011) as describing serious games as *'applications of interactive technology that extend far beyond the traditional videogame market'*; this definition is very broad and could conceivably encompass a number of types of application. Other names such as simulation, edutainment, digital game based learning, virtual learning environment, virtual reality, social impact games, games for change and persuasive games are used to describe applications that are associated within the umbrella term that is 'serious games' (Ludus 2010) (Carriker 2011). A consensus on terminology of serious games is down to a lack of cohesion between research and development communities according to de Freitas (2006).

3.1.2. What's in a name?

For the purposes of this report it is important to further investigate some of the main taxonomies surrounding the topic and in doing so we will be able to:

- Define the types of applications that are the subject of and are to be created for this research – games and simulations – whilst also discussing other important nomenclature associated with the term serious games.

- Comment on the place of games and simulations under a collective term.
- Suggest use of a better definition for the term ‘serious games’

3.1.2.1. Games

Wittgenstein (2009) suggests that to define a game is a difficult task, theorizing that while comparison of different forms will reveal similarities and relationships, no specific commonality to all forms will be apparent. In opposition to Wittgenstein’s view, comes a set of proposed common characteristics of games (Dempsey 1996; Kramer 2000):

- Games are a set of activities which involve one or more players.
- Games are rule based systems.
- Games involve constraints and consequences for the player, consequences which can be negative or rewarding in their nature.
- The course of a game is never the same, there is always an element of chance
- Games always involve aspects of competition, whether it is against an opponent or with oneself. Most games have goals that can include victory conditions or strategies for winning are also intended to be engaging and fun.

3.1.2.2. Computer Games

Computer games have become an incredibly popular and valuable form of entertainment. From crude beginnings in the 1950s and 60s in the form of games like *Tennis for Two (1958)* and *Spacewar!* (Graetz, Russell and Witaenen 1961), games have developed vastly in all aspects including technology, visuals and design as can be seen in the comparison within Figure 1.

Figure 1 - A comparison of Spacewar! 1961, to Battlefield 3 2011 (Unknown 1962; EA Digital Illusions CE 2011)

With an estimated global market value of $31.6 billion in 2006 and rising to $48.9 billion in 2011, computer games have become the third fastest growing sector of the entertainment and media market after TV and internet (Scanlon 2007). Statistics show that 72% of American households play computer games and the average gamer has spent 12 years playing games, which suggests great value of computer games in terms of both monetary and audience potential (Entertainment Software Association 2011).

3.1.2.3. Educational games

If we investigate the taxonomy of serious games in its strictest form of definition as that of an educational game, we can describe such an application as a blended package of game element and pedagogy. These features lead to learners being motivated by and immersed into the objectives and purpose of a learning interaction (Aldrich *et al.* 2007). Educational games at the most fundamental level are designed to improve some form of learning (Derryberry 2007). Examples of some educational games can be found in Appendix A1.

One of the products of this Masters project will be an educational game, which will feature as many of the characteristics that are outlined in section 3.1.2.4 as possible.

3.1.2.4. Common characteristics

Whilst we have attempted to briefly define traditional computer games and educational games separately, the commonalities between the two must also be discussed. The following is a list of characteristics that are present in computer games regardless of the game's end purpose, be it entertainment or education (Derryberry 2007; Prensky 2007).

1. **Rules –** Are the constraints in all areas of gameplay that restrict a player's actions and abilities
2. **Goals and Objectives –** These are what the player aims to achieve whilst playing a game. They form a big part of the motivation for the player; trying to beat your high score or collect all the items and beat the game can incite replayability.
3. **Outcomes and feedback –** Are how the player measures their progress against the goals that they have. Feedback takes place when the game changes in response to your actions. Often this is as simple as giving the player some form of numerical feedback during play in the form of things like time and score, but feedback can span a variety of feedback forms covering the visual and aural senses. Players can *hear* feedback from non-player characters or *visually* see how much damage they have received in many first person shooters for example through a reddening and blurring of portions of their view, an effect which is shown in Figure 2.
4. **Conflict/ Competition/ Challenge/ Opposition –** Forms the basis of any game, it is usually these factors that make a player want to experience a game and continue playing. Prensky

(2007) describes these as problems that a player is trying to solve during a game. Competition might be against the game, one's self or other human players.

5. **Interaction –** Comes in two forms in games today; first and foremost it describes the interaction between player and computer/ game, secondly it can be the social interaction of the player with friends locally or across the internet.
6. **Backstory or Story –** This is any narrative or story used in a game.
7. **Sensory environments –** The environments are what are formed from the 2D/ 3D graphics and sounds of the game.

Figure 2 - Screenshot from *Call of Duty: Modern Warfare 2* showing visual feedback of damage to player health (Gamespot 2009).

3.1.2.5. Simulations

Simulations are representations of theoretical processes, mechanisms or systems. They are often used to recreate real life situations whilst minimising involved risk for the user (Ludus 2010). Generally simulations are developed to allow learners to interact in situations that are impractical or expensive to achieve in the real world. In comparison to games, simulations often lack fantastical elements and so they tend to be more focussed on the learner's education in specific contexts (Charsky 2010). Gredler (1996) splits simulations into two categories; experiential and symbolic simulations. Experiential simulations place learners in a professional role such as that of a surgeon or business man. In such instances users must make decisions in a problem based system in order to accomplish goals (Charsky 2010). In these simulations the player/ user is a functional part of the simulation (Gredler 1996). Symbolic simulations involve the dynamic interaction of two or more variables (Gredler 1996). These types of simulations allow students to work in an environment where they are able to experiment with multiple strategies to the end of improving their understanding of events, practises and principles (Charsky 2010). In comparison with role based experiential simulations, symbolic simulations are focussed around allowing students to observe things which are either too difficult, dangerous or outright impossible to show in real world situations, such as speeding up or slowing down time or working with hazardous materials free from potential harm (Alessi and Trollip 1991). Some examples of simulations can be found in Appendix A2.

The second product of this Masters research project will most closely resemble what Gredler (1996) describes as a symbolic simulation.

Another main taxonomy surrounding the topic is that of virtual worlds or virtual learning environments as they are also known. This taxonomy is not a main focus of the project, however detailed information can be found regarding such applications in Appendix A3.

3.1.3. Can a collective term be used?

Thus far in this report we have stated that there is an ambiguous use of terms and definitions when discussing serious games, commenting on the cause of the confusion and subsequently clarifying some of the main taxonomies associated with the term. In doing so we have clearly defined what the two products of this research project are in terms of the characteristics that they will display. Two questions remain however; are we justified in investigating the effectiveness of two types of applications (games and simulations) whilst labelling them under a collective term (serious games), and is there a better definition for applications such as these and others that are associated with serious games?

3.1.3.1. Justification of a collective term

Aldrich (2004) states that the only way to understand simulations is to become familiar with today's computer games, going on to say that games are not educational simulations but the two forms of software share many of the structures, standards and techniques built into simulations. Due to the similarities it can become very difficult to discern a game from a simulation. Many games are often conducted within simulated environments and simulate environments, events, acts, processes and procedures themselves. Simulations typically revolve around the user's role or responsibilities and rarely use some of the features which games express such as fantasy representations (Caspian Learning 2008; Charsky 2010). Games also have many more aspects to them in regards to the list of characteristics of games formed from work by Prensky (2007) and Derryberry (2007). Speaking of virtual worlds Carr (2010 cited in Ulicsak and Wright 2010) asks the question of whether virtual worlds can be classed as serious games, stating that if by definition games are goal, rule based systems then virtual worlds such as *Second Life*(2003) are not games, however they go on to say that some could describe it as a game because it supports fantasy and identity play. While Gredler (1996) clearly separates games from simulations in her definition of the two - referring to the lack of winning goals in simulations but rather a goal of discovering relationships for instance, she also acknowledges the presence of applications which blend characteristics of the two describing them as 'simulation games' or 'gaming simulations' (O Neil, Wainess and Baker 2005; Jonassen 1996).

Smed, Kaukoranta and Hakonen (2002), and Caspian Learning (2008) have attempted to display this crossover and convergence of the main taxonomies we have investigated using the following diagrams seen in Figure 3 and Figure 4.

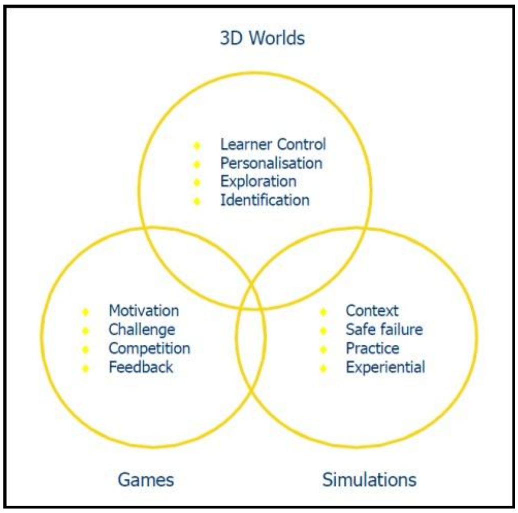


Figure 3 - A Venn diagram which shows the 'crossover' relationship between 3D Worlds, Games & Simulations (Caspian Learning 2008)

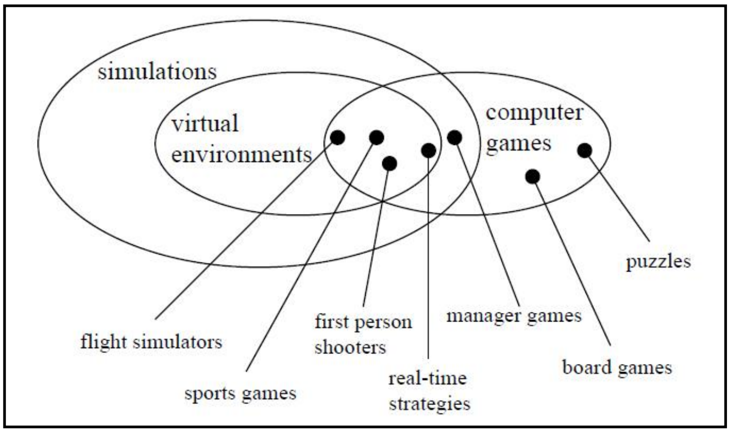


Figure 4 - A further diagram which attempts to shed light on the relationship between the main areas associated with serious games (Smed, Kaukoranta and Hakonen 2002)

While simple, these diagrams offer the clearest insight into the close relationship that is present between the types of applications that are associated with serious games, it is the author's opinion that because of this relationship the use of a collective umbrella term is warranted when discussing and investigating these types of applications.

3.1.3.2. Refining definitions

Using the term serious games may not be the most ideal nomenclature due to the connotations and preconceptions that the word ‘games’ brings about, so it could be suggested that it would be better to develop a new term to try and better encapsulate these types of applications, like that of Aldrich et al’s (2007) attempt ‘immersive learning simulations’. A survey carried out by the eLearning Guild asked it’s member base what their preferred term was for such applications. Figure 5 shows that overall 52.8% of members asked agree somewhat that the use of the word game is problematic and Figure 6 shows that overall 70.73% of members would rather use the term ‘immersive learning simulation’ over ‘serious games’.

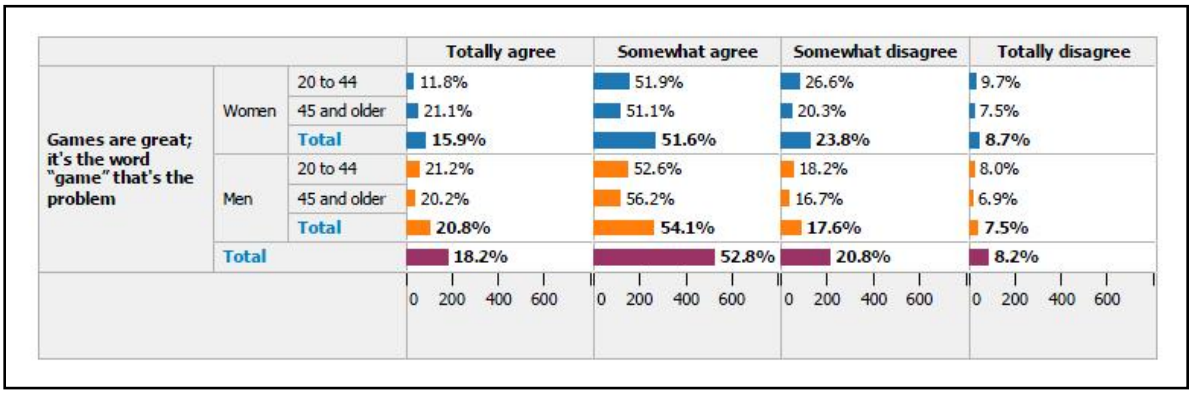


Figure 5 - Survey results showing aversion to the use of the word 'game' when describing and attempting to sell these sorts of applications (Aldrich *et al.* 2007)

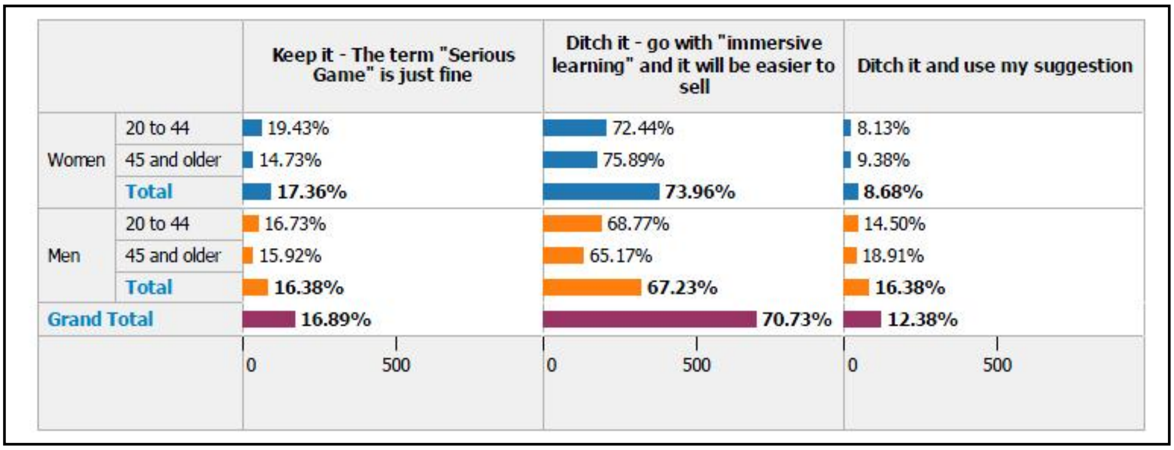


Figure 6 - Survey results showing a high desire for the use of a substitute term for 'serious games', in this case 'immersive learning' (Aldrich *et al.* 2007)

While the e-learning guild report provides compelling evidence, it is the author's opinion that in a climate where the term serious games has gained a lot of traction and is currently in widespread use, a new term would serve to only confuse matters further. A better course of action would be the continued use of the term serious games but with a more refined definition, such as,

"Serious games are the application of games technology, processes and design for purposes other than pure entertainment, as a mean of solving problems faced by educators and other organisations."

For the purposes of this report, from now on the term serious game will be used to refer to software which matches this description.

3.2. An effective learning solution in current educational settings

3.2.1. Overview

We have yet to properly establish what makes serious games effective learning tools and in terms of the context of this research project, why serious games could and should be used in educational settings - in this case in a higher education setting. The answer to these questions will be discussed from the following three perspectives:

- The learning benefits of serious games.
- The generation of new learners in education.
- The limitations of current methods of teaching and the learning materials available to students.

3.2.2. New learners

The first perspective on the possible reasons for using serous games in current educational settings focuses on a change in the learners themselves. The main leader in the literature surrounding this topic is Marc Prensky who suggests that students of today have not changed incrementally as has happened between previous generations but rather what Prensky (2001) describes as a large 'discontinuity' has taken place, resulting in a fundamental change in learners. The cause of such a change is the arrival and assimilation of digital technologies into every aspect of learner's lives in the past few decades. Learners of today have grown up not knowing a world without computers or being surrounded by digital images, video, music or mobile phones for instance (Prensky 2007). Prensky (2001) states that higher education graduates have spent less than 5,000 hours of their lives reading compared to 10,000 hours playing video games and 20,000 hours watching TV. The word that he uses to describe these learners is 'Digital Natives', people who are 'native speakers' of the digital language. The theory is one which is shared by many others; Tapscott (2009) states that the defining characteristic of an entire generation of learners was that they had 'grown up digital'. The term that Tapscott (2009) uses to identify this new generation is the 'Net Generation', whereas Veen and Vrakking (2006) use the term 'Homo Zappiens'.

Those that were not born into the digital world but have gradually begun to adopt digital technologies are what Presnky (2001) calls 'Digital Immigrants', and this is the other part of this problem with current education - instructors who are digital immigrants are struggling to teach their digital native learners because a digital language barrier exists between the two groups. Instructors think that methods of old still work and are applicable to students of the new age.

Some of the attributes of digital natives suggested by Prensky (2007) and 21st Century Fluency (n.d.) are as follows:

Multi-taskers – More comfortable carrying out multiple tasks at once.

Visual learners – Text is secondary to images for this generation. Whereas previously visuals were used to clarify text, now the opposite is true. Text is an accompanying clarification of present images etc.

Resource gatherers & fast processors – Digital learner's ability to make connections has increased because they prefer to take information from multiple sources and can process the large amounts of information they access at a high rate. Immigrants prefer slow release of information from limited amounts of sources.

More connected – Raised in a digital world, natives are more accustomed to the ability to communicate with people anywhere in the world at anytime 24 hours a day with using asynchronous means such as email and forums or instant synchronous means such as instant messaging, texting and calling.

Active learners – The new generation are experiential learners, preferring to learn through doing rather than being told to do.

Instant reward - Digital learners prefer to be given immediate feedback with the potential for immediate rewards whereas immigrants prefer delayed rewards.

Fantasy vs. reality – Fantasy permeates the lives of the new generation to a much greater degree than that of earlier generations due to technological access, making it easier and more realistic.

Perception of technology – A high proportion of the immigrant generation view technology negatively. They can see it as an obstacle or something to be merely tolerated for their purposes, which is very different to the native generation.

3.2.3. Limitations of current teaching methods and materials

Current educational environments present limitations to the learner in terms of the way in which they are taught and the learning materials they are provided with. These limitations are often linked to the attributes of digital learners which are detailed in the previous section but can also be due to such things as the complex nature of the content being taught; as was found during this project.

The majority of analysis into the limitations surrounding learning materials come from the author's experiences during the research project and in particular the process of developing the two products of the project, and so will be covered in depth during later sections of the report, in particular sections 5.7 and 7.7, which respectively detail the informal interviews carried out during the research stage and the development problems experienced during the project.

One aspect which has required research is that of learning styles. Research into the learning styles that are catered for in current educational settings is a factor which was not an original research goal of this project; rather the need for further investigation came about from interviews carried out with the target audience of the project. During the interviews, lack of tailoring to personal learning styles was something which was cited often, where it was apparent that students who felt themselves to be visual and active learners were being taught in non-visual, passive ways. This is something which gives more credence to Prensky (2007) and 21st Century Fluency's (n.d.) attributes of the new generation of learners, where they suggest that digital learners prefer processing pictures, video, sounds and colours before text, whereas educators tend to provide text before utilising these mediums. There have been various models developed around the field of learning styles, from Anthony Gregorc's 'The Mind Styles Model' to David A. Kolb's 'Experiential Learning Model'. The one which will be used and investigated in this project is Neil Fleming's 1987 VARK model, as it is one of the most commonly used and widely accepted models available. It is also the model which every single interviewee referenced during interviews. Whether they were knowledgeable of the origins of the styles they were referencing at the time is unknown. In the model the learning styles are defined as the following (Fleming and Mills 1992; Fleming n.d.):

Visual – This preference includes the depiction of information in maps, diagrams, charts, graphs, flow charts, hierarchies.

Aural/ Auditory – This style describes the preference of information which is heard or spoken. Students favouring this mode learn best from lectures, tapes, group discussion and audible tutorials.

Read/Write – Learners favouring this style have a preference of learning through words. People who prefer this style like to learn through reading and writing.

Kinaesthetic – This is a preference to learning through experience or practise whether simulated or real, learners learn best through manipulation of items, simulations and practical's.

This is the basis of Fleming's style which will be used as part of this research; however the author feels that an alteration needs to be made to the originally proposed style. As part of the style Fleming (Fleming and Mills 1992; Fleming n.d.) specifically states that the 'visual' mode of preference does not include movies or videos, but gives little indication where these mediums should be placed. It is the author's opinion that these things should be included into this style, as it is the natural place for them to go as they are primarily a visual medium, and it is felt that this is will avoid confusion when it comes to testing the target audience of the project.

3.2.4. Learning benefits of serious games

The aspects of serious games which make them beneficial for learning are numerous. Disseminating these aspects down into those that feature in games and simulations is a difficult task however. As per the previous section regarding the often overlapping relationship of these applications (while not exclusively the case) the benefits are often common to both forms.

Further to the benefits described within section 3.1.2, where it was described that serious games open up possibilities that would be unattainable or impossible in real-world environments, serious games simulate dynamic environments where internal variables such as difficulty and timescale can be change instantly to match the needs of the participants or instructors. Being computer based, these systems allow for real time user interactions and so enables individuals to have immediate feedback, letting them know if they have succeeded (Linn *et al.* 2008) (Csikszentmihalyi 1991).

When learners use serious games they become active participants in learning rather than passive observers, by becoming so they are part of the knowledge construction process, and doing so elevates learning potential (Driscoll 2002; Prensky 2007). An active participant is one who is learning by experience, serious games offer an experiential learning environment to the learner, allowing for reflective observation which can lead to new theories and then onto active experimentation and application of knowledge by the learner (Kolb, Rubin and McIntyre 1984; Caldwell College n.d.). Serious games can provide multiple representations of content in ways which are perhaps more accessible than traditional learning mediums. Furthermore one of the key aspects of these applications is their ability to make abstract or complex information more accessible so providing opportunity for comparisons to be drawn of the relationships between multiple concepts. In drawing these comparisons learners form connections and so construct further meaning from their experiences (Linn *et al.* 2008; Lindgren and Schwartz 2009; Scardamalia 2002; Gee 2003; Rieber 1996). Fun and engaging are terms often cited in literature surrounding the subject of the benefits of serious games. While it could be argued that simulations are not necessarily fun to use, both terms can have the same outcomes, that of enjoyment and pleasure (Prensky 2007). Enjoyment and fun are important parts of the learning process as they promote motivation and lead to a greater willingness to learn in the first place and a desire for a recurrence of the experience (Bisson and Luckner 1996). A significant feature of serious games which is closely associated with the previous points regarding fun and engagement is the potential of inciting the concept of flow in their users. Flow is a concept by Csikszentmihalyi (1991) which suggests a state in which a person becomes fully immersed in a task or activity to the point that nothing else matters. The experience of carrying out that task or activity is so enjoyable people will continue doing it just for the sake of it (Dietz 2004). For Csikszentmihalyi's *'flow'* to take place certain conditions must be present, conditions which are readily apparent in serious games. These conditions are:

- A challenging activity that requires skills to complete; too high a challenge will result in anxiety, too low a challenge and boredom will ensue.
- Clear goals and feedback about participant progress.
- Concentration on the task at hand; so much so no other thoughts intrude apart from those directly relating to the activity.
- A sense of control in difficult situations.
- Loss of self-consciousness; the participant merges with the activity.
- Loss of time; hours seem like seconds and second like hours.

3.2.4.1. Case studies

Across the literature there are multiple studies which show statistical evidence for the positives brought about through use of the two types of software that are being investigated. In comparative studies conducted at DeVry University by Blunt(2007) - which attempted to examine the difference in academic achievement between students who did and did not use video games in learning, Blunt found that students using games scored significantly higher than those who did not - shown in here in Figure 7.

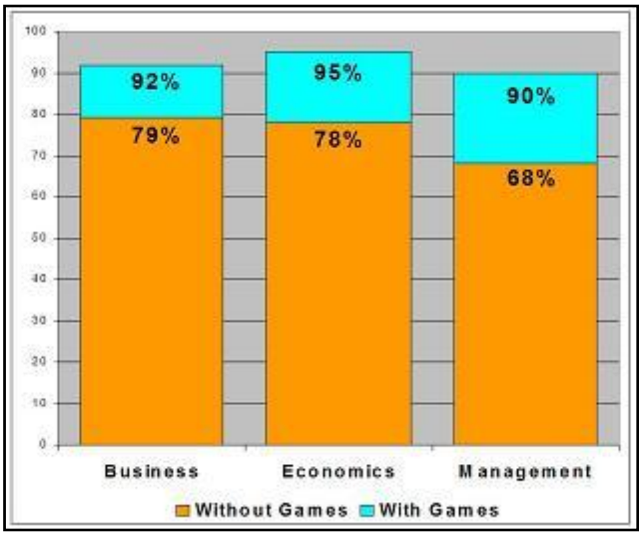


Figure 7 - Data showing the comparative results of students who use video games to learn and those who did not (Go Venture n.d.; Blunt 2007).

In a study focussing on supporting student experimentation strategies as they interact with a complex visualisation of the greenhouse effect Linn et al. (2008), found that post-test scores regarding understanding of the greenhouse effect were reliably higher than pre-test scores. Further evidence of the significant gains in student understanding comes from Keller et al. (2007) who showed that students who were shown a simulation of the behaviour of electric circuits showed statistically higher gain in conceptual understanding, compared to students who were either only shown a demonstrations or provided with a verbal explanation. Furthermore in regards to the proposed motivational benefits given by literature it has been found that there was 'overwhelming' evidence showing that simulations which incorporate interactivity, animation and context are able to create effective and powerful learning environments (Adams *et al.* 2008).

3.2.5. Why games over simulations?

Apart from the research relating to the effectiveness of serious games detailed in section 3.2.4, very little information could be found which pertains to the comparative effectiveness of each type of software being focussed on for the project. The reason for the hypothesis is that it is this researchers belief that the potential of achieving Csikszentmihalyi (1991) state of flow is more likely to take place in games than simulations because games are likely to be a more enjoyable user experience than simulations. Furthermore good game design results in a balanced but challenging activity that should be neither to hard or too easy, so fulfilling one of the requirements of flow. Also games are focussed on clear goals and objectives, and throughout a gaming experience the player is given feedback as to their progress, so achieving yet another state of flow. Finally from personal experience, loss of time is a familiar aspect when playing games, which fulfils yet another state of flow. While such things could be said to be applicable to some examples of simulations, it is the fact that games do such things naturally that makes them potentially a better solution in this researcher's opinion. Also as research shows, when a learner is an active part of the experience they learn more effectively, and it is again this researchers opinion that game are likely to be more active experiences than simulations. Yes simulations require user interaction in terms of input, but typically they are cause and effect systems where the user is simply an observer of a process.

Chapter 4. Methodology

4.1. Overview

In order to achieve the objectives stated in the main introduction a method of content delivery to anatomy and physiology students studying at the University of Huddersfield will be investigated. The project will draw educational theory and scientific knowledge from the School of Human & Health Sciences as well as knowledge of software development, computer games and games technology from the School of Computing & Engineering.

An application using games technology will be developed to satisfy Dr Jenny Killey's base requirements of a product which will help teach students studying anatomy and physiology (A + P) about the cardiovascular system, with the potential for integration within A + P lectures, tutorials and online materials. Furthermore another application will be developed using the same brief for this author's research purposes. This project is in line with the University of Huddersfield's strategy on blended learning. The products that will be developed for the client will form part of the author's research into the application of games technology for educational purposes, a field known as serious games, where the focus will be on the comparative effectiveness of two forms of serious games - simulations and educational games. These are two forms of applications which while similar as per the suggestions of Caspian Learning (2008), and Smed, Kaukoranta and Hakonen (2002), deliver content quite differently, as will be shown later in this report.

The software to be developed specifically for the client's satisfaction will be in the form of a simulation or what Gredler (1996) describes as a 'symbolic simulation'. In addition to this piece of software - and in line with this researcher's aims - an educational game will be created alongside the simulation. This second product will also aim to satisfy the client's needs even though it has not been requested. The target will be to develop two different pieces of software which attempt to satisfy the same educational goals and which express some of the benefits of serious games which were suggested by the likes of Gee (2003), Lindgren and Schwartz (2009) and Linn et al. (2008) discussed in section 3.2.4. The software will be tested with the target audience and data will be gathered in regards to the student's experiences with each type of software, so allowing the researcher to comment on their proposed hypothesis that educational games can be a more effective learning tool in a given context compared to simulations.

It is the clients hope that by carrying out this research project the capabilities and expertise of participating fields will be demonstrated with the scope for expansion of the software to included all of the human body's eleven systems, plus integration within A + P lectures, tutorials and online resources.

4.2. Project objectives, outputs and outcomes

The following are the objectives, outputs and outcomes of this project:

- A simulation which integrates educational theory/ scientific knowledge of the client and focuses on the cardiovascular system. This product will satisfy the client's software requirements.
- An educational game featuring some if not all of the characteristics outlined by Derryberry (2007) and Prensky (2007) in section 3.1.2.4. This game will again integrate the educational theory/ scientific knowledge of the client and will focus on the cardiovascular system.
- Development of anatomical assets and animation which could be purposed for use outside of the developed software's environments.
- Analysis of the students in Higher Education:
    - Are they what Prensky (2007) describes as digital natives?
    - Feelings in regards to the manner in which they are taught.
        - Effectiveness of teaching methods.
        - Satisfaction of preferred learning styles.
- Evaluation of the effectiveness of each piece of software developed.
- Evaluation of the value of each piece of software compared to traditional methods of teaching/ learning materials provided to the students.
- Evaluation of the comparative effectiveness of the simulation and educational game.
- Establish whether there is a desire for serious games in higher education.

4.3. Expected challenges

Foremost of the predicted challenges which the researcher will face during development of the products of the project will be:

- **There is a possibility that the technical proficiency of the target audience could cause problems during testing phase.** The client is unaware of the familiarity and comfort the target audience has with technology. Whilst discovering their technical proficiency during any interviews, questionnaires or tests is something which is obviously going to be important and useful in determining whether the target audience can in fact be categorised 'Digital Natives', if they are not confident computer users they may struggle to overcome any learning curve involved in using the programs during testing, so effecting results.

- **The scientific proficiency of the researcher.** The researcher will need a high level of understanding of the subject content in order to design, develop and test two products that focus on a topic which is very scientific in nature. Furthermore in order to be able to properly project manage and direct the team that will be working on both products, the researcher will need to not only be able to understand the content, but pass on the knowledge to other people.
- **Timescales of development.** While effective project scoping by the researcher should mean that the development of two pieces of software in the time dictated by the research project (twelve months) should be achievable, there is obviously a risk involved that one or both of the products will not be finished in time, so limiting or removing the ability to test. In addition the researcher must work to deadlines dictated by the availability of the target audience for testing. The academic year of the target audience finishes at the end of April, meaning that both products must be available for test within seven months of beginning the project.

4.4. Evaluation methods

The methods of evaluation to be used in this project can be seen in Table 1.

Factor	Method of Evaluation	Measure of Success
Are higher education students studying the foundation level anatomy and physiology module ‘Digital Natives’?	• Questionnaires • Interviews with target audience	Data referring to what sorts of learning resources they use, whether they see themselves as computer literate, and computer game players will be used to assess this. Also direct student feedback will pertain to this outcome.
How effective do students feel the way that they are currently taught is?	• Questionnaires • Interviews with target audience	This will be based off the student’s own personal opinions about the way they are currently taught A+ P.
How effective is each piece of software as a learning tool?	• Questionnaires • Informal feedback • Networking	Whether the student’s feel the software aid in the understanding of topics concerning the cardiovascular system.
How effective is each software compared to traditional teaching methods and learning materials available to students?	• Questionnaires • Informal feedback	Discover how the students feel the effectiveness of each piece of software compares to traditional teaching format concerning the cardiovascular system.
Which software do they feel is the most effective learning tool?	• Questionnaires • Informal feedback	The students will test both and compare one piece of software to the other, judging which is the most effective or successful at conveying information regarding the cardiovascular system.
Is there a desire for serious game applications in Higher Education?	• Questionnaires • Informal feedback	Would the student’s wish to use applications like the ones developed as part of their university study.

Table 1 - Evaluation methods to be used in the project.

The following sections of this report will act as a case study for the development, implementation and test of the two products to be developed for this project. Experiences and problems encountered along the way will be discussed throughout and the following will be detailed:

- Initial research by the researcher into the target audience and subject matter, and the client relationship.
- Design stages of the development.

- Development of the software and the project management that took place during the project.
- Networking with subject matter experts and industry developers.
- Testing methodologies.
- Testing.
- Results and analysis.
- Evaluation of the project aims.
- Conclusions to be drawn from the project.

Chapter 5. Initial research and the client relationship

5.1. Client and target audience identified

5.1.1. Client

The client that will be collaborated with for the research project is Dr Jenny Killey of the University of Huddersfield. Dr Killey is part of the academic staff at the University, teaching anatomy and physiology to students within the School of Human and Health Sciences.

The level of knowledge of the client in the subject area being researched and in terms of their own computer literacy was by their own admission relatively low. Indeed the researchers own level of knowledge in the client's subject area was also restricted. It was apparent in the early stages that the client did not know what to expect as a result of the development.

5.1.2. Target audience

The target audience of the software to be developed will be students studying anatomy and physiology at a foundation level in a university setting. In terms of the specific group of people that will be focussed on and collaborated with for this research, Dr Killey's students studying on the *Foundation Course for the Health Professionals* pathway, and specifically those studying the *Introduction to Anatomy and Physiology* module. These students will be used during the initial research stages of the project to hone the product feature requirements and participate in informal interviews regarding such things as student computing experience, learning experiences and expectations of their course.

The module aims to introduce students with little or no advanced level of knowledge to the topic of human anatomy and physiology. The main focus of the module is the theories surrounding the anatomy and physiology of the major bodily systems, with some discussion of the application of the knowledge in clinical situations. The aim of the module is to provide the knowledge and understanding necessary for the student to progress onto degree level courses. In terms of the level of knowledge expected from students, they must be able to demonstrate a basic understanding of the anatomy and physiology of the human body and have a basic understanding of how structure relates to the function of elements of human anatomy and physiology. On completion, students must be able to identify the major anatomical features of the human body and demonstrate the ability to observe and analyse basic physiological findings. Further information on the target audience can be found in the module specification of *Introduction to Anatomy and Physiology* module found in Appendix B.

5.1.2.1. Considerations

Some considerations which should be taken into account in regards to the target audience, which were in part put forward by the client, are:

- Students come from a variety of academic backgrounds – there may be those who have studying O levels, GCSEs or to college level. There may be students who have come straight from another level of education system or some have not been part of the education system for many years.
- Students will have varying learning style preferences – something which will be discovered and discussed in section 5.7.5**.**
- Students will have a variety of levels of computer literacy.
- The level of content within the products will need to be accessible and understandable to those that are new to the content and yet still satisfy the required learning outcomes.
- Simplicity will be key here in terms of software design.

5.2. Requirements from the client

Upon commencement of this project, the requirements of the software from the client were very brief. From their point of view they wished for software which could be used in the lecturing environment or provided to students to facilitate in the learning of the subject matter of the anatomy and mechanisms of the heart. It is important to again reiterate that the client was predominantly interested in a single piece of software being developed as mentioned previously in the report; all requirements were for one application. At its most basic the program must:

- Educate about the structure and anatomy of the heart.
- Educate about the mechanics of the heart (why things happen and what it looks like).

In order to try and better establish what the client wanted/ expected from the software, a list of questions was created and presented during a meeting with the client. These questions can be found in Appendix B3. The following sections are some of the key findings that came about from the questions.

5.2.1.1. Platform

Finding out what platform to develop for was one of the first steps. The platform chosen would have a big impact in terms of the design and development of the product. Factors which needed to be taken into account can be found in Appendix B2. The client was made aware of different platforms available and factors such as those in Appendix B2 were discussed and it was decided that developing for PC would be most suitable.

5.2.1.2. Visual Fidelity

Another issue that the researcher required feedback on was the visual fidelity of the 3D assets to be produced and implemented into any products created. This referred to the required level of detail and realism of any models that were created. On the one hand models could be created which resemble such objects found in Figure 8. These objects are simplified versions of the real object, presented in a stylized diagrammatical manner. Objects found in Figure 9, are of a much higher visual fidelity. They are much more detailed and closer to being what you would label as realistic representations of anatomy. The considerations that need to be taken into account when developing each level of detail, and which were brought to the attention of the client can be seen in Table 14 in Appendix B4.

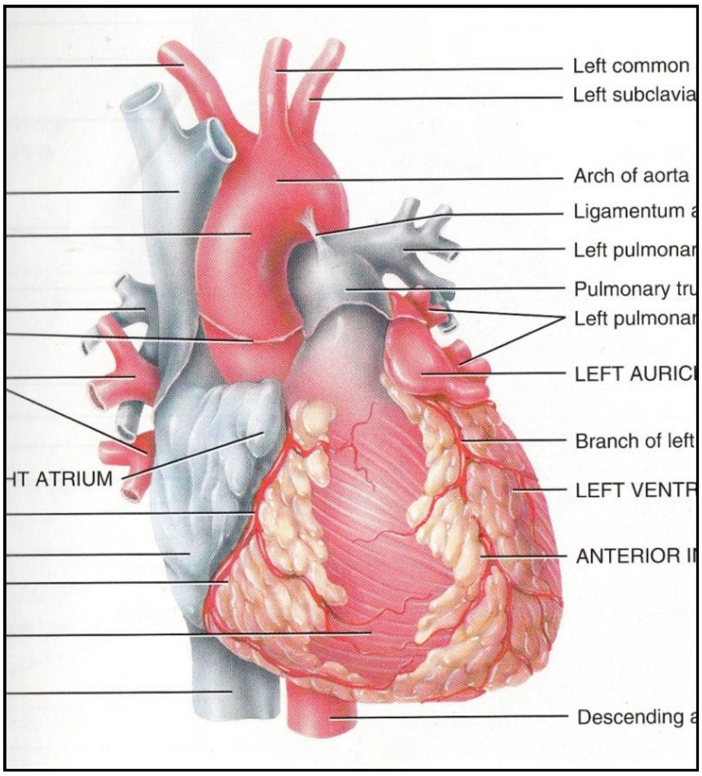


Figure 8 - An example of a low fidelity visualisation of a human heart (Tortora and Derrickson 2007).

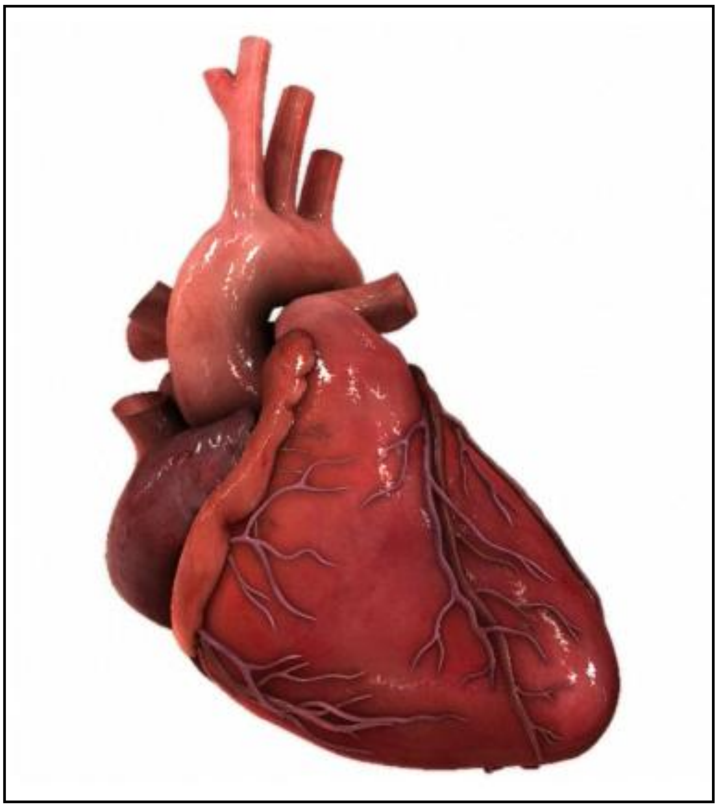


Figure 9 - An example of a higher fidelity visualisation of a human heart (HeartWorks 2011).

Regardless of the difficulties in developing higher fidelity objects, the client stated that it would be much more effective to have lower fidelity model. The client stated that there was a much greater need for diagrammatical medical visualisations because they are much easier for the students to digest and learn from compared to realistic visuals. As will be shown later the heart model developed for the first product was created with this diagrammatical vision in mind.

5.2.1.3. Features

In response to questions regarding any required features of the application, the client was of the mentality that the more that can be put into the application the better within the time restrictions in place. Some important information gained from these questions was:

- The product does not have to cover every aspect of the cardiovascular system; rather the client reiterated the importance of the anatomy, structure and mechanisms of the heart.
- Some form of testing or opportunity for student reflection within the application, while not required would be beneficial.
- The ability to dissect the heart would be beneficial.

5.3. Subject area research

In order to effectively design and implement any software, first it was required that a large amount of research into the subject area matter would have to take place. This research would further allow the refinement of software requirements and provide the researcher with a sufficient amount of knowledge required to progress with development. Researching at this stage involved three different methods of information collection, these were:

- Attending lectures and practical sessions of the subject matter at the beginning of the academic year for the module.
- Direct questions to the client through the methods of communication listed in section 5.4.
- Provision of learning resources by the client.

A mixture of learning resources were either provided by the client or sought out by the researcher. The main three resources that were used were client provided text books, client provided lecture slides and online resources.

The following are amongst the text books provided by the client, these resources were heavily detailed on the subject matter and required a lot of dissection of the information in order to take away that which was relevant to the target audience.

- ***Principles of Anatomy and Physiology*** (Tortora and Derrickson 2007)
- ***Laboratory Manual for Anatomy and Physiology*** (Allen and Harper 2008)
- ***Understanding Human Structure and Function*** (Scanlon and Sanders 1997)
- ***A Brief Atlas of the Skeleton, Surface Anatomy, and Selected Medical*** *Images* (Tórtora and Nielsen 2006)
- ***Anatomy and Physiology*** (Seeley, Stephens and Tate 2005)
- ***Essentials of Anatomy and Physiology*** (Martini, Seiger and Bartholomew 2006)

The lecture slides that were provided by the client were where the majority of the required software features came from. The slides were specific to the target audience and topic at hand and so showed exactly what the students were required to know for that part of the module, however they were brief in the coverage due to the simple fact that they were meant for accompanying narration by the instructor and so required much cross referencing with previously mentioned resources.

Two lectures and a single practical were attended on the subject matter including the following:

- Friday 15th October – Duration 2hrs – Pre-foundation level - A Lecture focussing on blood vessel and the electrical and mechanical events of a heart beat
- Monday 18th October – Duration 3hrs – 1st year Undergraduate – A lecture covering all aspects of the heart.
- Wednesday 9th February – Duration 2hrs – Foundation level – A practical in which students measure blood pressure and take part in cardio activities to measure the effects of exercise on blood pressure.

5.4. Client communication

Communication with the client took place in two ways, first there was any communication that took place using email correspondence and secondly there was face to face communication during meetings at either the researcher or client's place of work. Communication included:

- **Progress updates.**
    - Throughout the project at key stages of development progress updates were either requested by the client or by the researcher.
- **Anatomy help.**
    - At multiple stages during the development of the products of this project, help regarding anatomical content was required either by the researcher or development team. Required help tended to be focussed around elements during the modelling or animation stages of the product development.
- **Signing off on educational content.**
    - In addition to the provision of help the main role of the client was in the signing off of any educational content implemented.

5.5. Software pitch

Before the product could be developed, a software pitch had to take place between the researcher and client. This involved presentation of mock-ups and concept documents in addition to a walkthrough of the proposed features of the product. This pitch is described in further detail in section 6.2.

5.6. Knowledge transfer

An important thread throughout the project was the transfer of knowledge that took place. In this instance the knowledge transfer being referenced is that which took place between the client and the researcher/ project manager, later it will be expanded to include the researcher and development team. Not only was a high level of knowledge transfer experienced between the client and researcher, but a high level of knowledge attainment was experienced by the researcher of the project in regards to the topic of the cardiovascular system. For a developer of educational applications to create successful products they must attain a level of expertise in the subject area, becoming a student and learner themselves, and later as it will be shown in 7.5.2 progress into a teacher role.

In an attempt to shed some light on this knowledge transfer process and determine whether it is something which is experienced within the outside industry, a series of interviews were carried out with companies involved in the development of educational software. Ladley (2011) of *PixelFountain*, states that as the lead designer it is he who works with Subject Matter Experts (SMEs) and then designs the games/media, and that for him knowledge transfer is 'mining' SMEs for information. He also states that the need to often manage the SMEs as they often do not believe you could understand their subject so easily. Ladley (2011) also states that the only consideration is whether he can understand the subject matter not the team, which is different to what was experienced in this research project. Mellody (2011) of *Cyber-sites New Media Solutions* describes a sequence of knowledge transfer much closer to what was experienced in this instance. Mellody (2011) states that Cyber-sites works with a combination of SMEs and Instructional Designers (IDs). The sequence of transfer which they have in place is as follows:

- The SME provides the intellectual content to the ID.
- The ID will translate the intellectual content to a storyboard.
- The content developer will convert the ID's storyboards into engaging and interactive content and will then converse with the Ids, exchanging ideas in order to achieve the best results.
- Content is then reviewed by the SME.
- Finally the ID and the content developer will make amendments until the SME signs the course off as complete.

This is almost exactly the case of what happened during this project in which the researcher took on the role of 'instructional designer' and 'content developer' as described by Mellody (2011); thoughts and ideas were bounced back and forth between researcher and the team until final content was implemented. At which point reviews took place by the client and amendments were made. Content sign off was the last stage.

5.7. Informal interviews with target audience

Informal interviews with the target audience took place during a practical tutorial. The aims of the informal interviews carried out with the target audience in the early stages of the project were:

- Discover the level of computer literacy of the students, in relation to trying to determine whether or not they can be labelled as 'digital natives'.
- Find out about student's experiences with learning resources and teaching methods.
    - Find out whether the students are already actively searching for and using digital learning aids.
    - What do they feel are some of the limitations of the resources that they are provided with or use themselves?
- Identification of difficult areas for the students and their opinions on the ways they are taught. Which parts of the topic of the cardiovascular system traditional teaching struggles to convey?
- Discover what the student's expectations are in terms of things like delivery methods and resources available

A write up of the responses during the interviews can be found in Appendix B5. The following sections summarise the responses and reflect on the aims of the interviews which were stated previously.

5.7.1. Computer literacy

The results from the informal interviews seemed to suggest a mixed range of computer literacy's amongst the target audience, ranging from low level of computer knowledge to those that are comfortable using them. None of those interviewed considered themselves to be close to being expert users. All of the groups said they used computers for general internet use. There was also an expression of the willingness to use computer technology to further their education by one group. Of the five groups interviewed three contained gamers, who played casually for short amounts of time.

5.7.2. Experiences of learning resources and teaching methods

The majority of participants either used digital learning tools actively or had a desire to use more digitally interactive media to aid in their learning. Some used online resources like BBC Bitesize and two of the group found the CD-Rom provided by the instructor on their Chemistry module to be an excellent learning tool, stating that it was able to show mechanics better and was useful because it was very visual in nature. Only one of the participants within the groups interviewed said they would not actively search for a digital learning tool to aid them.

Participants felt that recommended text books for the module like Tortora and Derrickson's (2007) *Principles of Anatomy & Physiology* were not very effective learning resources. One group deemed them 'frightening' to use while another said that they are 'too heavy and scary' at the foundation level of the target audience. The interviewees conceded that while all the information that they need is contained within text books such as this, it is hidden amongst layers of other 'not needed' information. One group stating that Dr Killey's teaching methods were superior to text books like the one mentioned because Dr Killey teaches students exactly what is required to pass their exams, the teacher here acts as the filter. In respect to Dr Killey's teaching methods one group felt that she appealed to the needs of the members learning style needs.

An interesting point which is discussed further in section 7.7.2, here raised by one group in regards to the ineffectiveness of learning resources is that there is a level of inconsistency between materials, particularly in regards to diagrams.

More than one of the groups stated the importance of any representations of anatomy that they learn from being stylized and diagrammatical in term of the visuals, as opposed to realistic visualizations. One interviewee described realistic representations as 'otherworldly'. It was felt that using visuals on this module to teach about the cardiovascular system is a lot more effective than having to read large amounts of textual information, because it is a visually reliant topic.

5.7.3. Difficult areas

During the interviews the following topics were identified as being difficult to convey using traditional means of teaching:

- Blood flow around the heart.
- Mechanics of the heart are difficult to visualise using static diagrams.
- The concept of diastole (relaxation phase of the cardiac cycle) and systole (contraction phase of the cardiac cycle).
- Labelling and learning of names of anatomical parts.

5.7.4. Expectations of students

Multiple participants expected to be provided with digital interactives as part of the course, however there was a mixed response in regards to where those digital interactive would be used; one group didn't expect for them to necessarily be provided for use within classroom, others felt they should be within the classroom and others simply felt they should be provided. One group desired the use of interactive models within the classroom – models which are not necessarily of a digital nature it should be stated. One comment which seemed to sum up the general feelings well was the expectation of as many methods of delivery as possible on the course, digital or non-digital.

5.7.5. Learning styles

As stated in section 3.2.3 investigating the learning styles of the students who were the target audience was not something which was an original goal of the project, rather it was something which came from carrying out these informal interviews. All students who were interviewed mentioned their learning style preference at some point during the interview without being asked for the information. All participants also referenced styles found in Fleming's (1992) VARK model. Every participant either stated that they learned visually or by interacting and participating. There was no mention of any other styles of learning, and so from this we can deduce that for these participants at least, the audience seems to be made up of visual and kinaesthetic/ tactile learners.

5.7.6. Reflections from the interviews

At this stage the results of these informal interviews seem to suggest that the specific target audience that are being dealt with here are in fact not what Presnky (2001) describes as 'digital natives'. First of all the majority of those that were interviewed were actually mature students, meaning that they don't really belong in the category of the new generation of students who have grown up exposed to digital technology. Furthermore there seems to be low to mid level of computer literacy amongst the students; expectations would be for a higher frequency of mid to high literacy levels for 'digital natives'. At this stage it would seem that the majority of the target audience are close to what Prensky (2001) describes as 'digital immigrants'. Some participants did have experience with computer games, showing use of digital technologies for leisure activities, although the time spent on such activities was deemed to be low and games were ones of a casual nature only[1].

Students seem to be actively using digital learning tools on the whole, expressing the fact that they offer advantages over traditional methods of teaching, however use within the classroom environment and provision of these tools by the University is seemingly limited. The perceived ineffectiveness of recommended literature by these students is high. Reasons being that they offer too much information for students at this level and there is no way to filter out what they require.

[1] Casual games are games which are targeted or used by a mass audience of gamers, they can have any type of gamp-play but are typically distinguished by their simple rules and lack of required commitment (Winter 2011).

General consensus seems to be the while they think that the way they are being taught is effective, it could be improved upon with the use of more visual and active methods of content delivery and more filtered resources made available. At this point there is a good outlook for the software to be produced being well received as it will act as a focussed resource of the information that is required for this level, and will present information in a very visual and interactive manner.

Chapter 6. Design

6.1. Overview

The basis of the designs were developed from any requirements identified directly from either the client or the audience, discussed in section 5.2 and also from the research carried out into subject matter by the researcher using methods discussed in section 5.3. Requirements at this stage and the educational goals developed were focussed around the development of the first product of the research, as required by the client, which would be a simulation.

Broadly speaking the main application to be developed should:

- Enable the students to better understand the structure of the heart and its relations to the full circulatory system.
- Improve the students understanding of the mechanics of the heart.
- Improve the students understanding of what causes the mechanisms of the heart to take place.
- Improve the students understanding of the flow of blood through the heart and circulatory system.
- Enable students to be able to identify when certain events take place during a single heart beat.
- Allow students to recognize associated graphical information such as ECGs, and be able to link the graphs back to events in a heart's beat.
- Improve the identification of key parts of the heart's anatomy.

6.2. Simulation - Concept development and software pitch

Ideas for the direction that the software could be taken in had to be pitched and signed off on by the client. To do this a concept document was generated which would attempt to sell possible features that could be implemented into the proposed application to the client (this document is available in Appendix F1).

Mock-ups were also created which visualised what the software could potentially look like and how the proposed features would be implemented. Figure 10 shows one of the mock-ups which was provided to the client.

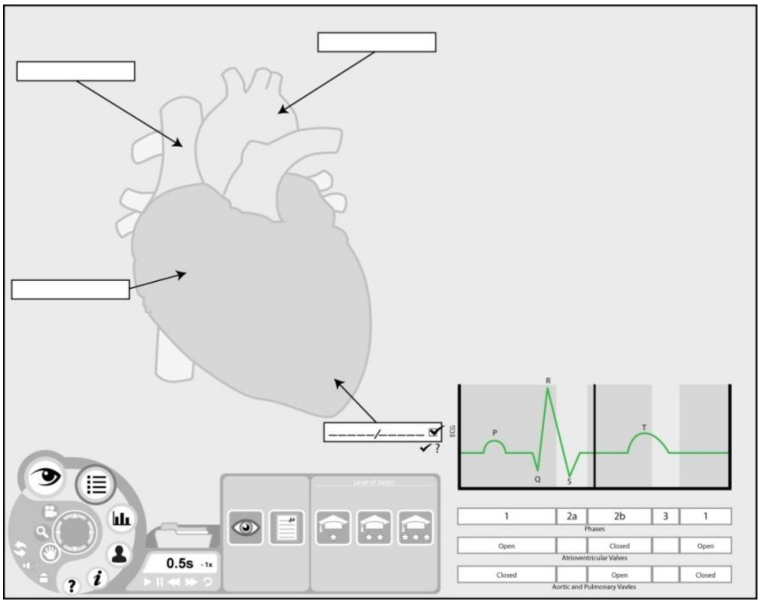


Figure 10- A mock-up of the simulation, which was used to try and convey potential features to the client during the pitch.

The client gave their feedback on the proposed features and visuals of the software, which allowed the project to progress to the next stage which was the development of final design documents.

6.3. Simulation – Development of a final design

Following the identification and affirmation of software requirements by the client, the next task was the creation of a design document for the simulation product. The design document contains all information required by a development team to enable them to implement the software. The document was created to account for all features of the simulation regardless of project scoping. The document covered the following aspects:

- Breakdown of the flow of the software.
- Required entry behaviours.
- Specific educational goals of the software and how to achieve them.
- Detailed breakdown of all proposed features.
- User interface requirements.
- Flow through of the user interface.

The full design document for the simulation can be as an accompanying document to this report.

6.3.1. Required entry behaviours

The knowledge that players must have attained prior to using the simulation are minimal. A user does not need to have any anatomy and physiology to physically ‘pick up’ and use the application, however in terms of understanding what is presented, the simulation is designed to be accessible to students who are studying at a foundation level and so users must only have a GCSE level of understanding of human anatomy. As well as this users must have basic computer literacy skills.

6.3.2. Specific educational outcomes

The following list is a breakdown of the specific educational outcomes of the simulation form the design document as proposed by the researcher.

Outcome 1 - Identify the different elements that make up the heart and circulatory system.

Outcome 2 - Identify the stages that make up the mechanics of a heart beat.

Outcome 3 - Identify the duration of a typical heart beat.

Outcome 4 - Be able to put the mechanical stages of a heart beat in chronological order.

Outcome 5 - Identify when the atrioventricular and semi lunar valves are open and shut during a heat beat, and what causes them to open and shut.

Outcome 6 - Understand the direction that blood flows through the heart and which side of the heart oxygenated blood and which side de-oxygenated blood travels through.

Outcome 7 - Understand where blood goes when it leaves the heart and where it has come from and the blood vessels which are involved in this.

Outcome 8 - Be able to relate the sounds made by the heart during a beat to other events during the cardiac cycle.

Outcome 9 - Understand the sequence of excitation during the cardiac cycle and the parts of the hearts anatomy that are associated with this, also how the electrical excitation relates to the mechanical events of the cycle.

Outcome 10 - Relate the mechanics and phases that the heart goes through to associated graphical data.

6.4. Simulation – Design difficulties

Throughout the design process some difficulties were encountered, one of the main problems was concerning the level of freedom and navigational abilities available to the user of the simulation. 360° navigation of the 3D model was one of the proposed key features of the simulation, a feature which would provide the user a high level of interactivity and freedom over the main element of the application. The problem was creating an intuitive control system that allowed such freedom using only the mouse. Many methods were tried but in the end it was decided that the benefits of complete freedom did not outweigh the disadvantages, and so an alternative navigational system was designed, which while more restrictive would allow for a less frustrating experience whilst still providing a measure of freedom. This system featured set camera views which the user could click through.

6.5. Game – Overview

The second product of this research project – an educational game – was to be produced without vested interest from the client. In accordance with the methodology however the game would be designed and implemented with the same context, target audience, educational goals, platform and other considerations, which had been gathered and researched to the present point. With no input from the original client the design phase of the game was comparatively shorter than that of the simulation, as there was no need for such things as software pitches. While shorter the design was more difficult than that of the simulation, as will be discussed later in section 6.9.

6.6. Game – Design background

When it came to designing the game product it was felt that the time that would need to be invested to come up with a completely original game mechanic and so game design would be beyond the scope of the project as a whole. With this in mind the game to be created was based around an already existing mechanic found in a game called *Pipe Mania* (1989). A modern version of the game can be seen in Figure 11.

Figure 11 - A modern version of the 1989 game *Pipe Mania* by Virtual Programming Ltd (Virutal Programming Ltd 2011)

The basic mechanic of the game is that the player must use various sections of pipe, which become available in a sequential manner, to direct fluid between two points. Fluid is not released from the origin until a timer countdown completes, the main challenge for the player is to lay enough linked sections of pipe down onto the game board before the fluid is released. If the fluid reaches an unconnected section of pipe it begins to leak and a meter begins to fill. If the meter fills the player loses.

6.7. Game – Initial designs

The next stage was the process of blending the educational content with the base mechanic that had been decided on. Initial thoughts were developed through diagrams such as the one seen in Figure 12.

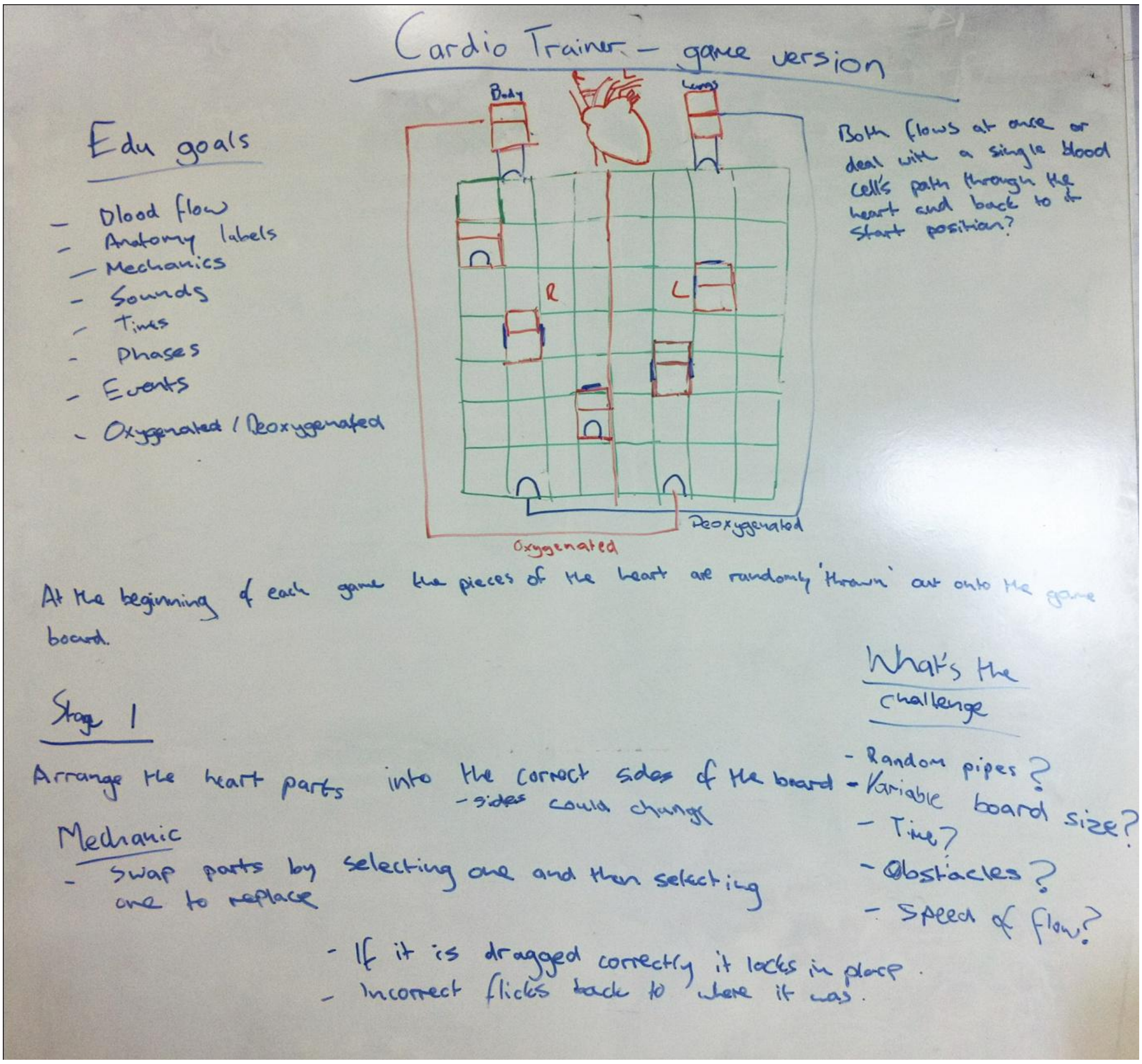


Figure 12 - A concept diagram for initial designs of the educational game.

Decisions had to be made regarding such things as the game objectives and goals, the challenge for the player, how the player would interface with the game, the consequences of actions amongst other elements. This initial design process involved much iteration, with different features and possibilities being conceptualised, analysed for potential value and then discarded or affirmed.

6.8. Game – Development of a final design

With initial designs and concept formulated - as was the case with the simulation - a design document had to be created. The following sections detail the main features, objectives and functioning of the game.

6.8.1. General objective

The general objective of the game is to direct blood through each side of the heart, passing correct parts of the heart's anatomy according to the cardiac cycle.

1. Blood must be directed from the body, through the right side of the heart and then to the lungs
2. Blood is then directed from the lungs through the left side of the heart and back to the rest of the body – so beginning the cycle again.

The general objective and the previously mentioned stages reflect the flow of blood around what is called the systemic and pulmonary circulation system within the subject area content.

6.8.2. Base Mechanic

The main mechanic of the heart game is centred on directing blood over a board of squares by way of pipes sections (blood vessels). These vessels come in various types and can be laid down by the player in order to form a continuous path to their destination.

On a board, the player must direct the blood to multiple destinations. Each destination is represented by a piece of the heart's anatomy; the aim is to direct the blood to each piece of anatomy in the order that it would appear in the cardiac cycle. If the player reaches the correct piece of anatomy in the sequence they are presented with a multiple choice question, which if they answer correctly will result in bonus points. If the player has gone to the incorrect piece of anatomy two things will happen; first they are asked a multiple choice question which they must answer correctly or lose a life, following the question they are transported back to the last correct piece of anatomy that they passed. After reaching a piece of anatomy a timer begins to countdown; the player must quickly lay down sections of blood vessel to the next piece of anatomy in the sequence or risk the blood leaking when it has been released. If all the blood leaks out the game is lost.

Figure 13 attempts to visualise what this design means in the context of the game world. Here the right and left sides of the heart are represented by the game board shown. The main hubs of the body and lungs are represented by the blue and red squares at the top and bottom of the game board. The anatomical parts of the heart that the players must pass through are represented here by the white squares. The order that the player must pass through them is defined here by the number sequence. Connections between goals would be made here by placing sections of blood vessel within each square of the game board, creating linked lengths of vessel.

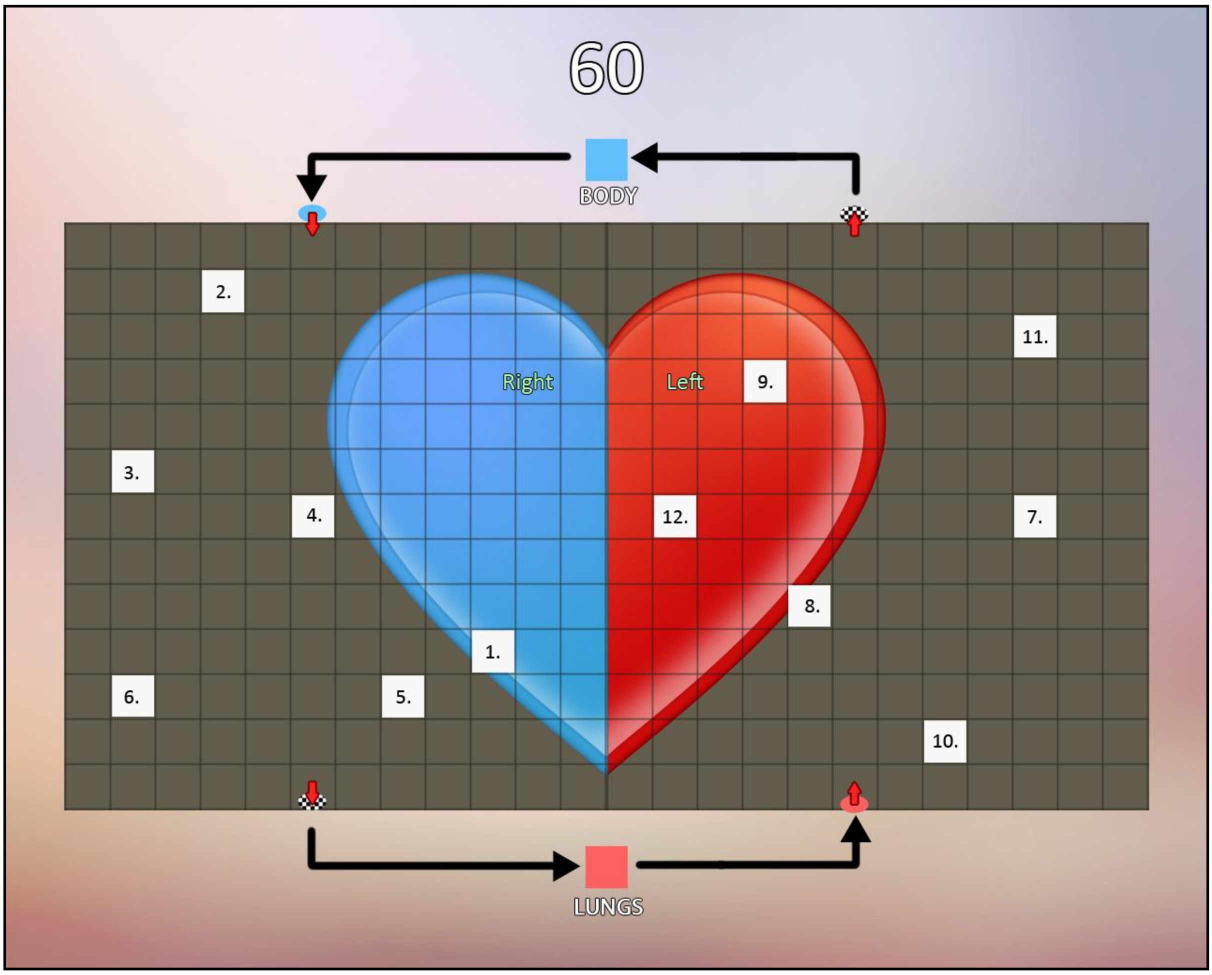


Figure 13 - A mockup of the basic mechanic in game.

This has given a brief overview of the main aspects of the game, for further information please refer to the full document which can found in accompaniment to the main report. The document covers in detail all aspects of the game's design.

6.8.3. Required entry behaviours

The level of knowledge that the player must have attained prior to using the game is different to that of the simulation. Whereas the simulation required no content knowledge to physically use, the game does actually require some knowledge in order to progress. In order to play, the player must already have some knowledge regarding the sequence of the cardiac cycle; otherwise they will not know where to direct the blood. It was deemed that this was an acceptable risk, as by the time of testing the target audience will all have covered the topic and so it was expected they would be able to overcome this hurdle. Other than this the entry requirements are the same as those of the simulation detailed in section 6.3.1.

6.8.4. Specific educational outcomes

The following list is a breakdown of the specific educational outcomes of the game as proposed by the researcher.

Outcome 1 - Identify the different elements that make up the heart and circulatory system.

Outcome 2 - Understand the direction that blood flows through the heart and which side of the heart oxygenated blood and which side de-oxygenated blood travels through.

Outcome 3 - Understand where blood goes when it leaves the heart and where it has come from and the blood vessels which are involved in this.

Outcome 4 - Bring in knowledge from all other areas of the subject area for multiple choice questions.

6.9. Game – Design difficulties

As with experiences during the design of the simulation, there were a variety of difficulties experienced during the process of concept through to design of the game.

The design of the game is a much more complex one than that of the simulation. While the simulation is feature packed, the design itself is relatively simple. The user is presented with a series of buttons through the user interface, which they are able to interact with in order to create some sort of visual effect. This is very different from the game, which features many of the elements detailed in section 3.1.2.4 such as objectives rules, consequences, and challenge. All of these elements need to be thought about in the design of a game, and they are all connected to one another. Changing one is likely to have an impact on another.

The level of complexity leads into the next point about the difficulty experienced in trying to merge the educational content into some sort of game mechanic. When designing the simulation it was a relatively simple case of taking the required educational content and then coming up with a way of presenting each objective visually in a linear cause and effect manner - the user interacts with the interface and an effect transpires. Whereas in designing the game, the educational content to be featured within had to link together in a flowing manner. If an educational objective was to feature in the game, the designer had to think how the learning outcome would integrate into and affect every aspect of the game. This point is perhaps highlighted best in a comparison of the number of educational outcomes satisfied by the game and simulation which is four and ten respectively.

Chapter 7. Development

7.1. Overview

The following section of this report will detail the development process that took place during the creation of the two products of this project. The following areas will be covered.

- Development timelines
- Product scoping
- Methods of development
- Quality control
- Project management
- Development problems

7.2. Product development timelines

A period of one and a half months was allotted at the beginning of the project for initial research to be carried out into the project area and the subject area of the two products being developed. Following this, design and development began on the applications. Figure 14 shows the projected durations for the main elements of the development process for each of the products being developed, which were formulated at the beginning of the project. Figure 15 shows the actual duration of the development of each product that was created.

As can be seen development took much longer than originally estimated. The reasons for the overrun become clearer later in section 7.7, where the problems experienced during development of the simulation are discussed. These problems had a knock on effect on the timelines of the educational game, which while only taking slightly longer to develop than originally anticipated, meant that development began much later. The length of the development times experienced meant that testing methodologies had to be changed over the course of the project.

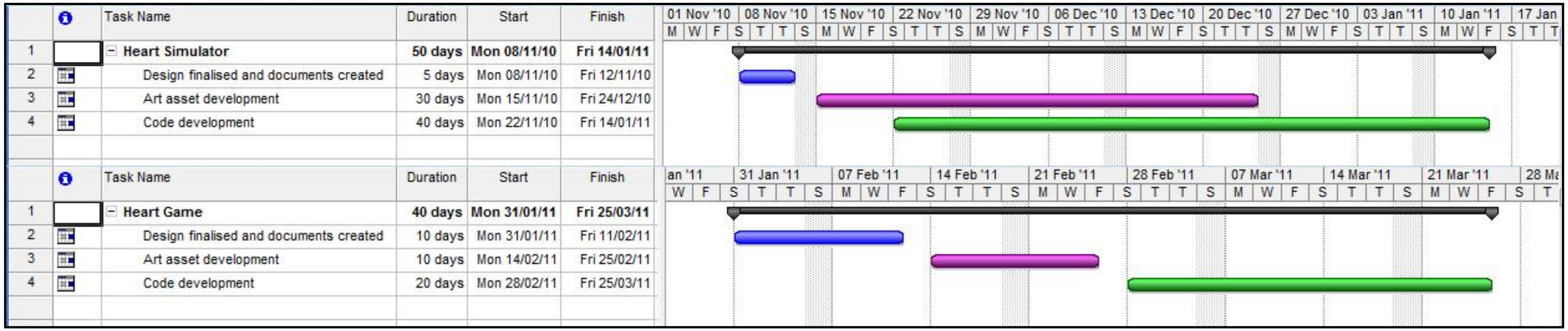


Figure 14 - A timeline showing the projected durations of main development elements for the Simulation (upper) and Game (lower)

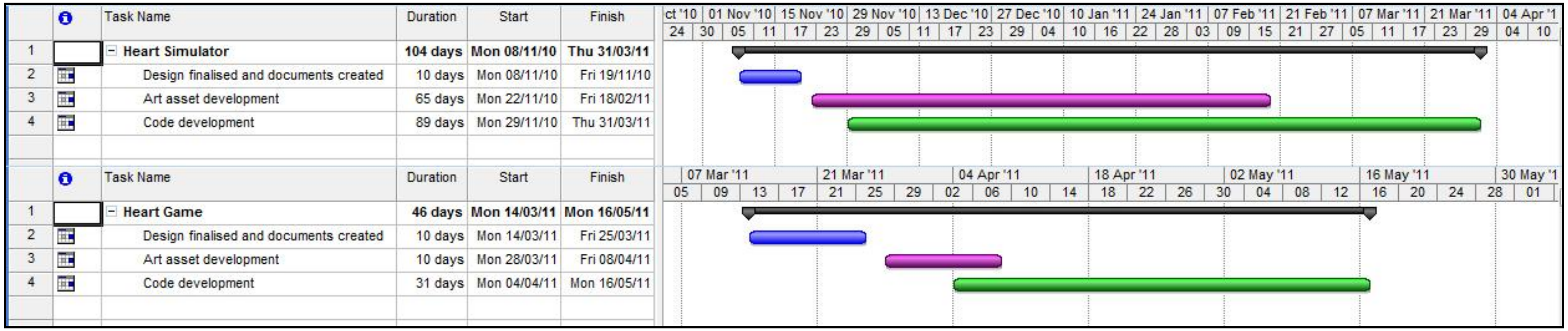


Figure 15 – A timeline showing the actual durations of main development elements for the Simulation (upper) and Game (lower

7.3. Product scoping

To ensure that two successful applications could be completed within the timescale available to the researcher, each development had to be scoped effectively. In order to do this Clegg and Barker's (1994) MoSCoW technique was used, which is one method of prioritisation often used in rapid application developments like this (Martin 1991). The MoSCoW technique places requirements in order of importance for delivery and is broken down as the following:

M – MUST – This is a requirement that needs to be satisfied in order for the project to be considered a success.

S – SHOULD – These are high priority items that should be included in the project. These can be critical requirements but if necessary can be satisfied through other means.

C – COULD – Desirable items which are not necessary for success but are to be included if time and resources permit.

W – WON'T – Items that will not feature but are possibilities for future work.

7.3.1. Simulation

The list of key requirements for the simulation were categorised using this technique, the results of which can be seen in Table 2.

Must	Should	Could	Won't
Anatomically correct heart.	Visual freedom for the user.	Audio feedback.	Ability to alter at least one external factor.
Fully animated to show the show mechanisms of the heart during a beat.	Show the conduction across the heart.	Ability to slow and speed up the playback of the animations.	Follow a single Red Blood Cell through the entire system.
Timeline that the user can constantly relate to.	Graphical feedback - ECG	Some form of test and feedback system for users.	
Feedback to the user as to what they have clicked/ are hovering over etc.	Feedback of the phases the heart is going through and any events taking place.	Ability to track to certain events during the heart beat.	
Ability to "label" the key elements anatomical elements of the heart.		Be able to view the heart as part of the full circulatory system.	
Blood flow.		Be able to visualise the heart as part of the systemic + pulmonary circulatory system.	

Table 2 - Features of the first product of the research project scoped using the MoSCoW method.

7.3.2. Educational game

Scoping the development of the educational game was a more difficult task than that of scoping the simulation. This was largely down to the points discussed in section 6.9 regarding the high level of interconnectivity within games due to the overlapping relationships between characteristics such as objectives, rules and consequences amongst others. It is simply not possible in many cases to put a low priority on features of a game, because it is likely that such a feature has a direct impact on another feature which may have been prioritised higher. Table 1 shows the breakdown of the project scope for the educational game using MoSCoW methods. Notice how the 'Must' features column is populated with features primarily relating to the integrity of the base mechanic.

Must	Should	Could	Won't
Placement of vessel on board	Introduction/ tutorial to the game	Dynamic labelling of anatomical destinations which respond to user interaction.	Manual placement of pieces on the correct side of the heart by the player. (according to Stage 01 of the Game's design document)
Timed blood release.	Posing of multiple choice questions to players at certain points during the game.	Inlet and outlets of the anatomical destinations could alter every game.	Intelligent placement of blood vessels
Flow of blood around vessels	Predetermined inlets and outlets of anatomical destinations.	A Helper avatar that gives the player feedback during the game.	Intelligent positioning of anatomical destinations
Blood leak from vessels and a leak meter to record level of loss.			
Destruction of blood vessels.			
Life system			
Scoring system (gaining and losing)			

Table 3 - Features of the second product of the research project scoped using the MoSCoW method.

7.4. Types of development

The type of software development that was employed during the development process of this project was most closely akin to the iterative software development approach, displayed in Figure 16. This type of software development is efficient and adaptable and was deemed most suitable because of the dynamic and uncertain nature of the project – uncertain in the sense that it is a project focussed on a subject matter out of the area of expertise of the researcher. This method suits the need for updating the subject matter expert and client with constant builds, allowing for rapid feedback to the development team. In accordance with such a method, testing took place throughout the process of development with builds submitted to the project leader (researcher) and action points developed as a result. This testing ensured quality control and accuracy.

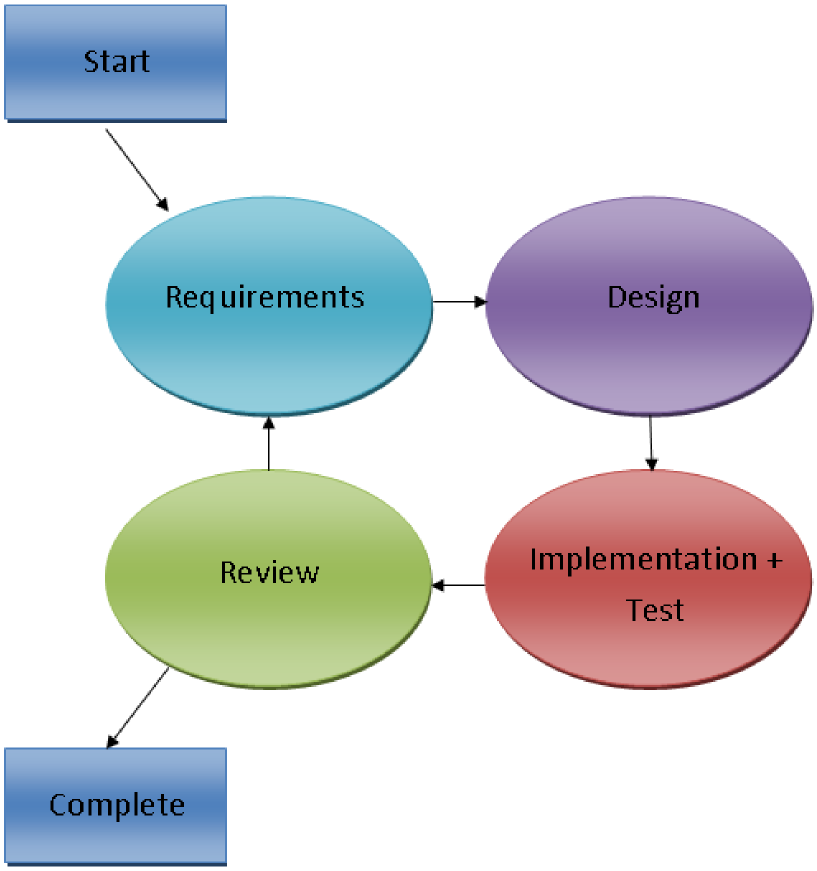


Figure 16 - A diagram showing a breakdown of the iterative method of software development, which was integrated into this project.

7.5. Quality control

Quality control was touched on in the previous section, where it was stated that constant review of asset and program iterations was how accuracy and quality was maintained. To detail this further Figure 17 shows how quality was maintained through the relationship between the client and researcher, researcher and development team, and directly between the client and development team.

Figure 17 - The process of quality control during the project.

7.5.1.1. Client and researcher/ dev team

The most important part of the quality control process was through the relationship between the client and the researcher. Throughout the development if there was either a problem or if a milestone had been met the client would be met with. At these meetings educational content was checked for accuracy and relevance by the client, which led to either content being passed for use or action lists being created for changes to be made. This happened on multiple occasions during the project, some examples of this can be found in section 7.7.

7.5.1.2. Researcher and development team

The second element of the quality control process took place between the project manager and development team. Throughout the development there was constant supervision between the researcher and the devleopment team, to ensure that work was created accurately and to standard. In reference to secton 5.4, this process was only able to take place because of the level of knowledge acquired by the researcher from the client and from their own studies into the subject matter. With this knowledge content was able to be signed off by the researcher only, without need of input from the client. Without this process taking place the client would have had to be constantly available for query regarding various aspects of the implentation.

7.5.2. Knowledge transfer

Further to the points covered in section 5.4 regarding a key experience during this research project; that of knowledge transfer of the subject matter. Here we can expand the point to not only include the knowledge transfer between the client but the knowledge transfer between the researcher and the development team, and the development teams natural attainment of knowledge. These two aspects are as follows:

1. **Necessary transfer of knowledge –** Throughout the project there were times when it was necessary for knowledge to be transferred to the team for them to properly develop assets for the products. This was particularly apparent during the development of the simulation's heart model and animations, where a lot of subject matter knowledge was required to develop accurate resources.
2. **Natural transfer of knowledge –** Even when required knowledge transfer between researcher and team was not taking place, it was apparent during communication with the team during the project that they were in fact gaining a level of knowledge in the subject matter of their own accord.

Knowledge is passed down level to level, with each level requiring a little be less knowledge in order to completed their required tasks. Furthermore an interesting reflection to make is that during the course of the project the researcher not only becomes the student to the client and subject matter but to an extent a teacher of the content to those being managed.

7.6. Project Management

Project management was carried out by this project's researcher in the instance of both products, however management varied across the development of the two products, with team sizes and skill sets of team members for each project differing. Products were developed mainly using human resources within Canalside Studios, a game development company based within the University of Huddersfield where the researcher of this project is employed as project manager, but work was outsourced to external developers when needed.

Internal management involved constant supervision of the development team, which allowed for frequent updates and dynamic task delegation as required by changing circumstance. Management of work delegated to external bodies involved the following:

- Again iterative in nature with tasks being delegated to individuals and then progress updates taking place with the project manager and action points being developed from submitted work.

- Work was submitted by external developers either in person through organised meetings and demonstrations or through a type of SVN[2] called Dropbox, where versions of work can be submitted and accessed from anywhere.

The following sections show the team structure involved in the production of each product.

7.6.1.1. Simulation

Figure 18 shows the structure of the team which worked on the development of the simulation and also the method of management of each member - whether they were internally or externally managed. The fact that the simulation is focussed on 3D models is reflected in the skill set of the art team. The complexity and time consuming nature of such work meant that more than one person was tasked with various parts of the development of the 3D heart model used within the simulation. Here the majority of the project management takes places internally, however the animation of the 3D heart model was outsourced to an external developer, and managed accordingly.

7.6.1.2. Game

Within Figure 19 the structure of the team involved with the development of the game can be seen, and again the nature of management of each member is shown. The first thing that is obvious is the comparative size of the team which worked on the game compared to that of the simulation. Here the only project management to take place was of the programmer on the project. All art assets were developer by the researcher of the project. Management of the programmer was a mix of internal and external due to the fact that this person left the employment of Canalside Studios during development.

[2] SVN – An SVN or Subversion is version control system which allows the management of files, folders and directories between shared parties. In this instance work can be accessed anywhere over an internet connection (Practical SEO 2010).

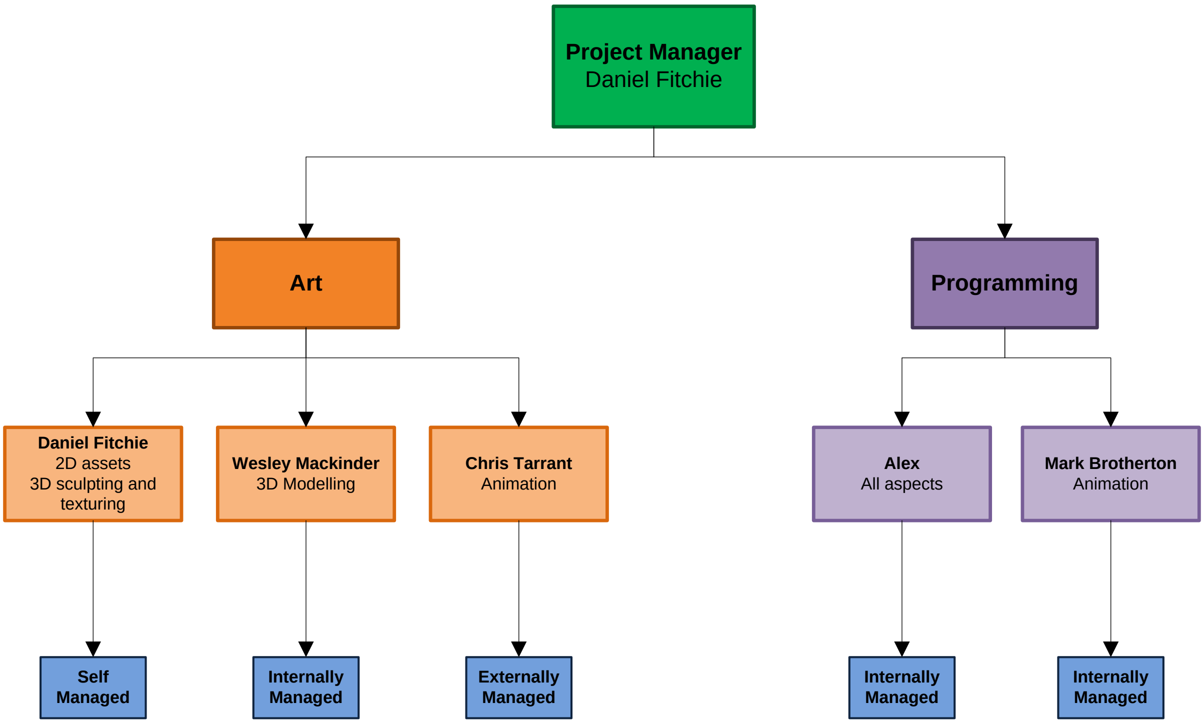


Figure 18 – Team structure and method of management for each team member involved with the development of the simulation.

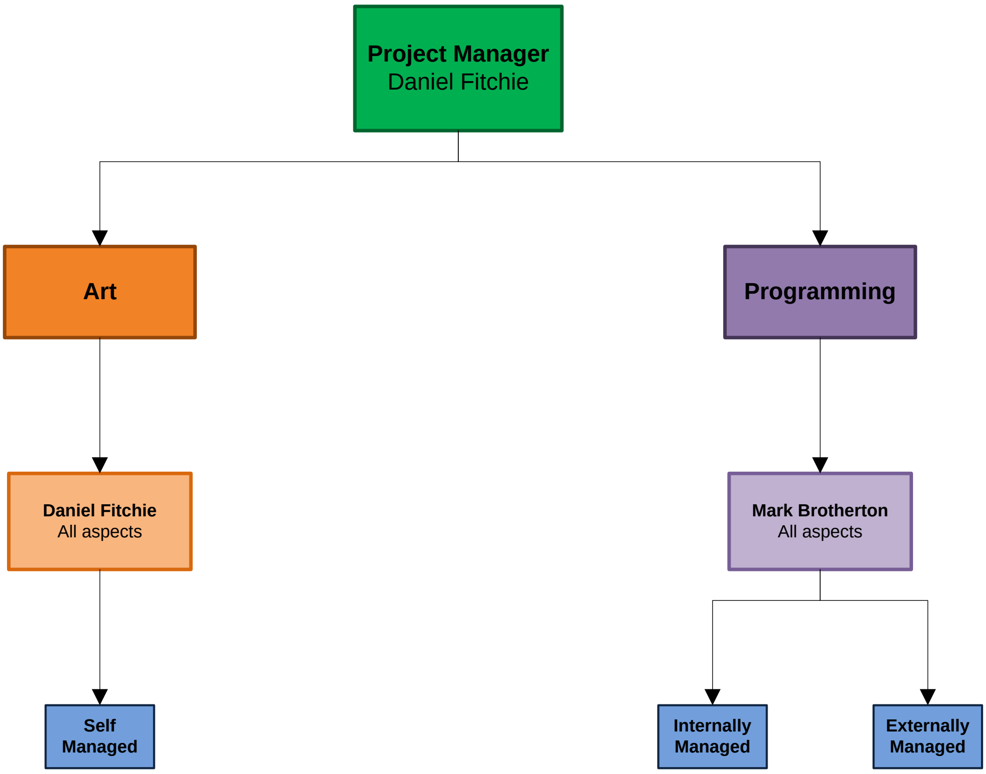


Figure 19 - Team structure and method of management for each team member involved with the development of the game.

7.7. Development problems

A variety of problems were experienced during the development side of the project. These problems will be discussed from the following three perspectives:

- Inaccuracy of available learning materials.
- Effectiveness of available learning materials.
- Development of anatomically accurate assets.

While related to development experiences many of the problems to be discussed are directly linked to the research objective of gauging the effectiveness of current learning materials discussed within section 3.2.3 of the literature review.

7.7.1. Inaccuracy of available learning materials

When the development of the simulation began the original plan hadn't been to create our own heart model, rather the plan had been to purchase one, which would allow us to rapidly begin prototyping, so shortening the overall development duration. To this end a 3D model of a heart was purchased for a reasonably substantial amount of money from a reputable online model resource. It wasn't until sometime into the development that it was noticed that there was a major anatomical flaw in the model. At the time the client had to be called in to verify the suspicion, the result being that this was confirmed as a flaw of the model. In a model that was sold as 'anatomically correct' this was a major error.

This experience highlighted the fact that not all of the resources available to students have necessarily gone through rigorous checking process in terms of accuracy. While not applicable to the likes of accredited resources provided by university courses, with many students using the internet as a main learning resource it is impossible to guarantee that everything that is being accessed is in fact one hundred percent accurate.

The problem with the purchased model meant that a new model had to be created by a member of the studio team, which caused large delays in the development of the simulation; delays which affected timeline targets for the entire project.

7.7.2. Effectiveness of available learning materials

At multiple points during development the effectiveness of many learning materials were questioned for a variety of reasons.

One experience was that representations of educational content differ across multiple resources. When implementing the graphical feedback feature of the simulation, it was found to be extremely difficult to compare the timings of ECG, Ventricular Volume, Pressure and Heart Sounds graphs in relation to the 0.8 seconds timing requirement from the client because each source used seemed to display the information in a different way. An example of this can be seen in Figure 20. In this example two representations of an electrocardiogram are shown, in this instance from the same source. The graphs are displayed in relation to the timing of a typical 0.8 second heartbeat, as you can see here the position of the peak of the part of the graph labelled 'P' is displayed differently between the upper and lower graph. Whilst this may insignificant, in actuality the impact for the researcher was great. Experiences like this were not limited to just the graphical content, but was found to be the case in many instances. Differing representations was a point which was made by students in the target audience during the informal interviews which were carried out for the project; this information can be found in section 5.7.

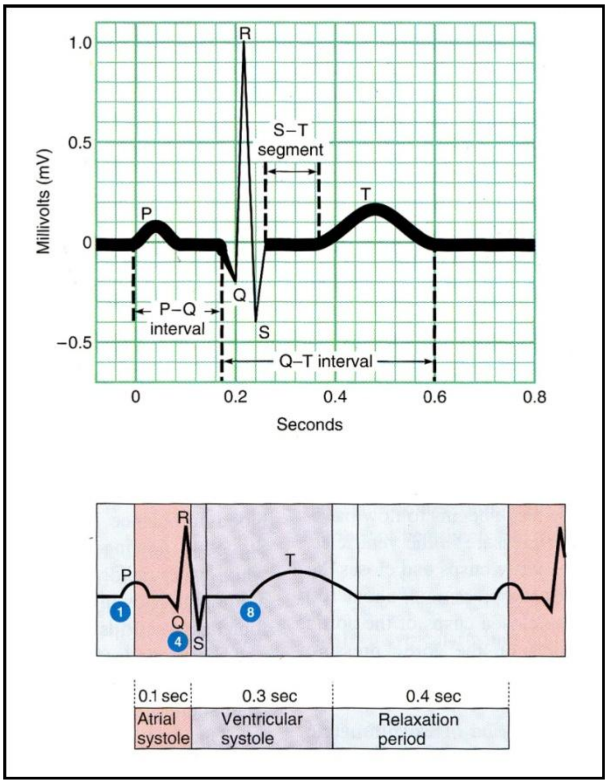


Figure 20 - A comparison of the representation of an ECG graph in relation to a typical 0.8 second heart beat (Tortora and Derrickson 2007).

Another experience was that traditional learning resources such as those provided to students in the target audience were ineffective at showing related concepts. Again there are many examples of this to be found, one such example can be seen in Figure 21, where the relationship between an electrocardiogram and the path of electrical excitation across the heart is shown. While this diagram does attempt to display one relationship, what if the student wanted to then relate this information to the visual mechanics of a heart beat or the flow of blood around the heart? Such diagrams found in traditional static learning materials are limited in how much information they can convey. This problem is not only limited to diagrams of course, as relating information across textual sources can be difficult also. These are problems which can be overcome using digital means such as the two products created for this project.

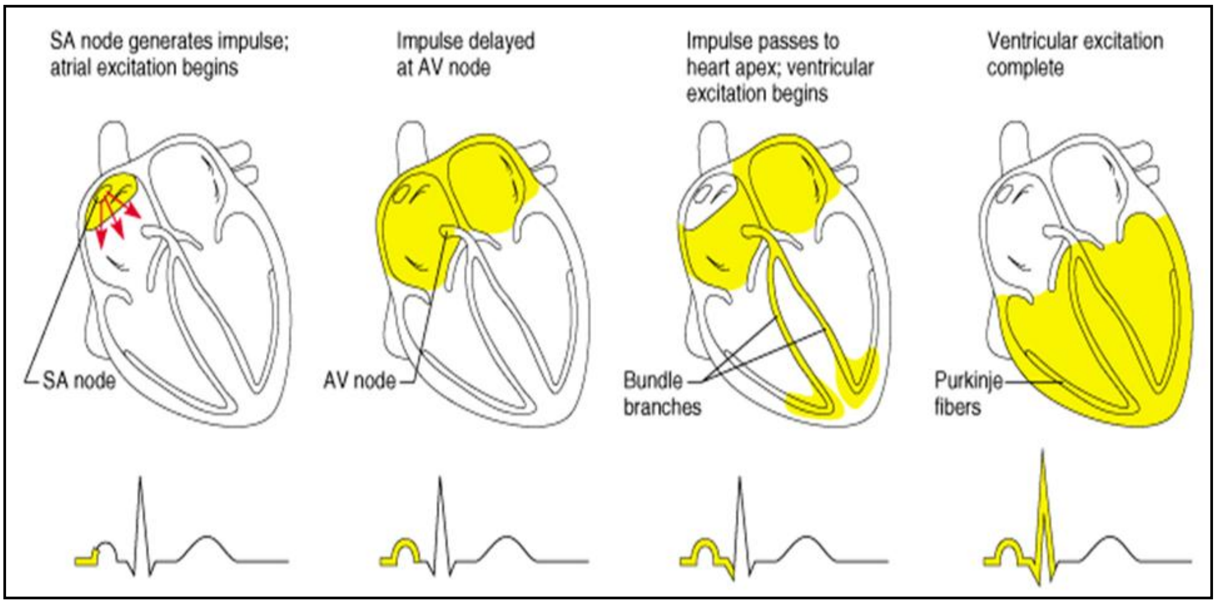


Figure 21 - A diagram showing the relationship between graphical data of an electrocardiogram and the visual electrical excitement that takes place across the heart (Killey 2011).

An interview carried out for this project with Stephen Florence (2011) – staff member at Sheffield Hallam University, who develops 3D medical animations for the Health and Wellbeing department – attempted to clarify whether the points raised were lone cases experienced by the researcher or whether they were in fact things experienced by other developers. Florence (2011) stated that,

‘Each source tells a slightly different story and each website presents information in a different way so getting a clear picture is difficult so I mostly relied on information and feedback from professionals that work here [Sheffield Hallam University] rather than online information.’

7.7.3. Development of anatomically accurate assets

While problems creating educationally accurate content were experienced across the board during the development of the two products, the problem was perhaps more apparent during the creation of anatomically accurate 3D assets. During 3D asset production, there were many occasions where use of traditional learning materials was not adequate enough for the researcher and development team to develop accurate models and animations which could be signed off without the need for the client. One such problem was during the creation of the heart valve models. During this time, direction of the modelling by the researcher was found to be difficult because a single overall view of what a heart valve looks could not be formulated from the reference images being used. In this case a document was generated and Figure 22 was supplied to the subject matter expert in an attempt to describe the problem. Communicating with the client in this way allowed for problems to be quickly overcome and work to continue on development.

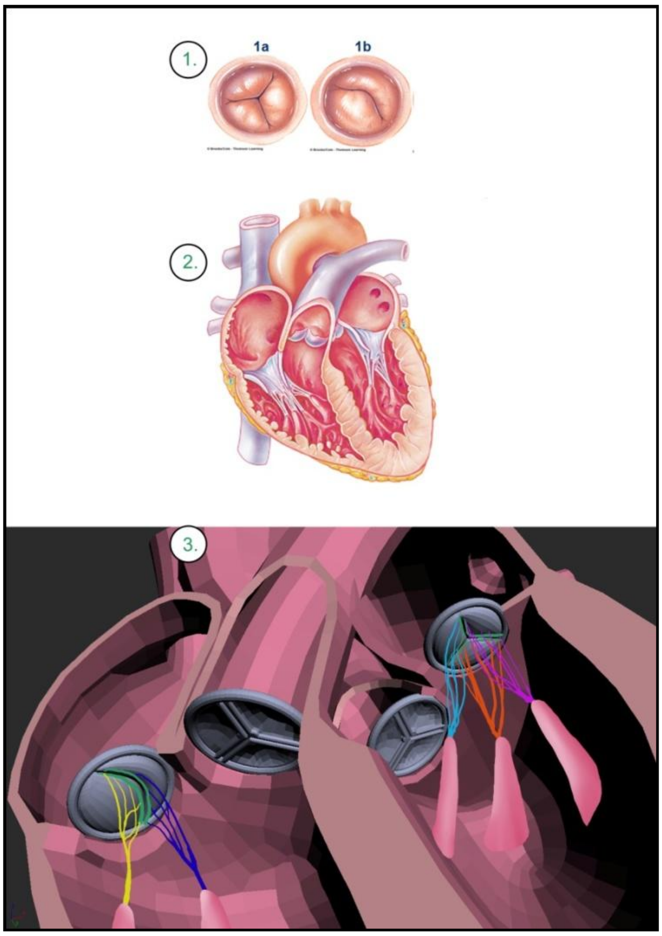


Figure 22 - An example of correspondence between the researcher and client when anatomical help was needed.

7.8. Product screenshots

The following images are screenshots taken from the final builds of each product developed for this research project. Figure 23, Figure 24 and Figure 25 are taken from the *Cardiac Simulation* and Figure 26, Figure 27 and Figure 28 are from the *Cardiac Game*.

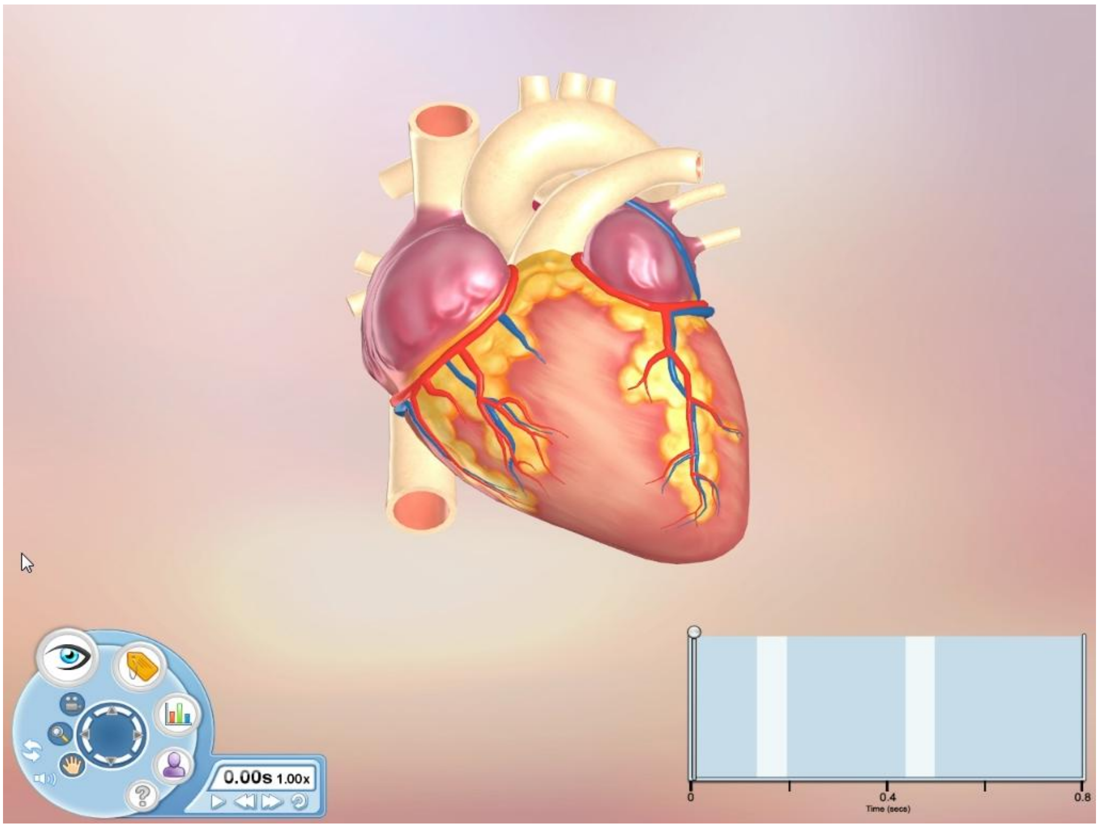


Figure 23 - A screenshot from the final build of the *Cardiac Simulation*.

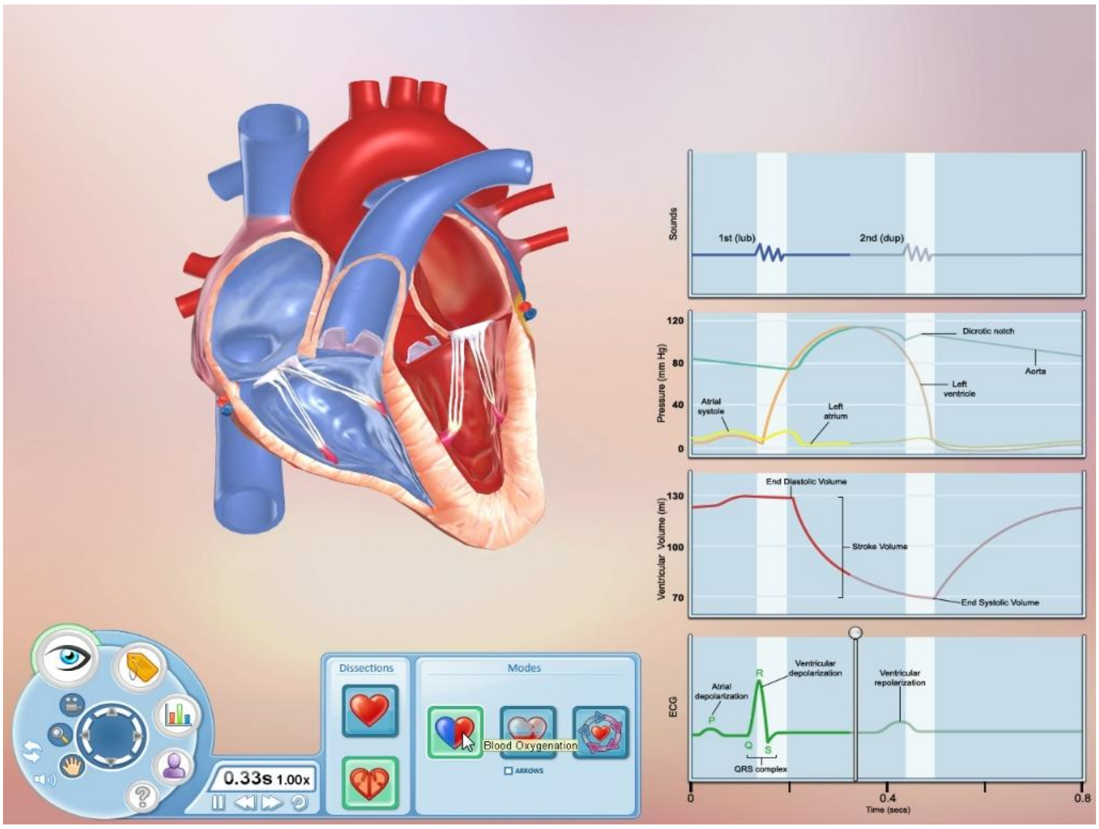


Figure 24 - A screenshot from the final build of the *Cardiac Simulation*.

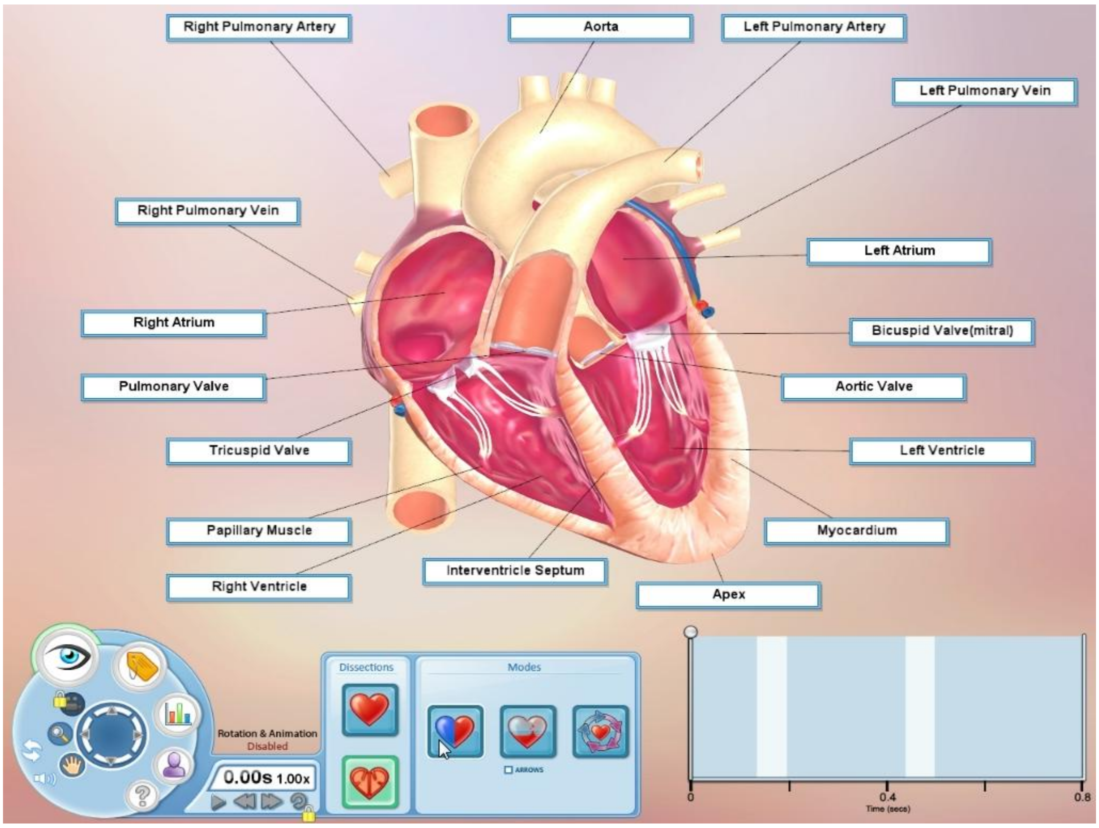


Figure 25 - A screenshot from the final build of the *Cardiac Simulation*.

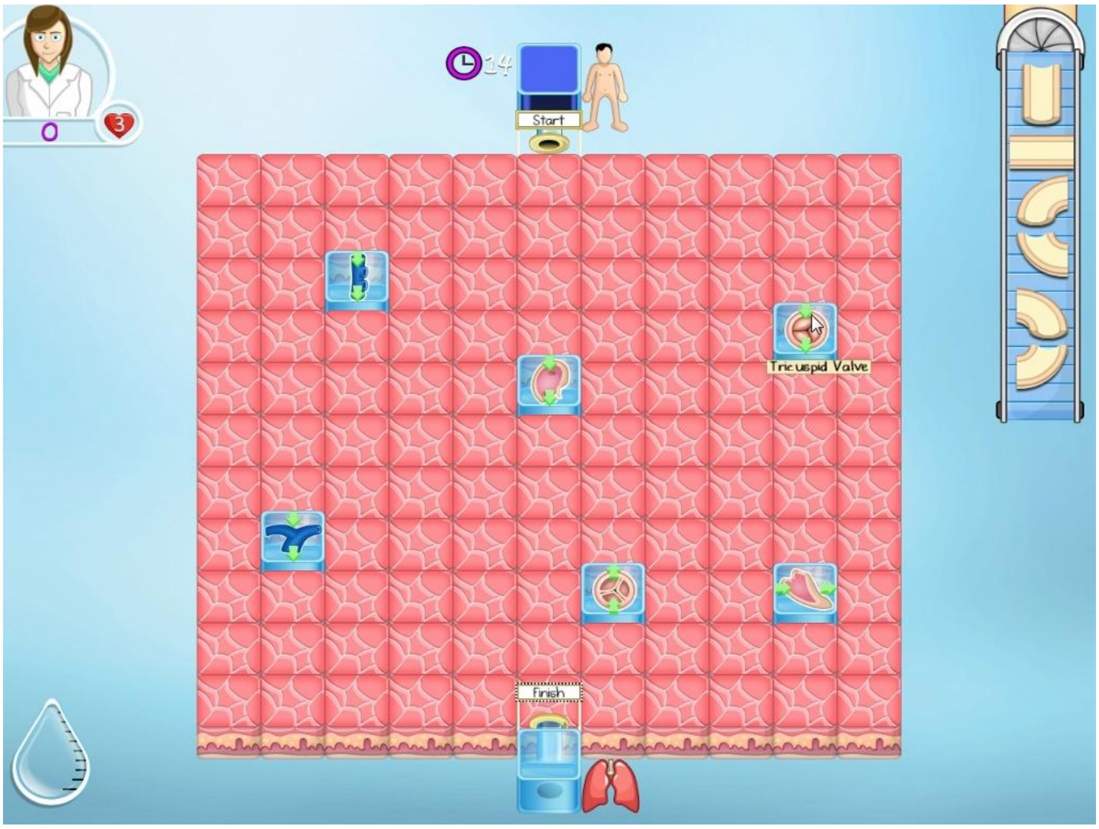


Figure 26 - A screenshot from the final build of the *Cardiac Game*.

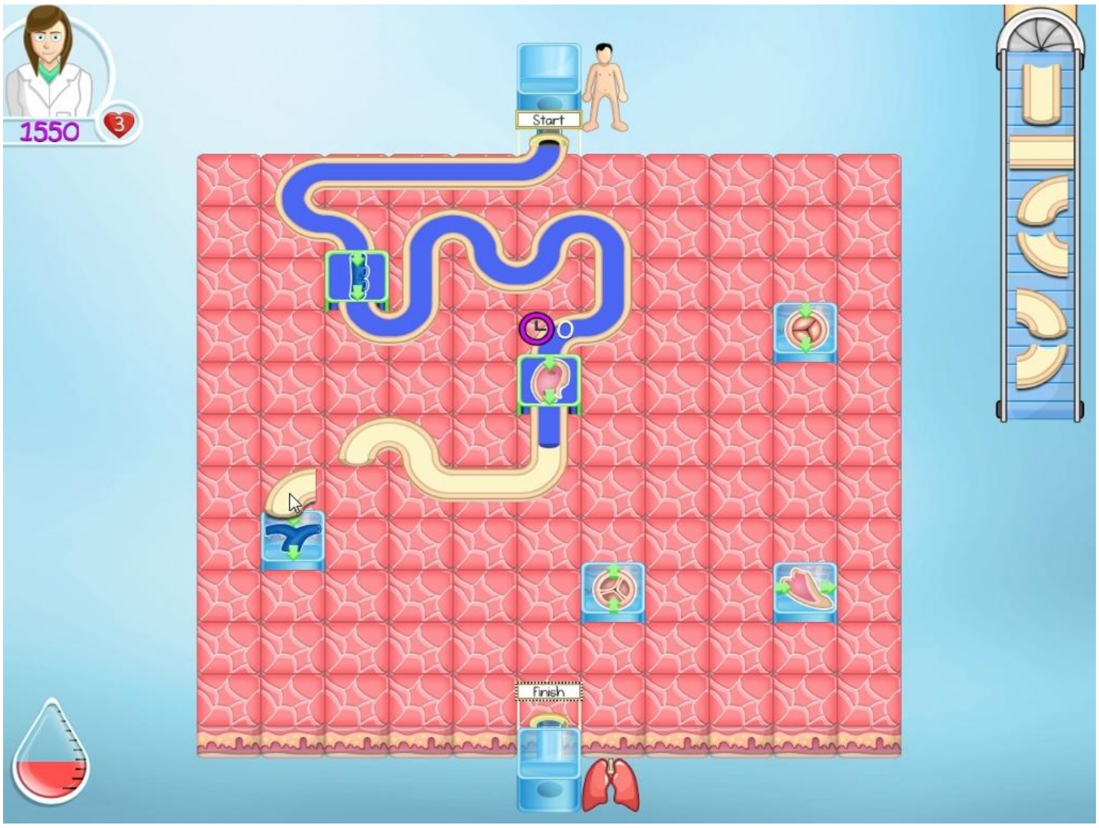


Figure 27 - A screenshot from the final build of the *Cardiac Game*.

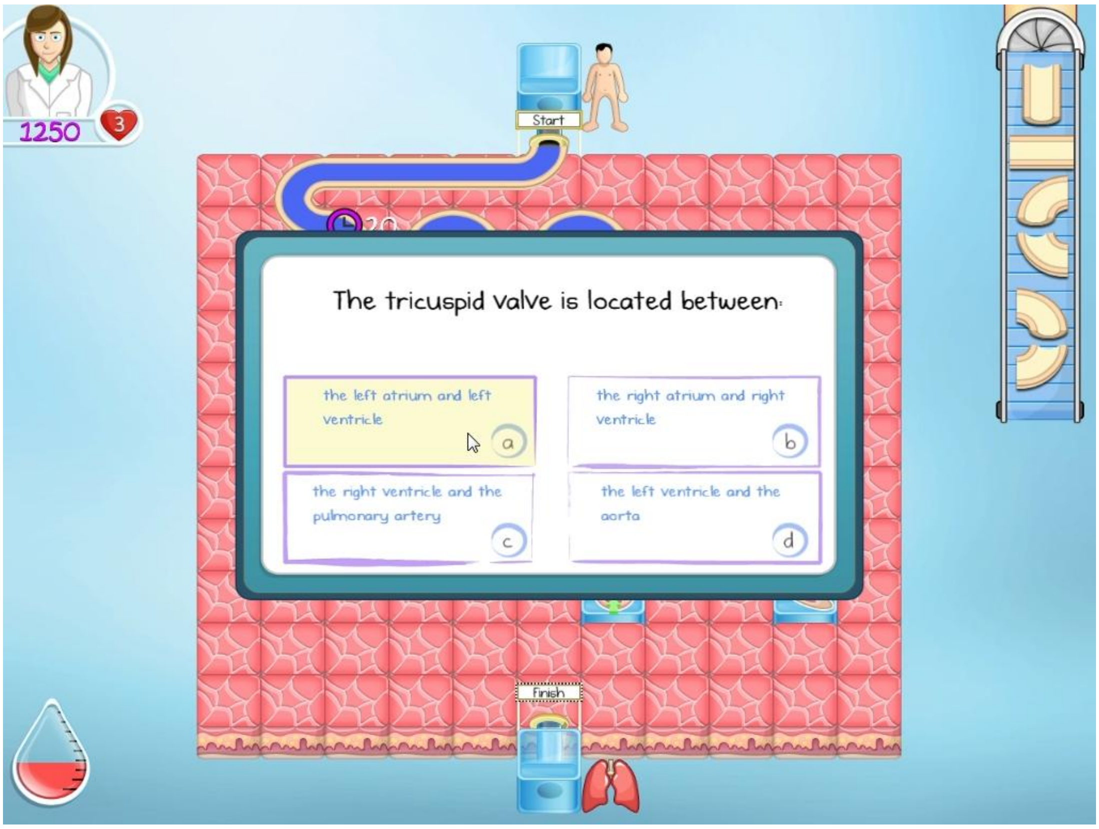


Figure 28 - A screenshot from the final build of the *Cardiac Game*.

Chapter 8. Testing

8.1. Overview

In order to evaluate the project objectives detailed in section 4.2, the two products developed had to be tested. This section will detail the process of developing the testing methodology and the tests themselves. The following points will be covered in this section:

- The actual test methodology employed in this case study.
    - Test methodology iterations.
    - Method of data gathering.
- Development of questionnaires.
- Details of the test set up.
- Details of the two tests carried out.

In brief, while the original plan had been to carry out a single test with the target audience described in 5.1.2, in actuality two tests had to be carried out for reasons explained in section 8.4.1; one with the target audience and one with a second set of students. See section 8.4.2 for details of this second set of test subjects.

8.2. Actual test methodology

The development of an actual test plan or methodology to be used in the case of this research was a constantly evolving situation due to changing factors over the course of the project. These changes were mostly down to the matter of development delays.

8.2.1. Test schedule iterations

The original plan had been formulated from product development time estimations shown in section 7.2, with the aim being to test the simulation with the target audience at the end of January 2011 as per the client's suggestion and the game just before the end of the target audience's academic year at the end of April 2011. Development delays meant that these targets were missed and so other plans had to be made over the course of the project. The final test plan and the one that was used, was the test of both pieces of software after April, following the academic Easter break. Carrying out the test at this stage of the year created substantial problems concerning the target audience, which is discussed in section 8.4.1.

8.2.2. Method of data gathering

The data gathered for use in evaluating the project objectives and determining the validity of the research hypothesis consisted of a mixture of quantitative and qualitative data. This data was based on opinions of test participants.

In terms of the actual methods of gathering information during the software tests, the majority of data was gathered using multiple questionnaires which were provided to participants during the test. However as will be shown, the first test had to be adapted to include a focus group session.

Questionnaires were implemented online using online survey tool *Survey Gizmo* (2011). Developing questionnaires online allowed for easy collation and analysis of data.

8.3. Questionnaire development

The questionnaires that were developed for use in the project went through much iteration from the first drafts of the preliminary and software specific questionnaires created to the final ones that were used on the day of test. Initial drafts of the two types of questionnaires can be seen in Appendix C, and final iterations can be seen in Appendix C2.

Questions were altered or removed over the course of questionnaire development for the following reasons:

Too numerous

The number of questions used in the final test was much lower than the questions present in early drafts. Table 4 shows the number of questions present in the draft and final questionnaires.

	Draft	Final
Preliminary Questionnaire	18 questions	9 questions
Simulation and Game Questionnaire	Shared 18 questions	Shared 9 questions with a single unique additional question present at the end of the game questionnaire.
Total	36 questions	19 questions

Table 4 - Comparison of the number of questions between draft and final iterations of questionnaires.

There were a variety of reasons for reducing the number of questions between iterations. One simple reason is the fact that a larger amount of questions means that more analysis would have needed to take place. It was also felt that the participants would not want to answer large amounts of questions and the question amount had to be limited to keep the duration of the test itself within reasonable limits. Also many questions were 'repeats' of other questions in the sense that the data that they would provide was already covered elsewhere.

Accordance with questionnaire best practises

During the questionnaire design process research was carried out into literature on effective questionnaire design practises. The advantages and disadvantages of using closed and open questions were taken into account to try and achieve the right balance between the two. Later iterations saw more open ended essay like questions added because they allow respondents to express ideas spontaneously in their own language, and provided the opportunity for new information or points to be raised that may not have be considered by the researcher when designing the questions (Siniscalco and Auriat n.d). If questions were not in compliance with existing formats then these were changed accordingly, for example 1 – 10 scales were used consistently, as were Likert (1932) scales[3]. Other best practises which were abided by included the avoidance of leading questions, removal or limitation of questions of a personal nature and appropriate language use (Siniscalco and Auriat n.d) (Deakin University n.d) (Loughborough University n.d).

Relevancy to research

Often during review the relevancy of questions in relation to the project objectives was queried. Numerous questions were removed because instead of being asked because they were required for effective evaluation, they were instead posed for the potential of the interesting responses that they could provide. One example of a question that was removed was the following:

Which of the following statements sums up your views on the course best?

"At this level of higher education, I expect to be taught the knowledge required to pass my exams."	☐
"At this level of higher education, I expect to be taught the knowledge required to practise my chosen field."	☐
"At this level of higher education, I expect to be taught the knowledge to both pass my exams and practise my chosen field."	☐

This was a question which was trying to discover whether students feel they should be being taught a sufficient level of knowledge required to just pass their exams and progress within University, or to practise in their chosen field; a question which while interesting has no relevance to the aimed outcomes of the project.

[3] Likert scales are ordered scales from which respondents choose one option the best reflects their own view.

8.4. Test Sessions

8.4.1. First test

The first testing session took place on the 23rd May 2011. The participants of the tests were the original target audience of this project. The projected amount of volunteer participants that would be available for the test at the beginning of the project was around twenty students, in actuality four students from the target audience agreed to be a part of the test. Such a low amount of volunteers was primarily because of the timing of the test in relation to the academic year. Members of the original target audience simply weren't available.

Such a small sample size meant that the usefulness of the data to be gathered from the questionnaires was limited and is not necessarily fully representative of the full class of students. The small sample meant that the researcher adapted the test methodology to include a focus group with the students available on the day. The focus group involved informal questioning between researcher and participants where responses were recorded. Due to the lack of voluntary participants it was decided that another test would have to take place, so increasing the sample size.

From now one participants of this test will be referred to as Group A.

8.4.2. Second test

The second test session took place on the 30th June 2011. The participants of this test were organised by Karen Currell, a senior lecturer in the School of Human and Health Sciences who teaches on a child nursing course. The students that were provided for the test were about to begin their first year of undergraduate study on a nursing course. The expected number of participants to be provided was twenty-two, unfortunately only a total of fifteen took part on the day of test. As was the case with the first test the background of participants was very mixed, with the possibility of very different academic backgrounds and ages.

It was not guaranteed that participants would have studied biology prior to the test let alone the cardiac cycle unlike the first test, which created a host of potential testing problems. It was deemed that certain questions which related directly to biological taught content would need to be adapted into contingency type questions (Siniscalco and Auriat n.d). These questions would separate the participants into subgroups, so filtering those who had studied the cardiac cycle to answer a certain question and those who had not to move onto the next question. The results of this are that the sample size for certain questions was reduced further, and as was found the number of respondents in relation to this was reduced from fifteen down to nine. Fortunately this only directly impacts two questions – question 10 on the preliminary and 4 on the software specific questionnaires. However even for questions which do not relate directly to previous experiences with taught content regarding the cardiac cycle, it was expected that people who were familiar with the subject and those who were not were likely to have very different perceptions of the software.

It was also expected that participants would particularly struggle with the game, which requires a level of prior knowledge of the topic in order to even begin to play. Regardless of software, a point to make is that these programs were designed to a specific set of requirements – those of the target audience. For this test group content may have been too hard or too easy. From now on participants of this test will be referred to as Group B.

8.4.3. Breakdown of test session

Tests took place at Canalside West within the School of Computing and Engineering at the University of Huddersfield. The hardware used for each test was installed on computer workstations of very similar if not identical systems specifications. This ensured that the running performance for all participants was very similar.

The test was led by Daniel Fitchie, who:

- Set up the testing environment.
- Carried out all instructions prior to and during the test.
- Ensured the test was carried out to specification and within the allotted time.

8.4.3.1. Format of the tests

The test was made up of two elements; the testing of software and questionnaires to gather data. Testers were required to fill in three different questionnaires. This includes a preliminary questionnaire and two software specific questionnaires. Answers across each of the three questionnaires were linked to an individual using a card system. Students were given a set amount of time to fill in the questionnaires, which they were made aware of on the day of testing.

Preliminary questionnaire

Students were required to complete a preliminary questionnaire at the beginning of the test, prior to any exposure to software. The contents of which aimed to gather information about the background of the tester. This information pertained to their age, computing experience and teaching/ learning experiences.

Software test

Participants were then given access to the two pieces of software for a set amount of time. The time was the same for each piece of software.

Software specific questionnaires

Students were required to complete two software specific questionnaires, each of which was related to one of the two pieces of software that has been developed. A piece of software was tested and then the relevant software specific questionnaire was completed. This questionnaire aimed to gather data related to the success of each application as a learning tool.

Cards

Each student that participated in the test was given a numbered card. This card was their unique identifier. Each questionnaire contains a question which asks for this number so that responses given across each questionnaire could be tracked to a single person without the need for personal information.

Details of any preparations that were required prior to the testing taking place are discussed in Appendix D.

The setup of the test environment can be seen in Figure 29 and Figure 30 on the following page.

Figure 29 - The testing environment is shown; here the Cardiac Simulation can be seen.

Figure 30 - The testing environment is shown; here the Cardiac Game can be seen.

8.4.3.2. How problems during the test were managed

Application problems were managed in a number of ways:

1. To lessen the learning curve of each piece of software a demonstration was given prior to the students being allowed to use each application. The duration for each demonstration was the same.
2. The limitations of the current versions of each piece of software were explained to the participants in the hope that confusion caused by said limitations was minimised. Also by explaining the limitations it is hoped that exposure to these problems could be avoided to an extent.
3. In regards to any non technical problems which could arise during the test, the problem was announced to all participants and the solution given. This ensured that no participant was advantaged over another through help they were potentially given.
4. In regards to any technical problems that may have arisen during the test, participants were told in advance to simply close and re-launch the software.

8.4.3.3. Schedule of the test

The specific schedule that was designed for the test can be found in Appendix D2. Here the specific timings and an indepth description of each stage of the test is given.

Chapter 9. Results Analysis

The following analysis section details results from the testing of the software developed. Results relate directly to the project objectives stated previously.

9.1. First test – Group A

Whilst analysis of the data gathered from the questionnaires used in the first test has been analysed in full in Appendix E, the sample size is so small that the data is limited to the extent of being of little use. As will be explained in the evaluation section of the report, it is felt that this data cannot be used to evaluate project objectives and so is not included in the main body of the report.

9.2. Group A – Informal discussions

As stated, the researcher adapted the first test to include a short group discussion session with the test subjects as a means of gathering more useful data.

The discussions highlighted some of the limitations of the software developed especially in relation to their effectiveness as learning tools. In addition to this important points regarding key considerations that must be taken when designing such educational software were raised.

9.2.1. Implementation problems

A complaint of the implementation of the game was that the icons which were used to represent the elements of the heart's anatomy were confusing, with participants finding it difficult to identify which part they actually related to. This is a significant problem due to the fact that the main game mechanic requires the blood to be directed to these pieces of anatomy in the order they should appear during the cardiac sequence. If the tester did not know what each piece represented they would not have been able to progress properly through the game. Due to this feedback a label feature was added to the game for the second test of the software to try to overcome the problem. Another problem identified, which could have created a frustrating experience for testers was the fact that the game was deemed too difficult because the twenty seconds players were given to link blood vessels to the next destination before blood was released was felt to be too short.

9.2.2. Design decisions

Participants felt the game mechanic to be illogical because it involved directing blood in directions far removed from how it would occur in reality. By nature many games represent the game world in abstract manner; such was a goal of the project - to represent the information in a manner completely removed from not only their traditional learning resources but also the simulation. Presenting any sort of educational content regardless of topic, is unlikely to be representative of the real-world in games. This point seems to go against one of the proposed characteristics of the new generation of learners which were covered in the literature review, which states that fantasy permeates the lives of such learners. It could be that this is evidence that the participants are in fact not digital natives as Prensky (2001) suggests.

9.2.3. Revision versus learning

Student's felt that the game was more suitable for use as a revision tool rather than a learning tool. There were two aspects to this argument. First of all participants felt that such an application as the game would be used more effectively if the student already had knowledge on the subject and was testing that knowledge through drill and practise. The second aspect of the argument was that participants indicated that in order to use the simulation you did not require any previous knowledge of the subject whereas in the game you actually needed working knowledge of the heart before hand to progress. This was a factor which was predicated as being a potential problem in section 6.8.3. At the time while this fact was considered a risk, it was felt it was one which could be taken due to the fact that the original target audience would have covered the required knowledge prior to testing the software. It is apparent that this was an incorrect choice on the part of the researcher. Again this a poor design choice by the researcher and also a major problem of the methodology used.

9.2.4. Level of knowledge

Post test, participants stated that they found both software tests but particularly the game test difficult because they had forgotten a lot of what they had learnt about the heart at the beginning of the academic year. A suggestion was made that had the test taken place closer to the time when teaching of the subject occurred, the experiences during the test would have been very different. This is something which could have improved the test results, however unfortunately testing closer such a time would be impossible given time constraints of the academic year. For this course of action to take place the software developed would have needed to already be available for testing at this point. Discussion of different ideal methodologies takes place in section 10.2.1. A comment to make regarding this is that it is apparent that in the case of this topic there seems to be a low level of knowledge retainment amongst the students. While the tests did take place some months after the students were taught the content, it was expected that students training to be health professionals might have remembered more of the content.

9.2.5. Amount of content

Two observations were made by the test subjects in regards to the amount of content covered by each program. Students identified that it was apparent the two applications were teaching different topics and that the game was able to teach far less than the simulation. This is one of the main factors that was experienced by the researcher during the project, and was reflected on in section 6.4 where the design difficulties experienced with the game were detailed and. An original objective of the project had been that both pieces of software that were to be developed would satisfy the same educational objectives, however in this section it was explained that such a thing could not happen. At first look this point may seem like a design failure by the researcher, and to an extent a better game design may have allowed for inclusion of more content; however it is felt that the ability to include less content in games compared to other applications is something inherent in the medium.

9.2.6. Learning curve

As with the previous point regarding the amount of content that can be incorporated into games, another piece of feedback given during the informal discussions that was a key factor experienced during this project was that of the consideration of learning curve when using such applications as a solution to educational problems. Participants felt that the game was an ineffective learning tool because in order to use it you first had to learn how the program worked. This does not relate to previous points regarding the knowledge entry requirement of the game compared to that of the simulation, but rather the requirement to understand elements of the game's design and mechanics prior to use.

9.2.7. Age of audience

A final point raised during the discussion was the use of games as educational tools would perhaps be more suitable for younger audiences

9.3. Second test – Group B

Please refer to section 8.4.2 regarding the limitations of the second test which could have effect the results experienced.

9.3.1. Teaching and learning experiences of students

Various parts of the questionnaire aimed to discover student's experiences in relation to the ways in which they are taught and learn. Participants were asked what their favoured learning styles were, the results can be seen in Figure 31. Data shows a preference toward the visual and kinaesthetic learning styles, so supporting other data collected from informal interviews carried out in the initial research stages of the project detailed in section 5.7. Preference to these learning styles is favoured to a much greater extent than the read/ write and aural/ auditory styles. The style that was selected least was the aural/ auditory category, an interesting outcome due to the fact that the main method of content delivery for students – lectures – falls under this learning style.

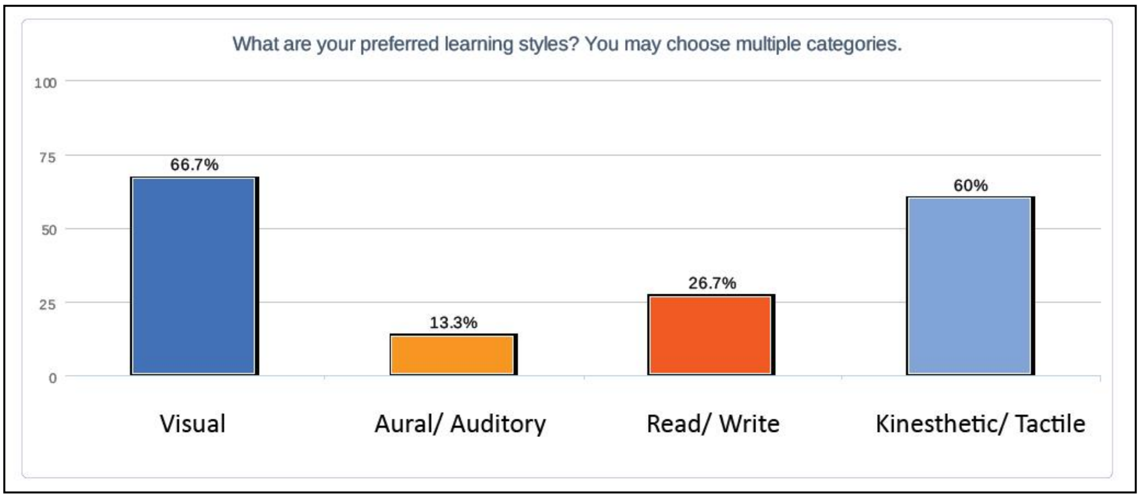


Figure 31 - Learning style preference amongst test subjects.

Group B were asked to rate on a scale of 1 to 10, how well they feel that the way they are taught matches their learning style preference. Over 90% of students rated this either 5 or higher, of those 50% rated either a 5 or 6, which displays an overall satisfactory opinion of how teaching tailors to student's learning styles, but with large room for improvement.

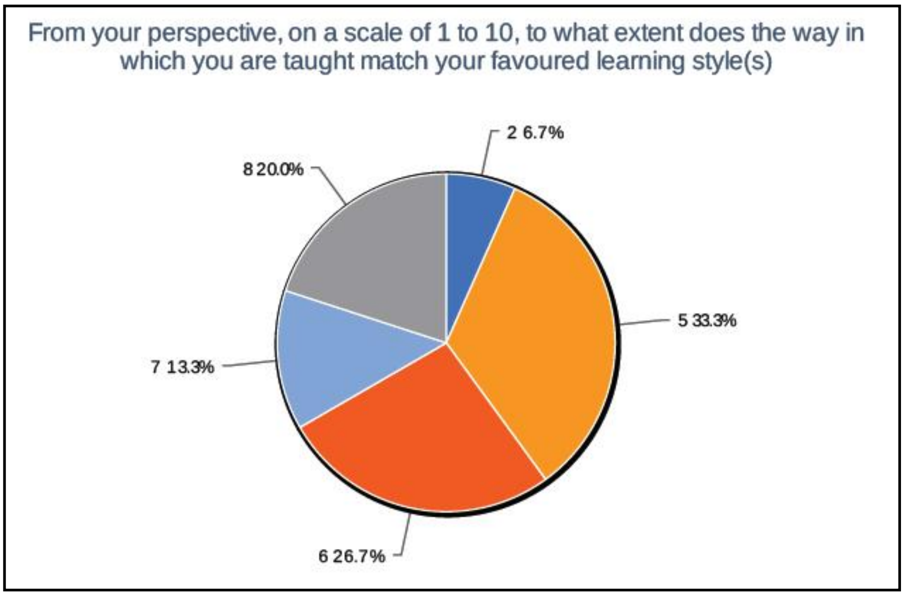


Figure 32 - A diagram which displays the results to the question, "To what extent does the way in which you are taught match you favoured learning style(s)?"

Students that had studied the cardiovascular system were asked to indicate which aspects of the taught content they felt traditional methods of teaching struggled to convey effectively. The results can be seen in Table 5. This question is one of the contingency questions where the overall group was separated into subgroups of those who have studied the content and those who have not, therefore the results here are indicative of only 9 participants of the test. The average scores given to all categories are relatively low, falling at the mid or below level of the scale. The mid level scores indicate that students feel that traditional teaching methods are just adequate and so satisfactory but again could be much better. The lower scores indicate dissatisfaction at methods in regards to conveyance of many of the main concepts surrounding the topic, with the lowest rated concept being the flow of blood around the heart – with a low average score of 3.

Main educational objective	Average score given for methods of teaching
How effective do you think the way you are currently taught is at educating you about what the heart and its associated anatomy looks like during a typical beat?	4
How effective do you think the way you are currently taught is at educating you about the events and phases that take place during a heartbeat and the order in which they occur?	3
How effective do you think the way you are currently taught is at educating you about blood flow around the heart?	4
How effective do you think the way you are currently taught is at educating you about names and positions of parts of the anatomy of the heart?	5

Table 5 - Participants are asked to rate how effective they feel current methods of teaching are at conveying main educational objectives of the subject matter.

9.3.2. Effectiveness of each software developed

Question 3 – Software specific questionnaire

Participants were asked to rate how effective they felt the software was at educating them about the main educational objectives on a scale of 1 to 10. The average scores given to each program that was tested are shown in Table 6. The simulation was deemed to be very effective at teaching categories 1, 3 and 4, but given an average satisfactory rating for the objective of teaching about the events and phases during the heart. As can be seen in the table, overall the game was given an average or below score for the majority of objectives, however for objective number 3 - that of teaching blood flow around the heart – the game was scored quite highly, with an average score of 7 given. This suggests that the game was successful at teaching the main topic which it is covered in the software.

Also in Table 6 a comparison is made between the average scores given to each piece of software and traditional methods of teaching in relation to the educational objectives. Here the simulation is deemed by students to be more effective in comparison at teaching all of the main concepts surrounding the topic. There can be seen to be a quite large difference between scores given by Group B in relation to this. While the game was scored reasonably low for all concepts, a comparison to the scores given to traditional teaching methods reveals that the game is deemed to perform better at teaching three of the main concept. While it would be simple to take the results of the last comparison at face value, it is difficult to accept that the game teaches these three main concepts better than traditional teaching. This is because other than the objective relating to blood flow, the other two objectives which data suggests are taught more effectively are not a focus of the software to any extent, and so it is this researcher's opinion that the scores in relation to this cannot be counted as being reliably representative.

The data here does show that participants feel the game to be less effective than the simulation as a learning tool.

Main educational objective *(Here 'X' refers to either simulation or the way participants have been taught)*	**Average score given for simulation**	**Average score given for game**	**Average score given for methods of teaching**
1. How effective do you think 'X' is at educating you about what the heart and its associated anatomy looks like during a typical beat?	8	3	4
2. How effective do you think 'X' is at educating you about the events and phases that take place during a heartbeat and the order in which they occur?	5	5	3
3. How effective do you think 'X' is at educating you about blood flow around the heart?	7	7	4
4. How effective do you think 'X' is at educating you about names and positions of parts of the anatomy of the heart?	9	6	5

Table 6 - A comparison between the average scores given by participants referring to the effectiveness of the simulation and the effectiveness of the normal method of teaching/ learning in relation to these objectives.

Further analysis of the results for the simulation in regards to this question display some interesting scoring by participants. Table 7 shows the count for specific scores given for each category where it can be seen that the simulation was scored very low for some of the objectives; in the case of objective 3 it was given a score of only 1 by a single participant. The reason that these results have been highlighted is due to the fact that they are so different from the majority of other scores given not only for the same objective, but across the board. In this same category 60% of participants scored the simulation 8 or above, which makes it difficult to understand why another participant could perceive it to be so ineffective in comparison. Analysis of individual responses using the card system implemented into the methodology shows that for each of the educational objectives, the lowest scores were given by a single participant. While these scores certainly cannot be counted as anomalous because all data gathered is based off student opinion and is therefore equally valid, they are again difficult to understand and analyse because the same participant in other questions said that such a program 'would greatly help' in their revision and learning of educational content and that 'yes' they would like to see the simulation used on their course. Results seem contradictory.

Main educational objective *(Here 'X' refers to either simulation or the way participants have been taught)*	**1 %**	**2 %**	**3 %**	**4 %**	**5 %**	**6 %**	**7 %**	**8 %**	**9 %**	**10 %**
1. How effective do you think 'X' is at educating you about what the heart and its associated anatomy looks like during a typical beat?	0	0	0	0	1	0	7	3	1	2
2. How effective do you think 'X' is at educating you about the events and phases that take place during a heartbeat and the order in which they occur?	0	0	1	0	2	2	3	5	0	1
3. How effective do you think 'X' is at educating you about blood flow around the heart?	1	0	0	1	1	2	0	4	4	1
4. How effective do you think 'X' is at educating you about names and positions of parts of the anatomy of the heart?	0	0	1	0	0	0	0	5	4	4

Table 7 - Table showing counts of scores given by participants on a scale of 1 to 10 for each of the educational objectives relating to the simulation.

Question 4 – Software specific questionnaire

Students were asked which elements of the content are taught better in each piece of software compared to traditional teaching; Table 8 shows the results of such enquiry. The simulation was deemed to convey many aspects of the educational content better than traditional methods. In this test the aspect which was rated most frequently as being conveyed better was the motion of the heart, followed closely by the labelling of the heart's anatomy. The following are some comments made by participants in regards to the effectiveness of the simulation:

- Many of the visuals at a college level are confusing and often difficult to make out, but here the graphics are felt to be clear and understandable.
- Arrows allow for easy understanding of the direction of blood flow around the heart.

Table 9 shows the results for the same question but for the test of the game. Results indicate that only a small number of participants felt the game taught any of the concepts better than traditional teaching, with lower counts visible for the selected elements. Taking into account the smaller sample size due to this question being a filter question, it can be seen that more than half of the filtered participants felt the game taught the concept of blood flow better than traditional teaching.

If you have studied the 'cardiac cycle' at college please answer this question, otherwise please go onto the next question. In regards to your taught content, are any of the following topics conveyed better in the simulation compared to traditional teaching/ learning methods?

Value	Count
Motion of the heart	6
Timescales of a heartbeat	2
Structure and look of the heart	4
Labelling the heart's anatomy	5
Phases of the heart (atrial systole, ventricular filling etc)	4
Events during a heartbeat (when valves are open/ shut, when blood enters the vena cava, aorta etc)	4
Pathway of blood through the heart	3
Identifying oxygen rich/ poor blood	3
Origin and destination of blood	3
Valve operation (why and how they open and shut)	4
Graphical feedback of a heartbeat	3
Sounds of the heart	4

Table 8 - Participants indicate which elements of content are taught better in the simulation compared to traditional teaching.

If you have studied the 'cardiac cycle' at college please answer this question, otherwise please go onto the next question. In regards to your taught content, are any of the following topics conveyed better in the simulation compared to traditional teaching/ learning methods?

Value	Count
Motion of the heart	2
Timescales of a heartbeat	2
Structure and look of the heart	1
Phases of the heart (atrial systole, ventricular filling etc)	4
Events during a heartbeat (when valves are open/ shut etc)	1
Pathway of blood through the heart	5
Identifying oxygen rich/ poor blood	1
Valve operation (why and how they open and shut)	2
Graphical feedback of a heartbeat	1
Sounds of the heart	1

Table 9 - Participants indicate which elements of content are taught better in the game compared to traditional teaching.

Question 5 – Software specific questionnaire

Participants were asked how much they felt each program could have helped in their learning and revision of the subject prior to taking an exam on the topic. Results for the game are relatively positive; while the majority of participants (50%) felt the game would only 'slightly help', no participants rated it lower than this category, indicating that everyone feels it could help to a certain extent. 42% of participants felt that the simulation would 'greatly help' their learning of the subject, with no ratings given for categories below 'moderately help'.

Question 6 & 7 – Software specific questionnaire

Previous analysis of results shows that overall Group B participants favour the visual (66% of participants) and kinaesthetic/ tactile (60% of participants) learning styles. On average Group B gave the simulation an average rating of 7 in relation to how much the application suited their preferred learning styles, indicating that the application tailored to this group's preference well. The game was given an average rating 5, meaning that it tailored to participants preferred learning styles to a lesser extent than the simulation but was on par with traditional methods of teaching which was also rated 5.

In a separate question, participants were specifically asked what level of suitability each application had to each of the four learning styles. Focussing on how well applications suited the visual and kinaesthetic styles, results for the simulation show that for the visual style the category with the highest frequency is 'perfect suitability' (57% of participants) while the highest frequency in relation to the kinaesthetic style is the 'suited somewhat' category (50% of participants), following closely by the 'suited well' category (43% of participants). Results for the game show that for the visual style the category with the highest frequency is 'suited well' (57% of participants). Results for the kinaesthetic style show the highest frequency again in the 'suited somewhat category (43% of participants), and as was the case with the simulation, the majority of the remaining participants selected the 'suited well' category (36% of participants). These results suggest that both applications seem to match student's learning style needs very well, certainly more so than traditional teaching, with the simulation being a closer match than the game. In this test the game scores averagely for effectiveness in relation to the ability to convey the educational objectives, regardless of this fact student's still see the application as suiting their learning style needs well.

Question 8 – Software specific questionnaire

In order to gauge the level of enjoyment participants experienced during the test of each software, and so comment and each applications potential of reaching Csikszentmihalyi (1991) theorised state of flow, testers were asked how fun they found the software to use. In the test of the simulation the majority of test subjects (57%) stated that the simulation was 'moderately fun' to use, however two participants did find the simulation 'not fun' to use. One piece of feedback from the comments stated that after you had discovered each feature once, the simulation lost its immediate appeal. In terms of enjoyment the game was well received, certainly more so than the simulation with 90% of participants rating it as being 'slightly fun' to use or higher, and four participants saying it was 'very fun'. The game was given some feedback which stated that the idea of placing things together was a good concept as you were learning whilst having fun at the same time. This analysis is interesting as it highlights a point regarding the concept and perception of fun. While the game version is designed to not only teach but be fun to play, it could not be said that the simulation is designed with the same level of end user fulfilment in mind. The latter application is certainly meant to be interesting and informative to use, but not necessarily 'fun', and so the trends in these results are to be expected. As will be commented on in the evaluation in retrospect this question should have perhaps simply referred to 'enjoyment' instead of 'fun', as it is felt more useful results would have been gained.

Question 10 – Software specific questionnaire

Subjects were asked specifically whether they would like to see each of the programs that were created used on their course for teaching about the cardiovascular and other bodily systems. All participants stated that yes the simulation was a tool which they would like to see used on their university course. Comments given in accompaniment to this question indicated that the simulation was easy to understand and information was presented well, with the concepts being easier to visualise and so it has the potential to make memorizing parts of the heart much easier. The results for this question and the game were more mixed; 65% of participants felt that they would like to see such a game used on the course, with the remainder obviously stating they did not.

Question 11 – Software specific questionnaire

All participants were asked to compare each piece of software, and state which they would prefer to use as a learning tool. Again results here were mixed, however the majority of participants felt they would prefer to use the simulation over the game (70%). Feedback in the comments section of this question sheds light on the results, with one participant stating that the game was more fun to use, meaning it would more likely be used and another stating preference for the simulation because it was more understandable, conveyed more information and so would be better for learning. This participant went on to say that the game would be more suitable for revision, so reiterating a point raised in the informal discussion with Group A in section 9.2.

9.3.3. Digital natives, digital learners

A main thread through this project is an attempt to discern whether the undergraduates that have been the target of this project are what Prensky (2001) and Tapscott (2009) describe as digital natives and the net-generation respectively. While the participants of this test are not the original target audience they are representative of students studying at an undergraduate level in higher education which is equally valuable. Referring back to the literature review, these individuals describe a divide that can be seen to exist between a younger generation who have grown up with digital technologies and an older generation who have begun to adopt these same technologies (referred to as digital immigrants). They suggest that learners today are digital natives and so digital learners, and because of this learn in a very different way to previous generations.

The first analysis to this end is in regards to the age of the student participants of the test. Theories surrounding digital natives suggest that people belonging to this group were born in the last decades of the 20^{th} Century, with Tapscott (2009) specifically stating that members of this group are aged between 11 and 30. Analysis of the second test reveals that of the participants only nine fell into this age range, with the remaining six participant's ages ranging from 31-55. If the previously mentioned theories are to be believed all of the participants should fall in the digital native age range however these results show this not to be the case, rather there is a mixture of natives and what Prensky (2001) would describe as digital immigrants.

Participants were also asked different questions which attempted to establish the level of familiarity with digital technologies amongst test subjects. 70% of Group B stated that they were either 'reasonably comfortable' or 'very comfortable' using computers, showing a relatively high level of computer literacy amongst these subjects. Participants were also asked whether they played any form of computer games. The numbers of those that do play games were much higher than expected with 60% of the group stating they did play computer games with the majority of these respondents stating they play on average 1-2 hours per week. Questions were also posed in regards to the analysis of the familiarity with digital technologies, which were specifically aimed at garnering whether participants were what would be classified as 'digital learners'. In response to a question regarding the types of extracurricular learning resources participants used the following is a selection of the items listed:

- Text books
- Journals
- Lectures
- Internet
- Library
- Library databases
- Games
- Debates

- Group work

The sample size is too small for comments to be made on significant trends between the balance of preferences of digital and traditional resources of all students. In this test participants seem to use a mixture of digital and non digital resources in equal amount. Another limitation of the data is that when resources such as debates and journals are quoted no indication is given by participants as to whether they are of a digital nature or not. Table 10 show a selection of the reasons given by Group B as to why they use or do not use digital resources. The main reason quoted by students for not using digital resources being lack of computer knowledge, which leads to difficult and complicated experiences. It must be assumed that these reasons must have been given by those participants who rated their comfort level with computers as being 'reasonably or very uncomfortable', which were two members of the total sample. Reasons quoted for the benefits of using digital technologies as learning tools were the ease of access, speed of results - so saving time and effort - and the reinforcement of taught content.

Why digital resources are used	Why digital resources are not used
• Faster results. Ease of access and everything is in one place. • Saves time and effort. • Digital visuals are exciting and easy to remember. • Reinforcement of taught content. • More tailored to the preference of independent working.	• Lack of computer literacy. • Lack of access. • Difficult and too complicate. • Lack of knowledge of available computer resources. • Time consuming.

Table 10 - A comparison of participant's reasons for either using or not using digital resources.

In the literature review of this report it was found that one of the suggested characteristics of digital natives was that for this group of people text was secondary to images. The previously stated results regarding a preference to the visual learn style seem to suggest that these participants are digital natives.

A comparison will be made between cross referenced results of specific participants – one which the literature would classify as a digital native and one which the same literature would class as a digital immigrant – in relation to the points made in this section regarding digital learners. One 19 year old participant stated that they were 'very comfortable' using computers, were computer gamers;

playing on average 1-2 hours per week, and used a mixture of digital and non digital learning resources outside of the classroom environment. Reasoning given by this participant for using digital resources was that they found it made for the best absorption of information. This participant matches perfectly to the notions of digital natives and digital learners suggested in the reviewed literature. Another much older participant of 50 years of age - who again according to the literature should not be very familiar with digital technologies, and would not learn using digital means and should not be classified as digital natives – stated they were 'very comfortable' using computers, and as was the case with the younger participants played computer games for 1-2 hours per week on average. This participant also used a mixture of digital and non digital learning tools because they are much easier to access than traditional resources. The data seems suggest that these theories are not quite applicable to this group of participants.

9.3.4. Factors potentially limiting the success of the software developed.

In order to gauge what factors could have affected the quality of experience for test subjects - factors which could have reduced the perception of success and effectiveness of each piece of software as a learning tool - a specific question was asked in regards to confusing elements of application, and also data can be gathered in regards to this from essay style comment opportunities throughout the questionnaires.

9.3.4.1. Simulation

In the specific question regarding interface, navigation and usability of the simulation, the majority of participants stated that they found nothing confusing during the test of the simulation (57%). Of those that did state confusion, the elements which were selected in highest frequency were the function of buttons on the user interface and the navigational controls. Comments suggested that the navigation tools were not obvious enough and there were multiple comments that stated a problem existed with the buttons, in that testers had to click them multiple times before an effect was registered. Unfortunately this is a known issue with the software, however the cause itself is not known - buttons seem to work on some pcs and not others. Others factors which are stated are that more time would be needed to properly familiarise with the interface. Again the lack of time for testers to effectively learn how to use the programs was something which was predicted to be a problem and is something which is discussed in the evaluation of the project in relation to the problems of the methodology. One participant unfortunately expereinced a shortcoming of the implementation of the software, which is the inability to have the labels displayed around the heart whilst the heart was beating. Such a feature would have furthered the learning experience but unfortunately could not be implemented in the available time.

9.3.4.2. Game

Table 11 shows the results of the same question but for the game. Group B experienced more problems with the game than they did whilst testing the simulation. Confusion related to most aspects of the game design, including the objective, scoring, controls, and consequences. Comments given by participants indicated that they found the game too difficult because the time a player is given to make a connection between anatomical destinations is too short. This is a problem which is caused because all testing of the software was carried out by the developer, and so familiarity with the game means that it is difficult to gauge how another audience would find the experience. To overcome such problems a usability test would need to have taken place as part of the process, which in ideal circumstances would have been carried out by the target audience. The predicted problem caused by the level of entry knowledge required for the game, put forward by the researcher in section 8.4.2 came to fruition, as multiple participants stated that they struggled because they were unfamiliar with the heart topic. As with previous analysis regarding a need to overcome a learning curve with each program, again this was indicated by participants concerning the game.

Did you find anything confusing about the game?

Value	Count
Objective of the game (Take blood around the systemic/ pulmonary system by directing blood through the correct pieces of anatomy in the order they appear in the cardiac cycle, place sections of vessel in lengths between anatomy hubs before either blood is released or blood leaks etc)	3
Controls (placement of vessel section, replacing vessel sections etc)	4
How you win	2
How you lose	1
How to score points	1
How to lose points	1
Consequences of actions (why you lost a life, why you were taken back to a previous anatomy hub and a length of connected vessels destroyed etc)	3
Progress feedback (have you gone to the correct or incorrect anatomy hub etc)	1
None of the previous	4

Table 11 - Results indicating confusing elements experienced within the game.

Chapter 10. Evaluation

In this section the process of carrying out the project will be evaluated. This section will detail; the limitations and problems experienced throughout, changes that would have improved the success of the project, the level of success at achieving the project objectives and other key findings from the experience. The project will be evaluated using data gathered during the project, which includes:

- Informal interviews carried out during initial research.
- Focus group/ informal discussions with Group A.
- Test data of Group B.
- Interviews with industry developers.

The test data of Group A, specifically data pertaining to the questionnaires will not be used in the evaluation. It is felt that the sample size is simply too small for useful information to be drawn. The data from Group B, while still from a relatively small sample will be used however.

10.1. Limitations

10.1.1. Research

During the review of literature surrounding the area being investigated, very little research was found which clearly defined between the learning benefits of simulations and educational games, instead benefits were often discussed as being global to the field of serious games. Moreover no research was found which compared the use of a simulation and an educational game for a given topic. This means that it is difficult to ground this investigation and the research carried out during the project in other findings and so again making it difficult to compare the outcomes experienced to any other information.

In the analysis section 9.3.2, the ineffective posing of a question relating to the amount of fun participants experienced whilst using each program was commented on. It was stated that instead of relating to fun the question should have related to enjoyment. The reason for such questioning was to enable the researcher to comment on Csikszentmihalyi's (1991) theories on the achievement of a state of 'flow', through immersion in a task. Due to this mistake it is felt that effective suggestions cannot be made by the researcher in regards to this part of the original research.

10.1.2. Design

In the case of the simulation it is felt that there were no obvious design mistakes which could have been potentially limiting factors to the success of the project. The same however cannot be said for the game. As was explained in the design section of this report a key finding of the researcher during the project was the difficulty experienced in implementing many of the educational objectives defined by the researcher into the game. A different design could have allowed for more educational content, but it is felt that the amount of educational content that can be incorporated into a game whilst retaining high design standards is less than such software as the simulation. This point will be discussed further in the evaluation during the other key findings section. Due to the lower amount of educational content present in the game, it could be suggested that such a test is unfair when a main objective is to compare the effectiveness of the two applications. Another key design mistake in relation to the game was the different level of knowledge entry requirements of this application compared to the simulation. The requirement of prior knowledge of the heart in order to play the game could again be deemed unfair when comparing the two programs. This fact caused problems during the test because the sample size was reduced further in the second test to filter those who had studied the heart previously. To summarise, the entry requirements mean that the game is only appropriate to a specific audience, meaning that is unlikely to be playable by those of a non-biological background and as was experienced limited the amount of appropriate test subjects during the project.

10.1.3. Implementation

Limiting factors associated with the implementation of the software will be discussed from a general point of view but also software specifically.

Development timescales of the software caused a variety of problems throughout the project but mainly impacted the development and implementation of an effective testing methodology for data gathering. Development ran massively over the projected timelines for the implementation of each application detailed in section 7.2. The reasons for such delays stemmed from the lengthy production of the simulation which was in turn caused by the purchase of an inaccurate 3D heart model, resulting in the need to create our own for the project – this problem is detailed in section 7.7.

10.1.3.1. Simulation

The main limitation to state here is that there is a fundamental problem in the coding of the simulation which causes the application to work incorrectly when used on a system featuring a monitor resolution with an aspect ratio that is not 16:10. When used with such a display buttons on the interface do not work correctly a hundred percent of the time. This is a problem which did not affect the testing of the software to any great extent, with only two participants experiencing any issues with button presses and so was not disastrous to the research carried out. However such a problem means that it is difficult to show the simulation off effectively to interested parties. Another limitation is the quite demanding technical requirements of the program. The highly detailed nature of the 3D assets produced, demand a reasonably high specification PC to run. Again while not a limitation which had implications on the research, it is something to think about for future work. In terms of the implementation of features into the simulation, the main limiting factor and most disappointing for the researcher was the lack of ability for labels to be active whilst the heart was animated. This feature was not present because of lack of time for implementation.

10.1.3.2. Game

Feedback from the testing suggested that the use of simple icons to represent anatomical parts of the heart was a limitation of the implementation of the game. Participants felt that it was not clear what each icon represented and so in some cases participants struggled to get the required sequence correct. While out of the scope of this project due to time, the lack of logic in terms of vessel placement and layout of anatomical pieces means that players could become stuck during the game with no means of progressing. Again the amount of impact this had was small due to participants being instructed to overcome such a problem by reloading the game. While not ideal, there is nothing that could have been done differently in the time available.

10.1.4. Methodology

10.1.4.1. Lack of usability testing

A lack of effective usability testing during the project had apparent effects on the experiences of participants during the tests. All usability testing was carried out by the developers, which is problematic simply because as a developer you become used to a program; making it difficult to spot problems. It is also difficult to judge how a certain set of people would perceive a piece of software without access to said people. Had the audience to be used as part of the testing been part of a usability test, such problems as the perception of anatomical icons used in the game as previously discussed would have been overcome prior to testing. In the development that was experienced during the project, an extensive usability test would have been out of the scope of the project.

10.1.4.2. Learning curves

A valuable finding of the project but one which limited the results of the testing greatly was that of the required learning curves when carrying out software tests. Feedback from the informal focus group carried out with Group A and the comments sections embedded within the questionnaires of Group B, suggested that there was not enough time available during tests to learn how to actually use the programs before being at a level to comfortably pass judgement. Such experience however was not quoted by all participants. Whilst such a limitation was put forward in connection with both applications developed, the majority was given in link with the education game. Such problems were predicted by the researcher, which led to the 10 minute demonstration being incorporated into the format of the test carried out; however as was apparent this was in no way sufficient time to overcome the learning curves. A solution could have been to implement in-depth tutorials into the programs, however not only would this have extended the duration of development further but the duration of the test also – which already was quite long at around 1 hour and 15 minutes.

10.1.4.3. Sample sizes

As has been stated multiple times in this report, small sample sizes have caused limitations in the data gathered from the tests. In the case of the first test that took place, it was decided to disregard the results completely because the size was simply too small. Prior to this decision it was still known that a second test had to take place in an attempt to increase the sample size, which meant appropriating new participants. New participants were found, however again the sample size was small and so again the data gathered needs to be considered limited.

The nature of the students caused a variety of problems. The main problem was the fact that the second group of participants supplied by Karen Currell was not guaranteed to have all come from scientific backgrounds, and even for those that do come from scientific backgrounds it was not guaranteed that they would have studied the topic covered by the software developed. This made questions within the questionnaire potentially inapplicable to certain participants and so there was a need for filter questions to be implemented. Further problems associated with this second set of students can be found in section 8.4.2.

The need to discount the results of the first group was not only due to the small sample size but it was felt that it would be impossible to collate the data of the two groups when evaluating the success of the project and specifically the objectives, because the two sets of participants are so different in terms of educational background.

10.1.4.4. Questionnaires

Basing the main method of data gathering on the analysis of student opinion had mixed effectiveness. On one hand some very interesting points were raised, however on the other analysis of results revealed inconsistencies and in some cases contradictions in the responses given by participants. Such occurrences are discussed in section 9.3.2. In one example a participant scored the simulation very low in relation to conveying educational objectives but later stated that such a program 'would greatly help' in their learning of the cardiac cycle topic, and stated that 'yes' they would like to see such a program used on their course in the future.

10.1.4.5. Voluntary participants

As has been stated in the report, the main reason for such a low turnout of the first test with the target audience was down to development delays leading to the time for testing being pushed further back into the academic year. This was to the point where it took place when most students were simply unavailable. However even with this acknowledgment it is felt that a small sample size could potentially have been found had the testing taken place much earlier, because participation by students in the tests was voluntary. Compulsory participation in tests would be ideal, but such a thing is acknowledged as being an unreasonable requirement.

10.2. Improvements

On reflection many improvements could have been made during the project which would have increased the effectiveness of the process carried out and the results gained from the project.

10.2.1. Methodology

10.2.1.1. Current methodology

Changes could have been made to the implemented methodology which would have improved results overall. It was found that during the project the most useful data was that which was gathered informally through group discussion or interviews. As the majority of evaluation is based on opinions, data collection through questionnaires is possibly not the most effective means. Had the test been carried out again, questionnaires would still have been used but an informal discussion with participants would have been made a part of the design format, not just an adaption due to the poor turnout of the first test.

Increasing the length of play time during the test could overcome the problem of learning curves to an extent, however such action does come with an attached risk; increasing the length of play time would obviously increase the total time that it takes for each test to be completed. Doing this could lessen the results as participants lose interest and so put less thought into answers given in the questionnaires. Had development schedules allowed it, access to completed programs could have been given to students prior to the test, so that they may practise with each program before the test itself. However the high technical requirements of particularly the simulation as commented on earlier would have made this an unlikely course of action.

10.2.1.2. Ideal methodology

In thinking about improvements that could be made to the methodology, an 'ideal' methodology for such a research project must be considered. From a general point of view, it is the feeling of this researcher that for any ideal methodology to happen certain conditions must be in place. The two pieces of software would either have to be developed in a much shorter time period; with guaranteed completion in advance of the end of the academic year for the target audience, or the two types of serious games being used to test would not be created by the researcher at all. Rather two already available and established applications would be used as part of the test, as is the case in other studies such as Blunt's (2007) research into the effectiveness of serious games. Risks of this methodology would be the inability to guarantee the delivery of quality applications before the academic year ends and the difficulty in finding a simulation and game tailored to the topic and academic level being focussed on for this project. Had either of these factors been the case the methodology would have been as follows.

Tests would take place immediately before the end of the academic year - with a definite amount of participants (compulsory attendance) - after students had learnt the topic in focus using the normal methods of teaching at the university and standard learning resources available. This would mean that all test participants would have been exposed to the same type of teaching and would have experienced a variety of typical learning materials with which they could draw comparisons to software tested. The timing of this methodology would mean that students had already sat any exams affecting their grades and progression within the university, and so the ethical issues arising from exposing groups of students to different learning resources which could have potentially aided one group over the other come examination are avoided.

The methodology would employ tests which record participant's level of knowledge, providing concrete quantitative data on how much of the topic area they know. Students would be separated into three groups:

- **Group 1 – Control –** This group of students are not given access to either of the software products, rather their level of knowledge of the topic is tested once.

- **Group 2 – Simulation –** This group of students are given access to the simulation. Their knowledge is tested once before and once after using the simulation.
- **Group 3 – Game –** This group of students are given access to the game. Their knowledge is tested once before and once after using the game.

Test questions would be the same across all groups and the questions before and after use of each program would also be the same. Groups are not informed of how well they scored at any point during the test.

Comparisons would be made of the before and after software-use scores of participants in Groups 2 and 3, allowing the determination of whether each software had increased participants level of subject area knowledge. Further comparisons would be made between the amount of difference between before and after scores of each piece of software. This would allow comments to be made regarding which type of serious game was the most effective learning tool. Additional informal discussions would occur with students in a similar manner to those which took place in the actual project, as a means of gathering other useful qualitative data.

10.2.2. Design

Very little could have been improved on in terms of the design of the simulation; however the game would have benefitted from a much simpler design. Whilst still containing the elements of such a medium like objectives, rules and consequences, the game would have done so in a manner that required less time to learn. Something like this could have occurred had there been enough time for more design iterations at that stage of the project. The main change to the design of the game would have been the need for no level of knowledge of the topic prior to play. The game would in this respect be less a revision tool as it is now and more a learning tool.

10.2.3. Development

More thorough testing of software would have further limited the occurrence of any problems that arose during the project. In the instance of the fundamental coding issue of the simulation, testing by the development team on hardware outside of the development environment would have possibly raised such a detrimental issue prior to testing. While it has been stated that an extensive usability test with the target audience would have been extremely difficult due to time and accessibility constraints, it is felt that individuals from the target audience could have possibly been brought in from time to time, informally, to carry out quick tests. The time requirement of such a venture would have been small and the need of only a few students would have overcome accessibility issues.

10.3. Evaluation of project objectives, outcomes and outputs

The objectives, outcomes and outputs of this project are stated previously in section 4.2. Each item will be evaluated using the data gathered and experiences of the researcher during this project.

10.3.1. Findings of students in higher education

10.3.1.1. Are students in higher education 'digital natives'?

Analysis of all the information gathered during this research projects suggests that on the surface yes students within higher education are digital natives. Data gathered from the tests show that participants have a reasonably high level of computer literacy with 70% of Group B stating they were either 'reasonably comfortable' or 'very comfortable'. 60% of those tested also play computer games in their free time, with the majority of these players playing 1-2 hours per week. Use of digital technologies as a means of leisure would be a defining characteristic of Prensky's (2001) 'digital native' and Tapscott's (Tapscott 2009) 'net-generation' theories. Students here could be classified as digital learners as in addition to stating the use of a variety of traditional materials such as text books, journals and group discussion, digital resources such as library databases and the internet were quoted as being used to the same extent. However there is a problem; the theories state that these terms are applicable to the 'new generation' of learners in education, with the statement of an age banding of between 11 and 30 for the native category; analysis of the results of questions pertaining to respondents ages, reveal that of those tested only nine participants fell into this age range with the remaining six participant's ages ranging between 31-55. Prensky (2001) classifies people that fall outside of this category as 'digital immigrants', people who are not native speakers of the digital language but have adapted to the introduction of digital technologies. Such people would not use digital technologies as a primary learning resource and would be of a lower computer literacy level. Further analysis tried indicate whether those outside of the age boundary could still be classified as digital natives and in this researcher's opinion some participants should be as the results analysed in section 9.3.3 suggest such is the case. Some of the participants did display digital immigrant qualities in responses but not all. The overall indication is that the majority of students in higher education are digital learners and can be classified as digital natives, but it is not a simple case of people within a certain age range are one label and those that fall outside of the same range are another label.

10.3.1.2. Experiences of students in regards to teaching/ learning

Results indicated that overall there is a level of dissatisfaction of students in regard to how they are taught and learn. Information from informal interviews carried out with the original target audience showed that students are in some cases daunted by the shear amount of information within resources such as the text books that they are provided with. They stated that is was difficult to filter the information down to what is applicable to their level; however Dr Jenny Killey acts as a filter in the classroom setting. Results of the test of Group B indicate that in terms of the cardiovascular topic, student's felt that current methods of teaching are satisfactory at conveying the key concepts but there is a large room for improvement. Visual reliant topics such as the motion of a heart beat and blood flow are deemed to be difficult to convey, this was not only apparent from the data where such topics were rated 3 or 4 out of 10, but also from the informal interviews carried out. Learners here showed high amount of preference to the visual (66% of participants) and kinaesthetic (60% of participants) learning styles, and results show that they do not feel that the way they are taught caters to their learning style needs to a great extent. The data gathered showed that the learning style with the lowest frequency of preference was the aural/ auditory category. The main method of content delivery to students i.e. lectures would be classified under this style of learning, which seems ineffective.

10.3.2. Development of a simulation

A simulation was designed and developed which integrated not only the technical knowledge of the researcher but the educational and scientific knowledge of the client in relation to the topic of the cardiovascular system. The product satisfied the client's requirements. Table 12 shows the original scoping of the simulation's features. The items highlighted in green are those which were achieved and those in red were not. As can be seen all of the 'must have' features were implemented and most of the 'should have' features. Unfortunately the feature relating to the conduction of electrical signals across the heart was not implemented due it being decided by the researcher that it was technically too difficult to implement in the available time. Even some of the 'could have' features were implemented into the solution.

Must	Should	Could	Won't
Anatomically correct heart.	Visual freedom for the user.	Audio feedback.	Ability to alter at least one external factor.
Fully animated to show the show mechanisms of the heart during a beat.	Show the conduction across the heart	Ability to slow and speed up the playback of the animations.	Follow a single Red Blood Cell through the entire system.
Timeline that the user can constantly relate to.	Graphical feedback - ECG	Some form of test and feedback system for users.	
Feedback to the user as to what they have clicked/ are hovering over etc.	Feedback of the phases the heart is going through and any events taking place.	Ability to track to certain events during the heart beat.	
Ability to "label" the key elements anatomical elements of the heart.		Be able to view the heart as part of the full circulatory system.	
Blood flow.		Be able to visualise the heart as part of the systemic + pulmonary circulatory system.	

Table 12 -Table showing which how successful the researcher was at delivering scoped features of the simulation.

Overall the simulation was well designed and well implemented with the exclusion of those limitations detailed in section 10.1.3.

10.3.3. Development of an educational game

An educational game was again designed and developed for the project which attempted to integrate the scientific knowledge of the client and technical knowledge of the researcher. The game featured the majority of characteristics of educational games that were discovered in the literature review. Unfortunately not as many of the educational objectives defined by the researcher were incorporated into the design as was hoped. This was due to the difficulties experienced during the design stages, which is detailed in section 6.9. Table 13 shows the original scoping of the educational game and again items highlighted in green were those that were achieved and those in red were not implemented. As was the case with the simulation all of the 'must have' features were implemented into the game, as were the all of the 'should have' features. Again overall the development of the educational game was a successful process, however the improvements detailed in section 10.2.2

and 10.2.3 to the design and implementation of the application could have made it even more successful.

Must	Should	Could	Won't
Placement of vessels on a board.	Introduction/ tutorial to the game.	Dynamic labelling of anatomical destinations which respond to user interaction.	Manual placement of pieces on the correct side of the heart by the player. (according to Stage 01 of the Game's design document)
Timed blood release.	Posing of multiple choice questions to players at certain points during the game.	Inlet and outlets of the anatomical destinations could alter every game.	Intelligent placement of blood vessels (some form of AI which stops players from being able to block themselves in)
Flow of blood around vessels.	Predetermined inlets and outlets of anatomical destinations.	A Helper avatar that gives the player feedback during the game.	Intelligent positioning of anatomical destinations.
Blood leak from vessels and recording method			
Destruction of blood vessels.			
Life system			
Scoring system (gaining and losing)			

Table 13 - Table showing which how successful the researcher was at delivering scoped features of the game.

10.3.4. Development of accurate anatomical assets

Specifically during the development of the simulation the development team created anatomical assets and animations which are accurate and appropriate to topic covered and could potentially be used for purposes other than the simulation environment.

10.3.5. Effectiveness of each software developed

The evaluation of the effectiveness of each piece of software developed will not only be done from the perspective of the software itself but in drawing comparisons to traditional methods of teaching through use of data gathered during the tests.

10.3.5.1. Simulation

Results show that the simulation was deemed to be very effective at conveying the main educational objectives of the topic at hand, with above average score for 3 out of 4 objectives and scoring higher than traditional teaching across the board. Of the taught content participants of the test consider that the simulation teaches many of the aspects better than traditional teaching. In the tests the aspect which was valued highest in relation to the simulation was that of teaching the motion of the heart. 42% of participants felt that the simulation would 'greatly help' their learning of the subject prior to taking exams, with no ratings given for categories below 'moderately help'. In regards to how well the simulation tailors to the learning styles of students, participants felt that on a scale of 1 to 10 the simulation scored an average of 7, whereas traditional teaching only scored 5. Furthermore bearing in mind student's preference of visual and kinaesthetic learning styles, 57% stated the simulation was a 'perfect suit' to the visual style and 43% stated it 'suited well' in regards to the kinaesthetic style. When asked specifically whether they would like to see the simulation used as part of their course all students stated that 'yes' they would like such an application. Reasons given included the information being well presented and easy to understand.

Overall the simulation was a great success and can be seen to be a very effective learning solution to the given problem, with results showing that it is not only effective in its own right but in comparison to traditional methods of teaching.

10.3.5.2. Game

In regards to the effectiveness of conveying the main educational objectives of the topic, the game scored averagely or below overall. While the game scored poorly in three of the categories, it did achieve an above average score of 7 in the category which relates to the main educational focus of the application; blood flow around the heart. This indicates that the application was successful at teaching its main topic. A comparison to the scores given by students for teaching in relation to the same educational objectives, indicate that they deemed the game to perform better. However as was discussed in the analysis section 9.3.2, it is difficult to accept that the game teaches three of the main objectives better than traditional teaching because as stated multiple times the game simply does not focus on such objectives to any extent. Results of whether student's felt the game would help in their revision and learning of the topic are relatively positive with 50% of students stating that it would 'slightly help' and no one categorising it lower than this. While results seem to show that the game is of limited effectiveness as a learning tool in its current incarnation, they do show that regardless student's feel that such an application is better suited to their learning style needs than that of traditional teaching, with 57% of participants stating that it 'suited well' to the visual category and 36% stating it 'suited well' in regards to the kinaesthetic style. Asked specifically whether they would like to use such an educational games as part of their course, 65% of students stated they would, with reasons given that it would make a great revision tool and would make learning 'fun'.

10.3.6. Which type of application is the better learning tool?

Following analysis of results relating to the effectiveness of each application as a learning tool, it is apparent that student's felt the simulation to be a much more effective learning solution. Not only did the simulation score higher than the game in all results discussed in the previous section 10.3.5, but when specifically asked in the test's questionnaire to compare the two pieces of software and judge which is most effective, 70% of students stated the simulation was the better learning tool. Feedback relating to this question reasoned that the simulation was more understandable, conveyed more information and required less learning time.

10.3.7. Desire for serious games in higher education

With the large amount of extremely positive feedback and data that was gathered during the project and the fact the results from the question specifically pertaining to such a line of enquiry indicates that in the case of both examples of software students would like to see such applications used as part of their course. So it can be said that yes there is a desire from students in current higher education for serious games.

10.4. Other key findings

As the project developed many crucial findings arose throughout the process; some directly related to explaining the outcomes of the project objectives, and others which were simply key to the experience. The following are some of these key findings.

10.4.1. Knowledge transfer

One of the most prominent experiences through the project was that of knowledge transfer surrounding the subject matter. In the first instance a high level of knowledge transfer took place between the client and the researcher as explained in section 5.6. For the researcher to effectively design, manage and develop such a piece of software a certain level of expertise was required. In this instance much research into the subject matter took place on the researcher's part to this end. Furthermore there was a secondary level of transfer that took place between the researcher and the managed team. On one hand there was a necessary transfer between certain developers, particularly the artists during the development of anatomically accurate 3D models, but on the other hand there was a natural transfer to members who didn't necessarily require knowledge to fulfil their roles but who naturally picked up on the content during the process. At each level of the development structure a lesser amount of knowledge was required for effective completion of tasks.

Again as per section 5.6, during interviews where industry leaders in the field of serious games were questioned as to their processes relating to this point, it was found that the experiences of two companies were both of a similar ilk. Mellody (2011) described a process where the subject matter expert provided intellectual content to the instructional designer, who then translated the content through use of storyboard for use by the content developer to the end of creating engaging and interactive content. Final content was then reviewed by the subject matter expert before being signed off on. In this instance the researcher of this project would take on the role of both the instructional designer and content developer. Hindle (2011) explained DESQ's focus on the creation of a content specification first and foremost, with regular progress updates with the subject matter expert to ensure everyone who is required to, has enough understanding to develop effectively. Both these processes while not an exact match to the process carried out for this project are very similar.

10.4.2. Revision versus Learning

It can be seen that student's felt that the game developed was more suitable as a revision tool as opposed to a learning tool, with the distinction being that as a revision tool the application reinforces already existing knowledge. While this opinion could be due in part to the need for knowledge prior to playing the game as has been explained, it is felt that this is a valid argument concerning the development of educational games. While games could certainly be designed to teach as well as reinforce, it is the researcher's belief that they are more suited to the revision aspect. As was explained, during this experience it was found that when designing a game there is a need to focus on a quite specific area within the content, which limits the application of such a medium to that of learning a vast amount of knowledge. In an interview, Mellody (2011) was asked whether he felt that this is a valid point to make regarding games – he stated that in his opinion games are best used to reinforce knowledge already covered in a unit of learning.

10.4.3. Grounding in reality

An interesting point to take from the informal discussion that took place with Group A and one which was not a consideration of the researcher during the early stages of the project is that of the possible need to ground software and particularly the representations of virtual worlds within the realms of reality. In the discussions students stated that they struggled with the educational game because they saw it as illogical due to content being presented in such a way that was far removed from how they are taught and how in this instance blood really passes through the heart. Students felt that directing the heart to a piece of anatomy in a direction opposite to how blood would really flow - while still accurate in a sequential sense - simply made no sense. It was as though participants could not detach themselves from the reality of the situation and apply their knowledge. More research would be required to determine whether such a problem is either specific to the level of study of those tested or the topic at hand, or whether it is a global problem. Ladley (2011), explained that his design principles are based on 'situated learning' and so he attempts to simulate real world activities, so such a problem doesn't exist. It is unclear from the interview however whether such a principle exists as a result of a similar finding through Ladley's previous experiences in the field or whether it is simply his company's natural process.

10.4.4. Age of audience

One finding of this process suggested that software such as the educational game could be more suited for use with younger audiences. It is impossible to unequivocally suggest that games should be used for younger learners across the board because this project is very limited in its audience, however this researcher would suggest that at this academic level and with the typical ages of students studying in higher education in mind, games may not be the most natural method of content delivery. It can be said that such a feeling isn't a result of lack of familiarity or preference of gaming either, as results of the test of Group B showed that 60% of the participants were in fact gamers to an extent.

10.4.5. Difficulties creating educational content

In undertaking a project of educational context such as this, difficulties in addition to those typically experienced in software and particularly game development should be considered by the dev team prior to commencement of the process. First and foremost is the need for accuracy, and so developers must be prepared to create iteration after iteration for the subject matter expert, and also from a technical standpoint such a need for accuracy leads to more complex and detailed models and textures, which increases technical demand of the team and software itself. Content needs to be adaptable, as was the case in the creation of the heart model, which needed to be dissected to reveal the insides in real time. Such a requirement leads to further technical considerations. Overall though, in this experience these points led to an increase in development time over that which is normally experienced.

10.4.6. Adaptable software

Particularly through the testing process of this project, the specific nature of the software developed in terms of the target audience caused many problems. The software was targeted at foundation level study originally which limited the appropriateness of the applications for different parties, making it difficult to find suitable test subjects. This problem highlights the need for adaptability of such software to different levels of study in this researcher's opinion. Ideally such software could be applied to different groups of students regardless of what academic level they are studying at, so the program could be dynamically altered by the educator to apply to GSCE or university level. While achieving applicability across such a level difference may not be achievable, if software could be adapted within levels, so a top set and bottom set GCSE group could use the same application, the program would be a much more effective learning solution. During an informal demonstration of the software developed with Sylvia Hepworth, such a point was raised. During the demonstration Hepworth (2011) expressed concern over such software being 'static', as content that students are taught is constantly changing and so such applications could date easily. For them to be most successful she stated a key feature should be the ability for the instructor to change the internal environment when required.

Chapter 11. Conclusion

Findings of the research conducted suggest a perceived satisfactory level of effectiveness at conveyance of the taught content during classroom sessions by those tested, however it is clear that students feel there is much room for improvement especially in relation to visually reliant topics such as that which is the focus of this project. Results show significant trend towards the preference of the visual (67% of participants) and tactile (60% of participants) learning styles of students that were the focus of the project, with results showing that students feel teaching falls short at tailoring to their preferred style. Of those tested only 13% stated the aural category as their learning style – the style which much of traditional teaching would fall under.

Results suggested mixed applicability of Prensky (2001) and Tapscott's (2009) theories surrounding the presence of new types of learners in education – what they term 'digital natives' and the 'net-generation respectively. The majority of participants did display digital native and digital learner qualities but in most cases it was irrespective of the age boundaries suggested by these individuals.

The two applications that were developed can both be considered a success with students finding both types of software taught many aspects of the educational content better than traditional means, and results suggesting a much closer tailoring to the preferred learning styles of students. All participants stated they would like to see software such as the simulation used on their university course, with reasons given that it made information clear and concepts easier to visualise. 60% stated they would like to see the game for reasons such as it being a 'fun way to learn'. A desire for serious games applications in higher education is apparent from this.

The original hypothesis had been that for a given topic games would be a better learning tool than simulations. In the case of this project the simulation was received much better than the game, being deemed to be a more effective tool for learning across all aspects of testing. 70% of participants stated a preference for the simulation over the game. It must be stressed that this is representative of this case study, using this topic and this audience. It is felt that such findings are in no way applicable for all situations. In this respect such a hypothesis and basis for investigation could be perceived ill considered. Research and experiences found that success of such educational solutions is so dependent on a variety of factors such as audience and topic and as Ladley (2011) suggests it is a case of 'horses for courses', with one solution being applicable to a certain situation but not another. That is not to suggest that this research is invaluable though. What can be taken from the process is a set of recommendations, considerations and factors that developers of such educational solutions can take into account prior to the commencement of a project, these being:

Development timescales – A longer development time compared to traditional game development should be considered when creating accurate educational content, particularly in reference to the creation of 3D assets. Such a consideration would however be dependent on the specific case and brief of the project.

Knowledge transfer – A requirement of the successful development of educational material is for the designer and/or person instructing the development team to develop a level expertise of the subject area. In this respect, research and access to the subject matter expert is key. Also expect the need to transfer some of this knowledge to members of the development team when needed.

Value of the subject matter expert – Access to the subject matter expert is invaluable for such development projects. In attempting to develop accurate educational content, the use of a range of sources will often confuse understanding of a topic due to the varying representations of information across resources; in these instances update meetings are vital in ensuring quality assurance and lowering development times.

Visual fidelity – Development of educational content which is diagrammatical in nature is much more important than achieving photorealistic results. It was found that this makes learning and teaching of the content easier by student and teacher respectively.

Amount of content – When developing similar software to that which has been developed, the amount of educational content that is able to be incorporated into an effective design should be considered. In this experience an effective and flowing game design allowed much less content than such a solution as the simulation.

Revision versus learning – Closely relating to the point regarding the amount of content able to be incorporated into each software, it is a finding of this project that educational games are more suitable to being used as revision tools as opposed to learning tools; reinforcing existing knowledge of players.

Representation in reality – A consideration should be made when deciding to represent the virtual world. In the case of this research having a completely abstract game environment that had no relation to topic's mechanics in the real world or the way students are taught created confusion amongst participants. However, further research would be required to clarify and expand upon such a consideration.

Learning curve – The provision of appropriate instructions and tutorials is vital to any type of educational software, however the amount of time needed to learn such software before educational value is apparent should be considered. During this project it was found that the time before value was gained from an educational game was greater than that of the simulation.

Adaptability of software – A more successful piece of educational software would be one which is adaptable depending on the requirements of the users.

Age of audience – Age of the audience of the software being developed should be considered. Just because a game could be made does not mean that it would be well received by all age groups. In the case of this study one reason for a lower perception of the game was because participants felt it was more suitable to a younger audience.

Appendix A

Appendix A1 Educational game examples

Undercover Uxo

A team of students and instructors at Michigan State University have developed *Undercover UXO* (2011a) - an educational game which aims to educate Cambodian children on the dangers of landmines and other unexploded ordinance (UXOs). The project is one which was under development for two years using a $78000 grant from the State Department (Rose 2011; Caoli 2010; Anonymous 2011).

The game uses image repetition to embed warning signals in players' minds (McMillin 2010). Players guide a pet dog to food while avoiding hidden dangers; score is accumulated by recognising danger indicators such as signs warning for mines, or more subtle clues like barbed wire fences (Anonymous 2011). Whilst the game was developed to run on low cost laptops, there are plans to make Mac, Linux, smartphone and web versions of the game at a later date (Anonymous 2011).

Figure 33 - Undercover UXO, a game that tries to teach children in Cambodia about the dangers of landmines (Michigan State University 2011b)

Tate Trumps

Tate Trumps (2010) is a game based on the classic children's card game *Top Trumps*, which is designed to be using by players whilst they walk around the gallery. The game uses location data from the gallery itself and the pieces of art therein to provide player's smartphones with a code which the player can then use to collect the item they are viewing. Once collected the player can uses the collected items in a game of Top Trumps with other players in the gallery. Each artwork is scored under categories such as fame, age size and absurdity (Bradshaw 2010; T3 2010). The game recently won an award at the Media Guardian Innovation Awards (Hide&Seek n.d.)

Privates

Privates (2010) is a education game aimed at teaching teenagers all about sex. The game was commissioned by Channel 4. It is a very light hearted platform shooter that was developed by indie developer Zombie Cow Studios for release on Xbox Live Arcade of the Xbox 360. Players lead a team into a 3D world which represents the human body's reproductive system, in order to fight off sexually transmitted infections. Unfortunately the developers were advised that the game would not make it onto the platform due to content being of an inherently sexual nature (IGN 2010; Fahey 2010), and so was not released. The game is now available for free on the PC.

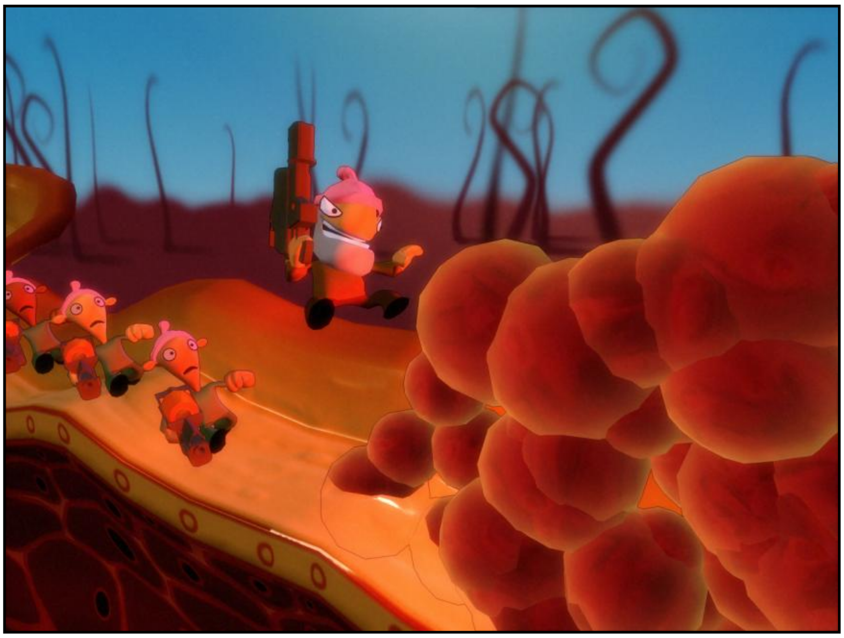


Figure 34 - Privates, a platform shooter sex education game(Size Five Games 2010)

Appendix A2 Simulation examples

Triage Trainer

Triage Trainer (2006) is a prototype application that is designed to train first aid responders on how to prioritize medical care following a major explosion in a simulated busy high street. In the simulation the user interacts with a three dimensional environment in which you view the world through the eyes of a first responder, a world that is populated with casualties with varying types and severity of wounds who react physically and emotionally to the injuries. Trainees have to follow set protocols in order to make their decisions (Thibodeau 2008).

Trainees approach casualties and enter an “examination mode” which offers five different triage options: talk to the victim to see if they are responsive; perform a capillary refill check for blood flow; and check their airways, breathing rat or pulse rate. After this step it is then that trainees label victims in order of priority (Caron 2008).

Triage Trainer has been tested in controlled trials across the UK, where it has been compared to traditional learning methods. In these tests it has been found that the game was significantly better at developing accuracy in casualty prioritisation and correct protocol adherent (Blitz Games Studios 2011).

Figure 35 - The realistic 3D environment present in *Triage Trainer* (Blitz Games Studios n.d.)

Visible body

Visible Body (2007) is a tool that is designed to allow learners to interact with 3D models of human body parts individually or the entire human body. The application features 2400 anatomical structures, which includes all of the body’s major organs. Users are able to view models from any angle with controls for hiding, rotating, zooming and transparency. They can also select body parts in order for the corresponding name to be displayed or use a search function to find the part they want (AppAppeal n.d.). The application works through web browsers, giving it the potential to reach a maximum learner base. *Visible Body* puts a wealth of anatomical knowledge at a learner’s finger tips allowing them to dissect and investigate the human body in a way that otherwise would not be possible.

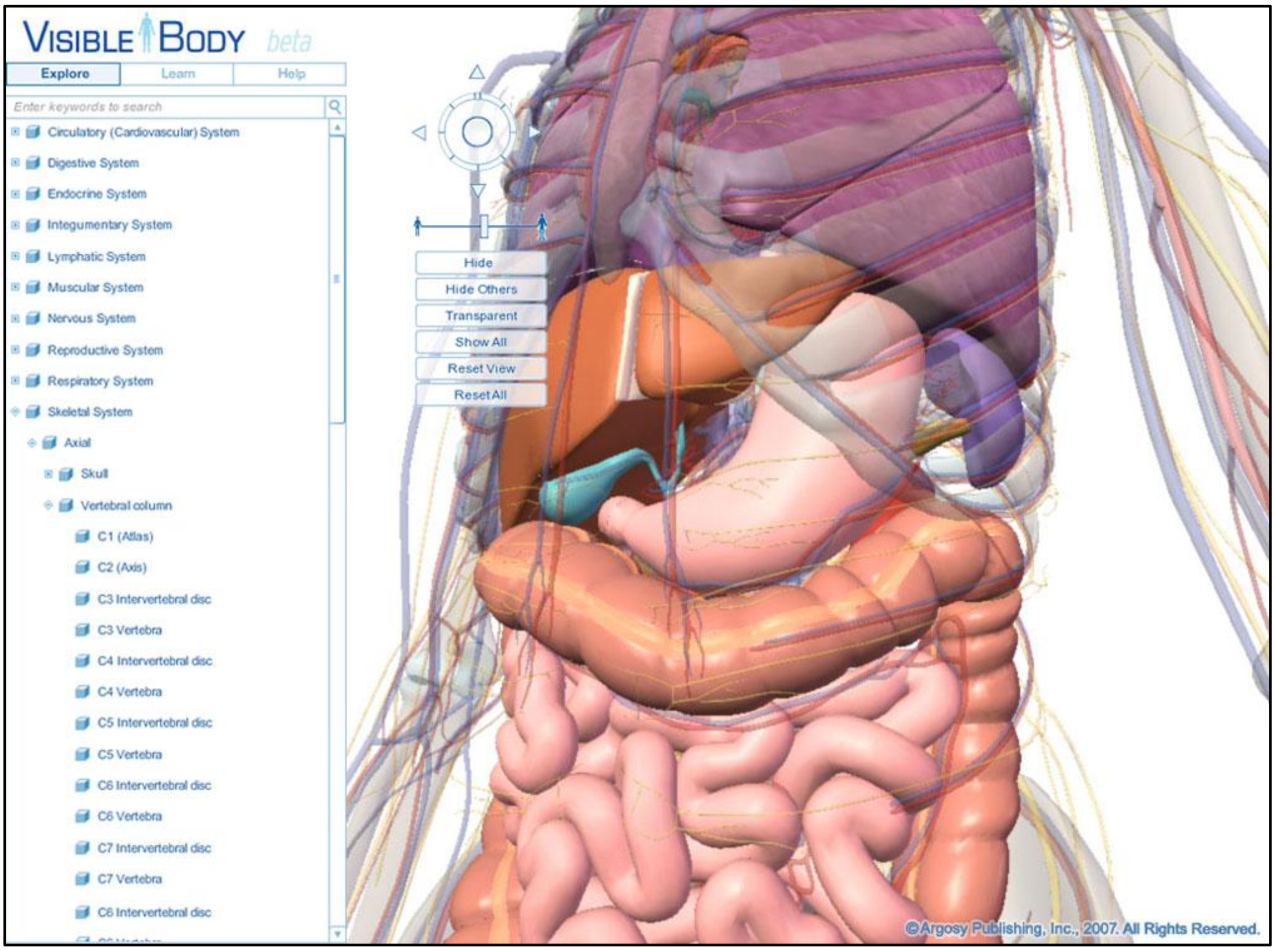


Figure 36 - A screenshot of *Visible Body*, a fully interactive anatomy simulation (Argosy Publishing n.d.)

Appendix A3 Virtual learning environments

Virtual Worlds and Virtual Learning Environments

Virtual worlds are environments where a user is able to interact with other humans. Human controlled 3D avatars existing within 3D environments are the most common form of interaction in virtual worlds (Caspian Learning 2008). An example of a virtual world is *Habbo Hotel* (2000), shown in Figure 37 which is a virtual hotel where users can socialise that is the world's largest online community for teenagers (Sulake 2011). On June 26th 2008 *Habbo Hotel* announced its 100 millionth avatar created, and as of July 2011 had 11,500,000 unique visitors per month (Sulake 2000; Sulake 2008). While virtual worlds of this type are not designed to be educational in nature, it will be shown that already established virtual worlds like this can be adapted to be used as Virtual Learning Environments (or VLEs) , and also worlds like this form the base environments of many VLE's.

Figure 37 - A screenshot from *Habbo* Hotel (2000), a virtual social environment aimed at teenagers (Virtual World Review 2004)

Virtual Learning Environments, like many words of its kind are used in a very broad way. OFSTED (2009) define them simply as "computer based systems that help learning", which while not necessarily incorrect, is a broad definition which again could encompass many types of application. A more concise definition would be that a VLE is an integrated environment which allows learners and instructors to interact with each other whilst providing a range of resources and tools (BECTA 2004).

Characteristics of VLEs include the following:

- A VLE is a designed information space, which is multi authored by students and domain experts.
- A VLE is a social space where social interaction about or around the information creates a learning environment (Dillenbourg, Schneider and Synteta 2002). VLEs have been found to increase the amount of collaboration and communication between users (Selinger 1997).

Interaction can be synchronous through system like instant messaging, where contact is immediate or asynchronous through email or discussion boards, where there is a delay between responses (Kennedy 2009; Chou and Liu 2005; Dillenbourg, Schneider and Synteta 2002).

- The virtual space is explicitly represented in environment which can range from text based interfaces to 3D rendered environments (Dillenbourg, Schneider and Synteta 2002).
- Students are not only learners in these environments, but also act as contributors to the information space. By sharing information using the communication aspect of these tools as described, learners themselves can to some level become the teachers.
- VLEs are not only used as distance learning tools; while distance is certainly one obstacle these tools tackle, time constraints on learners can also be overcome through use of VLEs. As Jacobsen and Kremer (2000 cited in BECTA 2004) state VLEs provided the "flexibility of 'anytime, anywhere' access".
- VLEs can transcend the virtual space, integrating traditional sources and media such as books and television and can promote interactions that are not just computer based such as face to face discussion amongst students and instructors (Dillenbourg, Schneider and Synteta 2002).
- VLEs can provided means for assessment, management and tracking (BECTA n.d.).

VLE examples

The HPV (human papillomavirus) service (NHS Direct)

Following on from our example of *Habbo Hotel* (2000) as a virtual world and our statement that it would be shown that such worlds have been adapted to be used as VLEs, we use the example of a virtual surgery and web chat service set up by NHS Direct using the *Habbo Hotel* service to advise young girls aged 12 to 13 about a new cervical cancer vaccine. As part of the service there were two types of confidential chat services available to users: one-to-one web chats where users could speak to an NHS Direct adviser; and one-to-many web chat, where Health Information Advisers were present in a room of *Habbo Hotel* for group question and answer session (NHS Direct 2009).

Appendix B

Appendix B1 Module specification for target audience

Module Code **HPP1000**

MODULE TITLE **INTRODUCTION TO ANATOMY AND PHYSIOLOGY**

School involved in Delivery Human and Health Sciences

Name of Pathway(s) Foundation Course for the Health Professions

Module Leader Jennifer Killey

Module Status Dedicated

Module Type Compulsory

Module Rating Pre-Foundation 20 credits

Learning Methods L/T/W 48 hours

Directed unsupervised study 152 hour

Pre-requisites None

Recommended Prior Study None

Co-requisites None

Professional Body Requirements None

Barred Combinations None

Module Grading Graded

Module Aims

This module seeks to provide a foundation of the anatomy and physiology of the human body to underpin the knowledge and understanding needed to progress onto pre-registration nursing, midwifery and AHP degree courses.

Module Synopsis

This module seeks to introduce the student with little or no advanced level knowledge to the terminology associated with human anatomy and physiology. Building upon this the anatomy and physiology of the major body systems will be considered. Where appropriate application of this knowledge to clinical situations will be discussed

Outline Syllabus

- Physiology of homeostasis
- Musculoskeletal system – skeletal system; articulations; muscle tissue
- Nervous system - sensory, motor and integrative systems; autonomic nervous system

- Cardiovascular system
- Lymphatic system
- Respiratory system
- Digestive system
- Reproductive system and development and inheritance

Learning Outcomes

On completion of the module, students will be able to:

Knowledge and Understanding

1. Demonstrate a basic understanding of the anatomy and physiology of the human body

2. Demonstrate a basic understanding of how structure relates to function in terms of human anatomy and physiology

Ability

3. Identify the major anatomical features of the human body

4. Demonstrate and ability to observe and analyse basic physiological findings

Assessment Strategy

Evidence

Formative assessment

A period of formative assessment runs throughout the module to provide opportunity for students to obtain constructive feedback

Summative assessment

1. 4 short multiple choice question in-class tests

2. A laboratory report demonstrating the ability to observe and analyse basic physiological findings. This element will be no more than 2000 words in length.

Full guidelines will be given to the student

Assessment Criteria

The generic assessment criteria and the Learning Outcomes will apply:

Assessment Weightings

4 short multiple choice question in-class tests	60%
Laboratory report	40%

Learning Strategy

A combination of lectures and problem-solving tutorials, in which help will be given with methodology and study skills for the assessment. Laboratory based workshops will give a practical application to the theory that has been covered.

Appendix B2 Factors affecting platform choice

Developing for an environment like Adobe Flash would have meant that there would be great potential in terms of accessibility to the application, but would have limited what could have done in terms of features and levels of detail in regards to 3D content because of technical restrictions. The PC platform has much less technical restrictions (but they do still exist), but would require installation of software on whichever computer it would used on – this would also make testing the project's products more difficult because of the need to install on multiple computers of the same specification and in the same environment.

Appendix B3 Establishing software requirements – Questions for client

1. Is it meant to be a singular experience or group work?
2. What platform are you aiming for? If PC, is it a low spec one?
3. Do you require the user to be actually tested at the end or during the experience, or is it more about the user's personal post reflection?
4. Cardiovascular system - Full system, or more focussed on say the heart functions?
5. What level of physical fidelity is required in regards to texture, is it necessary for the 3D models to resemble a real heart as close as possible or is something which is physically accurate but say stylized artistically acceptable? Show examples.
6. Would the electrical conduction associated with the system be required?
7. Alteration of internal and external factors – A few examples are given on the research proposal, such as:
   - Exercise (Changeable fitness, difficulty of exercise)
   - Eating a meal (Changeable size and contents)

Are there any others that would be desired? Also, are these factors external only, what internal factors would need to be altered?

8. Do we need to show the effects of health conditions?
9. What feedback would the players/ user need to see? Examples given of changes to heartbeat, blood pressure, body temperature, sweating etc on the proposal, are these all the factors that need to be shown or does more need to be taken into account?
10. How much dissection needs to take place? Anterior Cut, Lateral Cut.
11. What stage of the course will the users be at? Different years must be subject to varying degrees of content difficulty.

Appendix B4 Considerations when developing for different visual fidelity levels

Lower Fidelity Assets	Higher Fidelity Assets
Simply easier to create in terms of skills required	Much more difficult to create, required skill level of artists is higher.
Require less time to develop models, textures and animations.	Development time of assets is much higher as more detailed models and textures are needed.
Less demanding technically because of lower texture sizes, lower polygon counts and less need for realistic graphical effects in the engine.	More demanding technically, this could again potentially restrict the ability to test because of specification demands of the computer to test on.
Due to the fact that lower fidelity representations are more diagrammatical in nature you can almost 'get away' with more. What this means is that while they would certainly still need to be anatomically accurate and functional, they would not have to look or act quite 'real', the viewer doesn't expect this and so there is likely to be a higher level of acceptance of the models because of this fact.	Possibility of fewer acceptances of the models if they don't visually match up with what the viewer expects from real heart or realistic representation of a heart.
Not as difficult to get wrong. Simply put the less detail that needs to be put in the less that can go wrong.	Higher risk of making mistakes when creating realistic visualisations. Closely linked with the previous point; inaccuracies will be much easier to spot.

Table 14 - Comparison of the considerations to be taken into account when developing lower/ higher fidelity assets.

Appendix B5 Informal interviews with target audience

Student Group 1 – Three Participants

Computer literacy

- This group stated they played games such as Farmville, Cityville and other Facebook games.
- Expressed a willingness to use computers to further their education.

Experiences of learning resources and teaching methods

- These students felt that using visuals to instruct about the cardiovascular system is a lot more effective than reading large amounts of textual information.

Difficult areas to convey

- Blood flow around the heart was identified as a difficult to convey topic.

Expectations of the students

- Desire to see interactive media/ tools to be used in supplement to traditional methods of teaching

Learning styles

- This grouped stated that they were visual learners, deeming that books like Tortora and Derrickson's (2007) *Principles of Anatomy & Physiology* (their comparison) are too 'heavy and scary at this level'.

Student Group 2 – One Participants

Computer literacy

- Is a general internet user and plays basic games online.
- Uses a couple of different games to aid in their learning.

Experiences of learning resources and teaching methods

- Uses the online resource BBC Bitesize
- Finds that stylized and basic representations of the heart are better than realistic representations, which were deemed 'otherworldly'.
- Again Tortora and Derrickson's (2007) text book (their comparison) is deemed as 'frightening' to use. This interviewee felts that while all the information is within resources such as this, it is hidden among layers of other 'not needed' info.

Expectations of the students

- Desire to see digital interactive used within the classroom environment.

Learning styles

- This participant stated that they need colours to be used within any learning material they use.
- Felt that interaction and participation are important for them to learn effectively as it aids in their memorisation of facts.
- Is a visual learner, stating a need for image use.

Justification of design features

- Wants labels which link to anatomical elements in order to aid in memorisation of names.

Student Group 3 – One Participant

Computer literacy

- Computers used for web browsing.

Experiences of learning resources and teaching methods

- Feels that Dr Killey's method of teaching is useful.
- Uses the CD digital learning tool provided by their instructor teaching their Chemistry module quite useful as it is very visual in its methods of teaching.

Expectations of the students

- Would like digital interactive to be used within the classroom environment, because they would be useful supplements to traditional teaching.

Learning styles

- Deems themselves to be a visual learner.
- This participant is actively adapting his learning so that it matches their personal learning style.

Student Group 4 – Two Participants

Computer literacy

- Feel they are computer literate.
- Play games now and again, sometimes once or twice a week.

Experiences of learning resources and teaching methods

- This group feels that Dr Killey's methods of teaching are superior to resources like Tortora and Derrickson's (2007) *Principles of Anatomy & Physiology* (their comparison) as Dr Killey teaching the knowledge that the student required to pass the exam.
- Again this group use the CD provided by the Chemistry module instructor as it shows the mechanics of things better than traditional materials, there is also apparently a quiz mechanic.

- Representations of anatomy must be diagrammatical rather than realistic.

Expectations of the students

- Expect to be given digital interactives as part of the course to take away and use, not necessarily in the classroom.

Learning styles

- Prefer visual learning

Student Group 5 – Three Participants

Computer literacy

- A range of computer literacy present, from low to reasonably literate.

Experiences of learning resources and teaching methods

- Consistency of diagrams across learning resources is lacking.
- One of the participants in this group stated that they would not actively search for digital learning tools.
- Felt that Dr Killey's teaching methods met the needs of their favoured learning styles.

Difficult areas to convey

- Use of diagrams makes it difficult to learn about the mechanics of a heart beat because of their static nature.
- Mechanics of the heart is a difficult area.
- The concept of diastole (relaxation phase of the cardiac cycle) and systole (contraction phase of the cardiac cycle) is difficult to take in.
- Understanding blood flow around the heart and body is a difficult area for these students.

Expectations of the students

- Expect as many methods of knowledge and content delivery as possible.
- One improvement to classroom lectures and tutorials felt by this group was the inclusion of interactive models.

Learning styles

- Participants in this group either stated themselves to be visual learners or kinaesthetic learners.

Appendix C

Appendix C1 First drafts of preliminary and software specific questionnaires

Preliminary Questionnaire

Preliminary questionnaire – to be done before any testing takes place

Computing experience

1. Please rate how comfortable you are using computers.

Cannot use computers	Very uncomfortable	Reasonably uncomfortable	Comfortable	Reasonably comfortable	Very comfortable	Expert

2. Do you play any form of computer games?

Yes ☐ No ☐

3. On average how many hours do you spend playing computer/ video games per week?

0	1-2	3-5	6-10	11+

Hours

Teaching/ learning methods and experiences

4. What are your preferred learning styles? You may choose multiple categories.

☐	Visual	You prefer learning by seeing and memorizing things. You like information to be depicted in images, videos, diagrams, charts, graphs etc
☐	Aural/ Auditory	You prefer to learn by listening, following instructions/ dictation. You learn best from lectures, tapes, group discussion, and audible tutorials.
☐	Read/ Write	You prefer to learn through words. You learn best through reading and writing.
☐	Kinesthetic/ Tactile	You prefer to learn through experience/ doing things. You learn best by manipulating items, simulations and practicals.

5. Rate how much you agree with this statement? “The ways in which I am taught perfectly match my learning style needs”.

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree

6. Rate how much you agree with this statement? “The methods used to teach in the classroom are very effective at teaching the subject content”.

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree

7. Are there any of the following topics current teaching methods struggle to convey to you?

- ☐ Motion of the heart
- ☐ Structure and look of the heart
- ☐ Phases of the heart
- ☐ Pathway of blood through the heart
- ☐ Origin and destination of blood
- ☐ Graphical feedback of a heartbeat
- ☐ Timescales of a heartbeat
- ☐ Labeling the heart’s anatomy
- ☐ Events during a heartbeat
- ☐ Identifying oxygen rich/ poor blood
- ☐ Valve operation
- ☐ Sounds of the heart

8. Of those areas which you identified as being difficult to convey, how could they be taught better?

9. Rate how much you agree with this statement? “The resources and materials made available to us at university are very useful learning aids”.

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree

10. In addition to the learning materials provided by the university, have you used any additional resources to aid in your learning? Please list 3 types which are not currently provided on your course that you use.

1.	
2.	
3.	

11. Do you expect additional learning materials like the ones you identified in the previous question, to be available as part of the standard course content.

Yes ☐ No ☐

12. Which of the following statements sums up your views on the course best?

"At this level of higher education, I expect to be taught the knowledge required to pass my exams."	☐
"At this level of higher education, I expect to be taught the knowledge required to practise my chosen field."	☐
"At this level of higher education, I expect to be taught the knowledge to both pass my exams and practise my chosen field."	☐

Specific learning outcomes

13. On a scale of 1 to 10, please rate the following (10 being "very effective", 1 being "ineffective"):

How effective do you think the way you are currently taught/ learn is at	/10

educating you about the mechanics of a heartbeat. *The mechanics of the heart include what a beat looks like, how long a typical beat lasts for.*	
How effective you think the way you are currently taught/ learn is at educating you about the events that take place during a heartbeat. *The events that take place during a heart beat refers to such things as what happens to parts of the anatomy at certain stages in the cardiac cycle such as the valves and chambers.*	/10
How effective do you think the way you are currently taught/ learn is at educating you about the phases that take place during a heartbeat. *The phases that take place during a heart beat refer to the stages of and within systole and diastole.*	/10
How effective you think the way you are currently taught/ learn is at educating you about blood flow around the heart. *Blood flow around the heart refers to the direction of flow, origin and destination of flow and the level of oxygen in the blood within each vessel/ chamber.*	/10
How effective you think the way you are currently taught/ learn is at educating you about names and positions of the anatomy of the heart.	/10

Digital media and learning

14. Do you see yourself as a "digital learner"?

 A digital learner is someone who has a high exposure to digital technologies and actively uses them to aid in their learning.

Yes ☐ No ☐

15. How much do you use digital technologies/ media to aid in your learning?

Never	Rarely	Occasionally	Often	Very Often

16. What is the main reason for you using or not using digital media/ technology to learn?

17. Do you expect digital technologies to be used as part of your course?

Yes ☐ No ☐

18. Do you want to see more digital technologies used as part of your course?

Yes ☐ No ☐

Software Specific Questionnaire

Day of Testing

Pre test questions

1. Based on the knowledge required to pass your foundation course, how would you rate your current level of knowledge compared to the expected level of knowledge for the cardiovascular system. Please give a rating of between 1 and 10? (10 being "expert", 1 being "lacking")

/10

Post test questions

Interface, Navigation and Usability

1. Please rate how easy you found the simulation to use.

Very difficult	Quite difficult	Indifferent	Quite easy	Very easy

2. Please rate how easy you found it to navigate around the heart.

Very difficult	Quite difficult	Indifferent	Quite easy	Very easy

3. Did you find anything confusing during your experience with the simulation?

Simulation's success at delivering required content

4. Of the following taught content, are any of the following concepts conveyed better in the simulation compared to traditional teaching/ learning methods?

- ☐ Motion of the heart
- ☐ Structure and look of the heart
- ☐ Phases of the heart
- ☐ Pathway of blood through the heart
- ☐ Origin and destination of blood
- ☐ Graphical feedback of a heartbeat
- ☐ Timescales of a heartbeat
- ☐ Labeling the heart's anatomy
- ☐ Events during a heartbeat
- ☐ Identifying oxygen rich/ poor blood
- ☐ Valve operation
- ☐ Sounds of the heart

5. On a scale of 1 to 10, please rate the following (10 being "very effective", 1 being "ineffective"):

How effective you think the simulation is at educating you about the mechanics of a heartbeat? *The mechanics of the heart include what a beat looks like, how long a typical beat lasts for.*	/10
How effective you think the simulation is at educating you about the events that take place during a heartbeat? *The events that take place during a heart beat refers to such things as what happens to parts of the anatomy at certain stages in the cardiac cycle such as the valves and chambers.*	/10
How effective do you think the simulation is at educating you about the phases that take place during a heartbeat? *The phases that take place during a heart beat refer to the stages of and within systole and diastole.*	/10
How effective you think the simulation is at educating you about blood flow around the heart? *Blood flow around the heart refers to the direction of flow, origin and destination of flow and the level of oxygen in the blood within each vessel/ chamber.*	/10
How effective you think the simulation is at educating you about names and positions of the anatomy of the heart?	/10

6. Of the following taught content, are any of the following topics conveyed worse in the simulation in comparison to traditional teaching/ learning methods?

☐	Motion of the heart	☐	Timescales of a heartbeat
☐	Structure and look of the heart	☐	Labeling the heart's anatomy
☐	Phases of the heart	☐	Events during a heartbeat
☐	Pathway of blood through the heart	☐	Identifying oxygen rich/ poor blood
☐	Origin and destination of blood	☐	Valve operation
☐	Graphical feedback of a heartbeat	☐	Sounds of the heart

7. Which of the following statements is more accurate?

"The simulation only reinforced knowledge that I already have." ☐

"I learnt something from the simulation." ☐

"I learnt something from the simulation and it reinforced my existing knowledge." ☐

"I learnt nothing new from the simulation and it did not reinforce my existing knowledge." ☐

Overall questions

8. Which of the following statements is more accurate?

"The simulation would be a useful tool for the teacher to use within lectures and tutorials to convey certain topics". ☐

"The simulation would be a useful addition to the available learning materials that the student can use in their own time". ☐

9. Do you see simulations like this as being programs which could:

Help teach you the scientific knowledge required to pass my exams. ☐

Help teach you the knowledge required to practise in your field. ☐

Both of the above. ☐

10. How much do you think this program could have helped your learning and revision of the subject prior to taking your exams?

Would not have helped	Would have slightly helped	Would have moderately helped	Would have helped greatly

11. Did the simulation meet the needs of your favoured learning style?

Yes ☐ No ☐

12. Please list three things that you liked most about this program?

1.	
2.	
3.	

13. Please list three things that you like least about this program?

1.	
2.	
3.	

14. Please rate how fun you found the simulation?

Not fun	Slightly fun	Moderately fun	Very fun

15. To what level did the simulation hold your interest i.e. How engaging was it?

Held no interest	Held little interest	Indifferent	Quite engaging	Very engaging

Please list 3 things that could improve the program?

1.	
2.	
3.	

16. Would you like to see a program like this more readily available on the course?

Yes ☐ No ☐

17. After using the simulation what would you now rate your level of knowledge to be on the cardiovascular system out of 10. (10 being "expert", 1 being "lacking")

/10

Appendix C2 Final iterations of questionnaires

Preliminary Questionnaire

Preliminary Questionnaire - Version 1.02

Testee Number

Please complete this short preliminary questionnaire before testing either piece of software.

This section contains questions regarding your general background, computing experience and teaching/ learning experiences.

You have 10 minutes to complete this questionnaire.

1.) Please enter the number on the card in front of you.

____

Background & Computing Experience

2.) What age are you?

____

3.) Please rate how comfortable you are at using computers.

( ) Cannot use computers

( ) Very uncomfortable

( ) Reasonably uncomfortable

( ) Comfortable

( ) Reasonably comfortable

( ) Very comfortable

( ) Expert

4.) Do you play any form of computer games?

[ ] Yes

[ ] No

5.) On average how many hours do you spend playing computer/ video games per week?

( ) 0

( ) 1-2

( ) 3-5

( ) 6-10

( ) 11+

Teaching/ Learning Experience

6.) What are your preferred learning styles? You may choose multiple categories.

[ ] Visual - You prefer learning by seeing and memorizing things. You like information to be depicted in images, videos, diagrams, charts, graphs etc

[ ] Aural/ Auditory - You prefer to learn by listening, following instructions/ dictation. You learn best from lectures, tapes, group discussion, and audible tutorials.

[ ] Read/ Write - You prefer to learn through words. You learn best through reading and writing.

[ ] Kinesthetic/ Tactile - You prefer to learn through experience/ doing things. You learn best by manipulating items, simulations and practicals.

7.) From your perspective, on a scale of 1 to 10, to what extent does the way in which you are taught match your favoured learning style(s)

( ) 1

( ) 2

( ) 3

( ) 4

( ) 5

( ) 6

( ) 7

( ) 8

( ) 9

( ) 10

8.) In addition to the learning materials provided by the university, have you used any additional resources to aid in your learning? Please list 3 which are not currently provided on your course that you use regularly.

1.: ___________________________

2.: ___________________________

3.: ___________________________

9.) What is the main reason for you using or not using digital media/ technology to learn?

10.) On a scale of 1 to 10, please rate the following (10 being "very effective", 1 being "ineffective"):

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
How effective do you think the way you are currently taught is at educating you about what the heart and its associated anatomy looks like during a typical beat? (This includes the overall look of a beat, the look of each piece of anatomy during the beat and how long a typical beat lasts for)	___	___	___	___	___	___	___	___	___	___
How effective do you think the way you are currently taught is at educating you about the events and phases that take place during a heartbeat and the order in which they occur? (The phases and events that take place during a heart beat refer to the stages within systole and diastole such as atrial systole, isovolumetric contraction, ventricular ejection, atrioventricular valves/ semilunar valves open/shut etc)	___	___	___	___	___	___	___	___	___	___
How effective do you think the way you are currently taught is at educating you about blood flow around the heart? (Blood flow around the heart refers to the direction of flow, origin and destination of flow and the level of oxygen in the blood within each vessel/ chamber.)	___	___	___	___	___	___	___	___	___	___
How effective do you think the way you are currently taught is at educating you about names and positions of parts of the	___	___	___	___	___	___	___	___	___	___

anatomy of the heart?										

Thank You!

Thank you for completing the preliminary questionnaire, please wait for instruction on when to move on to the next stage of the test – use of the Simulation.

Software Specific Questionnaire

Questionnaire - Following Test of Simulation Version 1.02

Testee Number

Now you have had a chance to use the Simulation please answer the following questions regarding the usability of the software and how successful you feel it is as a learning tool.

1.) Please enter the number on the card in front of you.

____

Interface, Navigation and Usability

2.) Did you find anything confusing about the simulation?

[ ] General interface layout

[ ] Function of any of the buttons

[ ] The 3D model

[ ] Navigation controls

[ ] Animation controls

[ ] Animation timeline & track bar

[ ] Graphs

[ ] Events

[ ] Label feature

[ ] Label test feature

[ ] Visual modes (those contained in the visual tab, such as blood flow mode and blood oxygenation mode)

[ ] Help feature

[ ] None of the previous

) Comments to expand upon choices (if any) or anything not listed in Question 2.

How effective is the Simulation?

3.) On a scale of 1 to 10, please rate the following (10 being "very effective", 1 being "ineffective"):

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
How effective do you think the simulation is at educating you about what the heart and its associated anatomy looks like during a typical beat? (This includes the overall look of a beat, the look of each piece of anatomy during the beat and how long a typical beat lasts for)	___	___	___	___	___	___	___	___	___	___
How effective do you think the simulation is at educating you about	___	___	___	___	___	___	___	___	___	___

the events and phases that take place during a heartbeat and the order in which they occur? (The phases and events that take place during a heart beat refer to things such as atrial systole, isovolumetric contraction, ventricular ejection, atrioventricular valves/ semilunar valves open/shut etc)										
How effective do you think the simulation is at educating you about blood flow around the heart? (Blood flow around the heart refers to the direction of flow, origin and destination of flow and the level of oxygen in the blood within each vessel/ chamber.)	___	___	___	___	___	___	___	___	___	___
How effective do you think the simulation is at educating you about names and positions of parts of the anatomy of the heart?	___	___	___	___	___	___	___	___	___	___

4.) In regards to your taught content, are any of the following topics conveyed better in the simulation compared to traditional teaching/ learning methods?

[ ] Motion of the heart

[ ] Timescales of a heartbeat

[ ] Structure and look of the heart

[ ] Labelling the heart's anatomy

[ ] Phases of the heart (atrial systole, ventricular filling etc)

[ ] Events during a heartbeat (when valves are open/ shut, when blood enters the vena cava, aorta etc)

[ ] Pathway of blood through the heart

[ ] Identifying oxygen rich/ poor blood

[ ] Origin and destination of blood

[ ] Valve operation (why and how they open and shut)

[ ] Graphical feedback of a heartbeat

[ ] Sounds of the heart

[ ] None of the previous

) Comments to expand upon choices (if any) or anything not listed in Question 4.

5.) How much do you think this program could have helped your learning and revision of the subject prior to taking your exams?

( ) Would not have helped

( ) Would have slightly helped

( ) Would have moderately helped

( ) Would have greatly helped

6.) To what extent do you think the simulation suited the following learning styles?

	Didn't suit at all	**Poor suit**	**Suited somewhat**	**Suited well**	**Perfect suitability**
Visual	( )	( )	( )	( )	( )
Aural/ Auditory	( )	( )	( )	( )	( )
Read/ Write	( )	( )	( )	( )	( )

Kinesthetic/ Tactile	( )	( )	( )	( )	( )

7.) From your perspective, on a scale of 1 to 10, to what extent did the simulation meet the needs of your favoured learning style(s)?

( ) 1

( ) 2

( ) 3

( ) 4

( ) 5

( ) 6

( ) 7

( ) 8

( ) 9

( ) 10

8.) Please rate how fun you found the simulation to use?

( ) Not fun

( ) Slightly fun

( ) Moderately fun

( ) Very fun

) Comments for Question 8 if any.

9.) To what level did the simulation hold your interest i.e. How engaging was it?

( ) Held no interest

( ) Held little interest

( ) Quite engaging

( ) Very engaging

) Comments for Question 9 if any.

10.) Is an interactive simulation like the one I have created something you would like to see used on the course for the cardio and other bodily systems?

( ) Yes

( ) No

) Comments for Question 10 if any.

Thank You!

Thank you for completing the short questionnaire for the Simulation, please wait for instructions on when to move on to the next stage of the test – use of the Game.

These same questions were posed following the test of the game, with the addition of the following question at the end of the questionnaire.

11.) Comparing the two pieces of software tested, which type would you prefer to use as a learning tool?

( ) Game

( ) Simulation

) Comments on Question 11 if any.

Appendix D

Appendix D1 Testing preparation

Prior to the students participating in the test, certain elements were prepared and in place in advance.

Release of Questionnaire

The questionnaires were published so that they are available online on the day of the test. All three of the questionnaires were opened in a web browser on each of the computers being used to test in preparation for use. As a backup links were written in a notepad document that was open at all times during the test. Students could copy and paste this into their browser.

Software Installation

Software was installed and tested on each computer prior to the day of test.

Cover Letter

Whilst the questionnaires' format is online, a cover letter was included to accompany the test. A cover letter was placed at each testing workstations. The cover letter used can be found in Appendix D3.

The purpose of the cover letter was to:

- Give the participant some background into the research area that I am investigating.
- Highlight the specific research goals of the project.
- Highlight the importance of the research and so the student's participation.

Accompanying instructions

A set of accompanying instructions was provided to the participant for use during the test. The main point of these instructions was to provide participants with the hyperlinks for each online questionnaire. Instructions also included general help concerning; how to launch applications, close applications, full screen the application.

Cards

Cards were prepared in advance. Cards will be placed on each of the testing workstations, ready for the test.

Appendix D2 Schedule of tests

Intro

After all participants are given a workstation from which to carry out the test, an introduction to proceedings will take place. The introduction will:

- Give the participants background information to the research and inform the as to what the author research specifically is.
- Inform the participants of the schedule and format of the test.
- The purpose of the cards will be described at this point.
- Direct participants to the 'cover letter', which gives a reasonably in depth insight into the research (to be placed at the participants workstation prior to test). Reading of which is not a requirement.
- Highlight the fact that help will not be given during the test outside of that given within the demonstration portions of said test.
- If there is a technical problem the software must be restarted.
- Inform them of what will be open on their computers at the test start.
- Introduce 3 x questionnaires
- Introduce 2 x software
- Identify the accompanying instruction document
- Commence the test.

Preliminary Questionnaire

Duration - 10 minutes

The test begins with a short preliminary questionnaire. The participants are informed of the purpose of this questionnaire i.e. to give an insight into student's background and teaching/ learning experiences. Participants are asked to refrain from use of either piece of software during this questionnaire.

Demo – Simulation

Duration – 05 minutes

A demonstration will be given of the use and features of the Simulation application prior to test. This demonstration will be given at the front of the testing room upon a computer which is linked to a projector. Demonstration content:

- How to maximise software window and/or start the software.
- Camera controls for 3D model
- Animation controls
  - Typical controls and the track bar.
- Feature tabs – Care will be taken to simply inform the participants of the features contained within each tab without actually showing them each one in turn. The participants should discover the effects of each interaction themselves during the test.

In addition to demonstrating the use and functionality of the Simulation, participants will also be informed of the limitations of the current version of the software so as to avoid confusion during testing.

The limitations of the Simulation include:

- Sub system selection tab
  - No other sub systems can be chosen.
- Labelling tab
  - No detail levels can be chosen.
  - When in either labelling mode, zoom, rotate and animations are disabled.

Simulation Test

Duration – 15 minutes

Following the demonstration of the Simulation, participants will be asked to launch the Simulation – using the associated desktop shortcut - and test the software for a duration of 15 minutes. Participants will be reminded and that if any technical problems occur, to restart the software as demonstrated.

At the end of the 15 minutes the participants will be asked to either minimise or close the piece of software.

Questionnaire – Simulation

Duration – 10 minutes

Following the test of the Simulation participants are required to complete a questionnaire specifically related to the Simulation. Participants will be informed of the purpose of the questionnaire i.e. to judge the success of the software as a learning tool.

Demo – Game

Duration – 05 minutes

A demonstration will be given of the use and features of the Game application prior to test. This demonstration will be given at the front of the testing room upon a computer which is linked to a projector. Demonstration content:

- How to maximise/ minimize the game.
- Objective of the game.
- Rules.
- User interface.

In addition to demonstrating the use and functionality of the Game, participants will also be informed of the limitations of the current version of the software so as to avoid confusion during testing.

The limitations of the Game include:

- The game has not been polished to the extent of the Simulation
- The main limitation of the Game is a known bug which manifests itself by players getting 'stuck' in the sense that they are no longer able to reach their intended destination. This can be due to the fact that either they have laid down vessel sections in such a manner that they have unfortunately blocked their own path, or the anatomical tanks are randomly positioned in such a way to make it either near impossible or impossible to reach the correct destinations at times.

Game Test

Duration – 15 minutes

Following the demonstration of the Game, participants will be asked to launch the Game - using the associated desktop shortcut - and test the software for a duration of 15 minutes. Participants will be reminded that if any technical problems occur, to restart the software as demonstrated.

At the end of the 15 minutes the participants will be asked to either minimise or close the piece of software.

Questionnaire – Game

Duration – 10 minutes

Following the test of the Game participants are required to complete a questionnaire specifically related to the Game. Participants will be informed of the purpose of the questionnaire i.e. to judge the success of the software as a learning tool.

Closing Comments

Participants will be thanked for taking part in the test and will be allowed to leave the room.

Appendix D3 Cover letter for test

Creating Better Serious Games for Learning - Daniel Fitchie

23rd May 2011

Dear Participant,

My name is Daniel Fitchie and I am currently working to complete a Masters by Research in the field of digital learning solutions, with a focus on Serious Games.

Use of digital technology as educational and training solutions is becoming more and more widespread as awareness of the advantages of using such applications increases. Technologies afford the ability to simply convey concepts to students in new ways that would not be possible, efficient or effective using traditional methods. Students that are currently in education can also be classified as being part of a new age of learners, more specifically these students are labelled "Digital Learners" – learners who have a high exposure to digital technologies and use them regularly in their day to day lives - and by altering teaching and learning methods by correctly incorporating such technology we are able to more effectively reach this audience.

'Serious Games' are seen as an effective type of digital learning solution. The term is used to encompass many forms of educational and training solutions such as games, virtual worlds & simulations. While applications classified under this label may differ in terms of their delivery, their primary purpose is always one of educating the end user.

My research is aimed at trying to determine which form of learning tool is able to offer the best learning experience for the user, with the focus of comparing two distinct types of applications; educational games and learning simulations. For this research I have created two pieces of software for a client, namely Dr Jenny Killey, and have aimed to create something which could help foundation level students learn/ revise the topic of the cardiac cycle.

My specific research goals are to:

- **To discover whether the potential audience for the software developed is in fact part of the group of new age learners described.**
- **To highlight the limitations of the traditional methods of teaching and learning from the student's point of view.**
- **To investigate the benefits and limitations of using each form of serious games as a learning tool.**
- **To determine whether the applications created fulfil their "secondary" purpose of being engaging and/ or fun.**
- **To determine how effective each application is as a learning tool.**

This software test and accompanying questionnaire forms part of my research project and will provide insight into some of the aforementioned research goals. It is not necessary to divulge any confidential information. By taking part you will contribute to the body of knowledge surrounding the field of Serious Games with the hope of improving the way in which students are learn in and out of the classroom.

Yours faithfully,

Daniel Fitchie

I confirm that Daniel Fitchie is a registered student at the University of Huddersfield and that the information he requests is for research purposes only. Your assistance is appreciated.

Ruth Taylor

Course leader for Computer Game Design BA(hons)

Appendix E

Appendix E1 First test – Group A – Analysis of test results

Teaching and learning experiences of students

Participants were asked what their favoured learning styles were, the results can be seen in Figure 38. Data shows a preference toward the visual and kinaesthetic learning styles, so supporting other data collected from informal interviews carried out in the initial research stages of the project, detailed in section 5.1.2. Participants stated that their learning style was of the aural/ auditory category, a style which is relevant to information given through lectures - the main method of content delivery for students.

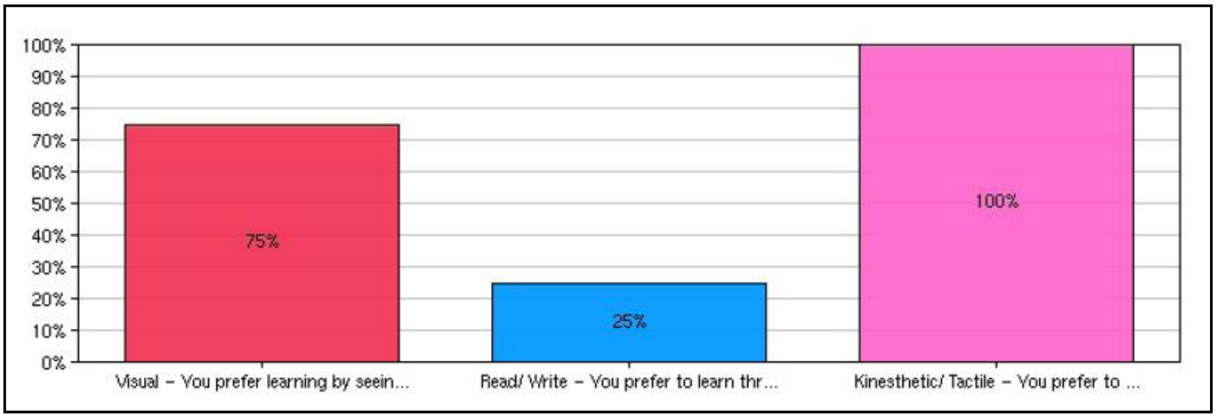


Figure 38 - Learning style preference amongst test subjects.

Students were asked to rate on a scale between 'strongly disagree' and 'strongly agree', how well they feel that the way they are taught matches their learning style preference. The data here is mixed with ratings ranging between 'strongly disagree' and 'agree' categories but trending towards the disagreement end of the spectrum, indicated a level of dissatisfaction with how much traditional methods of teaching tailor to students specific learning style.

Students were finally asked to indicate which aspects of the taught content relating to the cardiovascular topic they felt traditional methods of teaching struggled to convey effectively. This would be used later for comparisons to the software developed. The results of this enquiry can be seen in Table 15 where ratings are consistently high across the board, which seems to suggest that students feel current methods of teaching are quite effective at teaching the main educational objectives of the subject matter.

Main educational objective	Average score given for methods of teaching
How effective do you think the way you are currently taught is at educating you about what the heart and its associated anatomy looks like during a typical beat? (This includes the overall look of a beat, the look of each piece of anatomy during the beat and how long a typical beat lasts for)	7
How effective do you think the way you are currently taught is at educating you about the events and phases that take place during a heartbeat and the order in which they occur? (The phases and events that take place during a heart beat refer to things such as atrial systole, isovolumetric contraction, ventricular ejection, atrioventricular valves/ semilunar valves open/shut etc)	7
How effective do you think the way you are currently taught is at educating you about blood flow around the heart? (Blood flow around the heart refers to the direction of flow, origin and destination of flow and the level of oxygen in the blood within each vessel/ chamber.)	7
How effective do you think the way you are currently taught is at educating you about names and positions of parts of the anatomy of the heart?	7

Table 15 - Participants are asked to rate how effective they feel current methods of teaching are at conveying main educational objectives of the subject matter.

Effectiveness of each software developed

Question 3 – Software specific questionnaire.

Participants were asked to rate how effective they felt the software was at educating them about the main educational objectives of the software developed on a scale of 1 to 10.

The results for the simulation can be seen in Table 16. For all objectives, ratings were at the higher end of the scale with no respondents scoring the simulation less than a 7 on any point. Comparing this to the results of the game in Table 17, where it can be seen that for three of the educational objectives participants did not score the game higher than a 4, showing it to be of low effectiveness at teaching the objectives.

On a scale of 1 to 10, please rate the following (10 being "very effective", 1 being "ineffective"):

	1	2	3	4	5	6	7	8	9	10
How effective do you think the simulation is at educating you about what the heart and its associated anatomy looks like during a typical beat? (This includes the overall look of a beat, the look of each piece of anatomy during the beat and how long a typical beat lasts for)	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	1 25.0%	2 50.0%	0 0.0%	1 25.0%
How effective do you think the simulation is at educating you about the events and phases that take place during a heartbeat and the order in which they occur? (The phases that take place during a heart beat refer to things such as atrial systole, isovolumetric contraction, ventricular ejection, atrioventricular valves/ semilunar valves open/shut etc)	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	1 25.0%	2 50.0%	0 0.0%	1 25.0%
How effective do you think the simulation is at educating you about blood flow around the heart? (Blood flow around the heart refers to the direction of flow, origin and destination of flow and the level of oxygen in the blood within each vessel/ chamber.)	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	1 25.0%	2 50.0%	1 25.0%
How effective do you think the simulation is at educating you about names and positions of parts of the anatomy of the heart?	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	1 25.0%	3 75.0%

Table 16 - The results of a question regarding the effectiveness of the simulation at educating about the main educational objectives of the software developed.

On a scale of 1 to 10, please rate the following (10 being "very effective", 1 being "ineffective"):

	1	2	3	4	5	6	7	8	9	10	Totals
How effective do you think the game is at educating you about what the heart and its associated anatomy looks like during a typical beat? (This includes the overall look of a beat, the look of each piece of anatomy during the beat and how long a typical beat lasts for)	3 75.0%	0 0.0%	0 0.0%	1 25.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	4 100%
How effective do you think the game is at educating you about the events and phases that take place during a heartbeat and the order in which they occur? (The phases that take place during a heart beat refer to things such as atrial systole, isovolumetric contraction, ventricular ejection, atrioventricular valves/ semilunar valves open/shut etc)	3 75.0%	0 0.0%	0 0.0%	1 25.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	4 100%
How effective do you think the game is at educating you about blood flow around the heart? (Blood flow around the heart refers to the direction of flow, origin and destination of flow and the level of oxygen in the blood within each vessel/ chamber.)	3 75.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	1 25.0%	0 0.0%	0 0.0%	4 100%
How effective do you think the game is at educating you about names and positions of parts of the anatomy of the heart?	3 75.0%	0 0.0%	0 0.0%	1 25.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	4 100%

Table 17 - The results of a question regarding the effectiveness of the game at educating about the main educational objectives of the software developed.

Table 18 shows a comparison between the average scores given by participants referring to the effectiveness of each software, and the effectiveness of the normal method of teaching/ learning in relation to these objectives.

In the table it can be seen that while the difference in average scores given by participants between the simulation and teaching may be small, students deem the simulation more effective at educating students about the main educational objectives of the researcher and project, in all cases. The greatest difference was in relation to the fourth objective, that of educating about the names and positions of the parts of the heart's anatomy (a difference of 3 points). It should also be stated that whilst the lowest average score given for any objective in regards to the simulation was 7, respondents gave low scores of 4 and 5 in the case of traditional teaching.

The table also shows that participants deemed the game as being much less effective at conveying educational objectives than not only the traditional teaching methods but also the simulation.

Main educational objective *(Here 'X' refers to either simulation or the way participants have been taught)*	**Average score given for simulation**	**Average score given for game**	**Average score given for methods of teaching**
1. How effective do you think 'X' is at educating you about what the heart and its associated anatomy looks like during a typical beat?	8	2	7
2. How effective do you think 'X' is at educating you about the events and phases that take place during a heartbeat and the order in which they occur?	8	2	7
3. How effective do you think 'X' is at educating you about blood flow around the heart?	9	3	7
4. How effective do you think 'X' is at educating you about names and positions of parts of the anatomy of the heart?	10	2	7

Table 18 - A comparison between the average scores given by participants referring to the effectiveness of the simulation and the effectiveness of the normal method of teaching/ learning in relation to these objectives.

Question 4 – Software specific questionnaire

Table 19 show the responses by participants asked to identify which elements of taught content are conveyed better in the simulation compared to the way in which the student currently learns and is taught. Subjects were allowed to select multiple elements without restriction.

Value	Count
Motion of the heart	3
Timescales of a heartbeat	1
Structure and look of the heart	2
Labelling the heart's anatomy	3
Phases of the heart (atrial systole, ventricular filling etc)	3
Events during a heartbeat (when valves are open/ shut, when blood enters the vena cava, aorta etc)	4
Pathway of blood through the heart	3
Identifying oxygen rich/ poor blood	3
Valve operation (why they do what they do)	2
Graphical feedback of a heartbeat	3
Sounds of the heart	3

Table 19 - Responses to the question "Are any of the following topics conveyed better in the simulation compared to traditional teaching/ learning methods.

Participants felt that the simulation conveyed many aspects of the content better than the way in which they normally learn and are taught. The element that participants felt was taught the best in comparison was the events during a heartbeat i.e. when valves open and shut, when blood enters vessels etc.

Only one participant felt that the game managed to teach any element of the taught content better than traditional methods of teaching and that was the topic of the origin and destination of the blood.

Question 5 – Software specific questionnaire

When participants were asked how much they felt each software could have helped in their learning and revision of the subject prior to taking their exams, all respondents stated the simulation “Would have greatly helped”. 75% of participants felt that the game ‘would not have helped’ in their learning or revision of the subject.

Question 6 & 7 – Software specific questionnaire

As previously students responded that their preferred learning styles according to Fleming's (1992) VARK style model were the visual (75% of participants) and kinesthetic/ tactile (100% of participants) style of learning.

In this test students rated to what extent the software matched their learning style preference; on a scale of 1 to 10 (1 being no match and 10 being an exact match).

The average score for the simulation was 8, showing the simulation to be very tailored to participants needs. 75% of participants gave the game a score of 1 in response to this question, obviously feeling that the game did not suit their learning style at all.

In addition, looking at the results of question 6 from the software specific questionnaire for the simulation, which is shown in Table 20, we can see that in fact all students felt that the simulation had "perfect suitability" to the visual learning style, and 50% felt that it had the same suitability for the kinaesthetic/ tactile style. While the simulation is not regarded as suiting the two other styles (read/ write or aural/ auditory) to a very great extent, it is not scored any less than "suited somewhat" in these categories, showing a certain level of applicability to these styles also.

To what extent do you think the simulator suited the following learning styles?

	Didn't suit at all		Poor suit		Suited somewhat		Suited well		Perfect suitability	
Visual	0	0.0%	0	0.0%	0	0.0%	0	0.0%	4	100.0%
Aural/ Auditory	0	0.0%	0	0.0%	3	75.0%	1	25.0%	0	0.0%
Read/ Write	0	0.0%	0	0.0%	2	50.0%	2	50.0%	0	0.0%
Kinesthetic/ Tactile	0	0.0%	0	0.0%	0	0.0%	2	50.0%	2	50.0%

Table 20 - Results of the question "To what extent do you think the simulation suited the following learning styles?"

In reference to both the visual and kinaesthetic learning style 75% of participants stated that the game "didn't suit at all". On reflection such a high result for this category is surprising, while participants may have found the game ineffective as a learning tool; it is still completely visual and tactile in nature.

Question 10 – Software specific questionnaire

Subjects were asked specifically whether they would like to see each of the programs created used on their course for teaching about the cardiovascular and other bodily systems. 100% of the students did not want to see the game used on the course, with one reasoning given that such an application may be more suited to a younger age group. This is the complete opposite in the case of the results of the simulation where every single participant wanted to use such an application. In regards to the simulation participants gave such reasons as it, “would provide an added resource and reinforce information received through lectures”, and it has the ability to be expanded and adapted as a learning tool for all aspects of anatomy and physiology.

Question 11 – Software specific questionnaire

All participants were asked to compare each piece of software, and state which they would prefer to use as a learning tool. All participants gave the simulation as the answer to this question. In the attached essay response to this question, students stated that:

- The simulation was “brilliant and very informative”.
- The simulation was “logical and easy to understand with options to return to any aspect at any time”.
- Background knowledge of the heart would be essential to understand the concept of the game.

Digital natives, digital learners

A main thread of the project is to discern whether the students being tested are what Prensky (2001) and Tapscott (2009) describe as digital natives and the net-generation respectively. In section 9.3.3 it was stated that the literature suggest that the age range of digital natives is 11 and 30 (Tapscott 2009).

Analysis of the data for this first test shows us that only one of the participants fell into the 11 to 30 age range, with other participant’s ages ranging from 35-45. Already this would seem to suggest that in fact learners in higher education are not all digital natives as Prensky (2001) and Tapscott (2009) would lead us to believe, but in this case in accordance with restriction on age by the definition a higher proportion of learners here belong to the digital immigrant group.

Participants were asked a variety of questions to the end of establishing how familiar they were with digital technologies. The first question in relation to this asked how comfortable students were using computers on a likert scale between ‘cannot use computers’ and ‘expert’. The highest frequency of responses rated comfort level with computers as being ‘reasonably comfortable’, which would be perhaps higher than suggested by the theories described previously. Testers were asked whether they played computer games, to try and determine whether digital tech permeates their leisure activities. A factor like this would be a defining feature of digital natives. Only one participant stated that they played computer games as a leisure activity.

Age and computer literacy is only one aspect of this analysis, questions were also posed with the aim of determining whether participants could be classified as digital learners. Participants were asked what sorts of additional resources they used to aid in their learning in an attempt to find whether students used traditional or digital resources. A mixture of traditional and digital resources were quoted such as:

- **Traditional:**
  - Group study
  - Medical journals
  - Local library
- **Digital:**
  - Internet
  - Google scholar
  - BBC Bitesize

The poor sample size did not allow for analysis of favouring to either type of resource. Table 21 shows a comparison of reasoning regarding why students do or do not use digital resources. Reasons for not using digital resources seem to stem from level of computer literacy of participants, and their ability to access and filter digital content. So while the majority of participants felt they were 'reasonably comfortable' using computers as stated previously, there is apparently still a barrier for some which limits or restricts their experience while using digital resources. Others stated that digital resources save time and effort and help to clarify topics that were misunderstood in lectures.

Why digital resources are used	Why digital resources are not used
• Faster results. • Saves time and effort • Sometimes information is not understand in lectures and digital resources help to clarify such occasions	• Lack of computer literacy • Lack of knowledge of available computer resources • Too much information • Time consuming (this must related to previous point regarding computer literacy)

Table 21 - A comparison of participant's reasons for either using or not using digital resources.

Factors potentially limiting the success of the software developed.

In order to gauge what factors could have affected the quality of experience for test subjects - factors which could have reduced the perception of success and effectiveness of each piece of software as a learning tool - a specific question was asked in regards to confusing elements of application, and also data can be gathered in regards to this from essay style comment opportunities throughout the questionnaires.

Simulation

In the specific question regarding interface, navigation and usability of the simulation, participants during this test stated that the confusing aspects were visual modes and the graphs features. In regards to the graphs no detail was given as to what was confusing about the feature. Possible reasons for such confusion could be that the graphs are not detailed enough or this information is towards the upper end of expected knowledge requirements at this level; in which case it could have been a mistake by the researcher to implement such a feature for this level of audience. This is only speculation however. Suggestions were made for the possible need for accompanying verbal descriptions of certain parts of the content being conveyed within the simulation such as, why valves function as they do. Although this is something could be explored in future work. Adding such verbal descriptions and other aural feedback would take the simulation to another level, improving the software as a learning tool in general but also allowing the application to tap into the aural learning style to a much greater extent.

Game

Results for the same question regarding confusing elements within the games can be seen Figure 39. Subjects were allowed to select multiple points and as you can see it suggests a much more problematic experience for testers.

Did you find anything confusing about the game?

Value	Count
Objective of the game (Take blood around the systemic/ pulmonary system by directing blood through the correct pieces of anatomy in the order they appear in the cardiac cycle, place sections of vessel in lengths between anatomy hubs before either blood is released or blood leaks etc)	3
Controls (placement of vessel section, replacing vessel sections etc)	4
User interface (points display, lives display, the leakmeter, the helper avatar etc)	2
How you win	2
How you lose	2
How to score points	2
How to lose points	2
Consequences of actions(why you lost a life, why you were taken back to a previous anatomy hub and a length of connected vessels destroyed etc)	2
Progress feedback (have you gone to the correct or incorrect anatomy hub etc)	3
Label test feature	3
Tutorial (prior to the game commencing)	1
Instructions (prompts from the helper avatar throughout)	2

Figure 39 - Results indicating confusing elements of the game for testers.

The results seem to indicate that participants experienced confusion surrounding all aspects of the game. The confusion experienced is to such an extent that the poor perception of the game by the testers is unsurprising. Reasoning for such confusion became apparent during the informal discussions which took place following the test with this set of participants detailed in 9.2.

Appendix F

Appendix F1 Concept Document

Introduction

The proposed digital learning tool to be developed is an interactive educational simulation for the PC, which instructs users about the different biological systems within the human body, and is designed for use by teacher and student alike - inside and outside of the classroom as a supplement to their traditional educational learning materials.

Description

The application has the potential to provide users with virtual access to the body's eleven physiological systems, which will allow them to:

- examine accurate 3d visualisations of the organs which make up the different systems with visual freedom
- access further supporting educational content
- view real time animations which depict certain bodily mechanisms
- alter a variety of internal and external environmental variables in order to analyse the body's physiological responses and consequences

For the purposes of this prototype only the circulatory system will be developed and within this system it will be the structure, mechanisms and associated physiology of the heart that will be focussed on in greatest detail.

After accessing the circulatory system in the menu you are presented with the options of viewing the full system as a whole, the pulmonary and systemic circulation system (as visualised and presented within the students syllabus), and finally the heart itself. Selecting any of these options will take the user to the next stage, which is the associated 3D visualisation. Within this stage they will still have the ability to quickly switch to these other visualisations however.

As stated after selecting the heart you will be taken to the next stage of the simulation – the 3D organ- where the user is presented with the default view of the organ, which in this case a full non-dissected anterior view of the heart. The user is able to freely navigate the model using the provided navigational tools (pan, rotate & zoom) and can also choose to view the heart with the front half of the model removed to be able to see the interior structures. Mechanical animations are accessible through simple playback controls and a timeline depicting the duration of a single (typical) heartbeat is available for comparison. You are able to select graphical feedback to be displayed over the timeline for information such as the ECG, ventricular volume, heart sounds and ventricular pressure. The user can also select specific physiological events to track to within a single heartbeat from beneath the timeline. Users are able to select from multiple visual modes including electrical conduction and blue/ red colour overlay, the visualisation of the heart will change in response to this. At any stage you are able to select the option to turn on labelling, which will display the correct names for the individual parts of the heart and will differ depending on the current anatomical state that the heart. The teacher is also able to put the labels into test state where the text is removed and students can be asked to input the correct corresponding name and are given feedback as to whether they guessed correctly or incorrectly. Interaction with certain elements of the model will result in educational textual feedback to the user within the interface and further educational content can be accessed via a dedicated information button. At any time you are able to return to the main menu and potentially select another system or sub system.

Key Features

- Designed to be accessible to people with varying degrees of existing content knowledge.
- Anatomically correct 3D models.
- Fully animated 3D models that show the mechanics of the body's systems.
- Ability to Pause, Slow and Speed up animations.
- 360° visual freedom around the body systems.
- Audio feedback.
- Dynamic labelling systems, which can be altered according to the amount of detail required by the user.
- Ability to input into the labels as a form of testing system for the student, feedback is given as to whether the correct name has been input.
- Real-time visualizations of conduction across the heart.

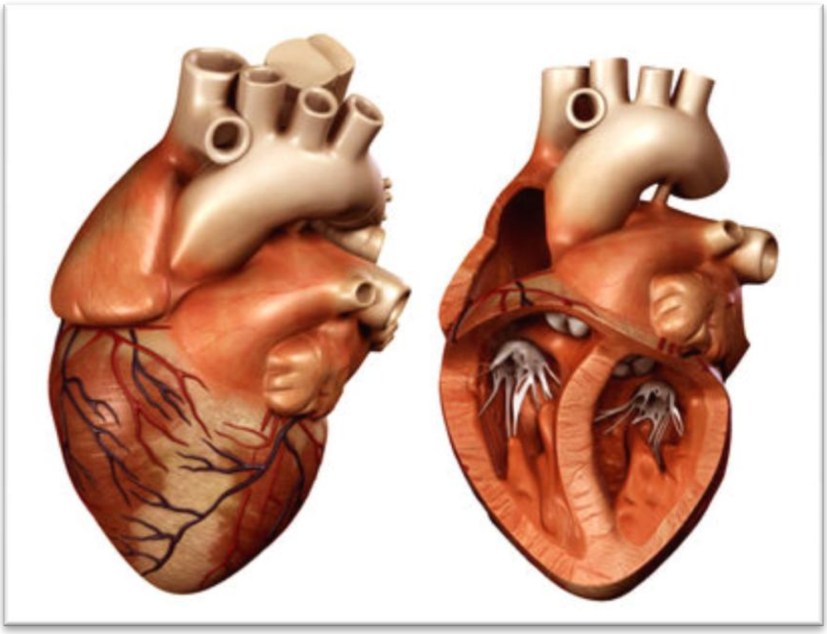
- Graphical feedback of Electro Cardiograms, heart sounds ventricular volumes, and blood pressures.
- Ability to visualise the heart as a part of the full circulatory system.
- Ability to track to certain mechanical and electrical events during a single heart beat

Genre

This application is a Serious Game, or to be more specific an educational simulation that is designed to further the user's level of knowledge on the subject area, and/or facilitate the teacher's ability to effectively educate the students.

Platform

The target platform PC for the simulation will be PC. The simulation must be able to function on reasonably low specification computer's, to ensure maximum accessibility.



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