An Investigation into the Efficacy of Computer Simulation as a Mechanism to aid Adult Students in the Comprehension of Anatomy and Physiology Curriculum.

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Declaration

I declare that the work described in this document is, except where otherwise stated, entirely my own work and has not been submitted as an exercise for a degree in any other university.

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Abstract

This study set out to investigate computer simulation as a mechanism to enhance adult students understanding of Anatomy and Physiology curriculum. More specifically to determine the main issues faced by this set of students and in what ways does computer simulation improve the level of understanding of complex curricula. To address this, a series of e-lessons were designed using the ADDIE instructional design model (Arkün, 2008). The research began by evaluating ten simulation software applications against criteria derived from Gagne's 9 Events of instruction design (Gagne, 2008). Once a specific application was chosen a series of lessons were developed in line with action research methods (Mills, 2000). During the induction phase students were shown a series of demos (worked examples) on how to use the simulation software, this approach was used to reduce cognitive load on the students (Wyeld, 2016). After the induction, five instructor lead lessons ran over a seven-week period whereby students created portfolios using the simulation software. For this task the Biodigital simulation software was used as the primary resource. Students were required to carry out various investigations of systems in the body and present a portfolio of work in the final class. The mixed methods approach produced both quantitative and qualitative data. The quantitative analysis found students who participated in the simulation lessons reported low cognitive load scores and reported improved understanding of the subject matter. Qualitative evidence from the follow up surveys and the focus groups showed most students had a more enjoyable experience learning A&P using the Biodigital simulation software. The results from this study supports the use of computer simulation for adult students who are returning to education or those who are less academic and are faced with the challenge of learning complex curricula. There was evidence to support the use of computer simulation to address the learning difficulties with adult students in a given domain under specific circumstances.

Table of Contents

List of Tables

List of Figures

Acronyms

ADDIE	Analysis, Design, Development, Implementation, Evaluation
A&P	Anatomy and Physiology
CAO	Central Applications Office
CPD	Continuous Professional Development
C&G	City and Guilds of London
DES	Department of Education and Skills
EGFSN	Expert Group on Future Skills Needs
ETB	Education and Training Board
FET	Further Education and Training
HEA	Higher Education Authority
MIS	Management Information System
ITEC	International Therapy Examination Council
NFQ	National Framework of Qualifications
NYU	New York University
STEM	Science, Technology, Engineering and Maths
PLC	Post Leaving Certificate Course
QA	Quality Assurance
QQI	Quality and Qualifications Ireland
RPL	Recognition of Prior Learning
SOLAS	An tSeirbhís Oideachais Leanúnaigh Agus Scileanna
SST	Specific Skills Training
VLE	Virtual Learning Environment

Chapter 1: Introduction

1.1 Background and Rationale

The background to this study relates to the difficulties adult students in further education face in comprehending Anatomy and Physiology curriculum. Currently these type of courses are typically syllabus driven, taught through conventional didactic methods with limited student engagement and critical thinking (Falasca, 2011). The rationale for the study was to investigate how computer simulation can address learning difficulties associated with this type of curriculum. A comprehensive analysis was conducted of learner experiences in using computer simulation, with respect to concept formation and views on the learning process. Key indicators were measured including the impact of simulation software on learner engagement, the capacity for concept formation, the visualisation of abstract material and the application of knowledge.

1.2 Research Question

The research set out to investigate the efficacy of computer simulation as a mechanism to aid students in the comprehension of Anatomy and Physiology, in particular adult students engaged in further education and training courses. This topic is broken down into a series of sub questions:

- How can computer simulation address the difficulties associated with learning complex information?
- How effective is computer simulation in learning biological concepts which cannot be seen by the naked eye?
- What features of computer simulation best facilitate the comprehension and application of abstract knowledge?

1.3 Methodology overview

Methodology is defined as, a way of thinking about and studying social reality and falls broadly into two approaches namely, quantitative and qualitative. Method on the other hand is defined as a set of procedures and techniques for gathering and analysing data (Strauss & Corbin, 2008). The research methodology was informed by a literature review which explored the difficulties associated with learning complex information and outlining the affordances of simulation in addressing these difficulties. A mixed method approach was used investigating the effects of computer simulation lessons on a target group of adult students. Lessons were designed to engage students using the BioDigital[1] simulation software. Observations of the classes were recorded and post-activity questionnaires were given to students. Teacher interviews were conducted after the series of lessons took place. A focus group was also conducted with each group. A framework to implement best practice was then specified based on the findings.

1.4 Roadmap and chapter outline

This study is divided into six chapters. The first chapter provides the background information, context and rationale for the study. This is followed by the literature review which provides a summary of the current

[1] BioDigital is commercially available software that was selected after a comprehensive evaluation of various simulation applications.

state of knowledge on specific issues that relate to learning abstract information, and the affordances of simulation technology to address these issues. Chapter 3 describes the design of lesson plans which were used to assess the effectiveness of computer simulation as a learning aid in this context. Chapter 4 describes the methodology used to implement the simulation exercises described in Chapter 3. This chapter also discusses the methods used to assess the learning experiences from participants and outlines the analysis of the data. Chapter 5 examines the results arising from the survey of students providing a discussion of the main characteristics of students before progressing to estimate the impact of computer simulation against a series of outcome measures. This chapter also examines the students' perceptions with respect to the advantages and disadvantages of computer simulation and views on the learning process and guidance arrangements. Chapter 6 begins with a series of conclusions based on the research question, this chapter also includes a framework to implement best practice and areas for future research.

Chapter 2: Literature Review

2.1 Introduction

The background to this study relates to the difficulties in learning and comprehending information which is abstract and complex; particularly Anatomy and Physiology**.** The context of this research is to investigate the effectiveness of teaching Anatomy and Physiology to students using computer simulation. Literature will be discussed regarding the ways in which computer simulation can address the difficulties identified in learning this type of curriculum. The rationale for this literature review is to identify the difficulties in learning Anatomy and Physiology, and the affordances computer simulation can bring in addressing these learning difficulties. The aim of this chapter is to review academic debate and themes which relate to computer simulation and the cognitive load difficulties associated with learning abstract information. This review will begin by outlining various difficulties associated with learning Anatomy and Physiology, and the barriers to comprehension currently in place. Literature on the cognitive load theory will then be discussed, the limitations of working memory in the formulation of long term memory and how simulation enables the efficient use of working memory. This review will then examine literature on conceptual understanding of Anatomy, Physiology and meta conceptual awareness, and how this can be achieved through visualisation and interaction. Computer simulation will then be discussed, and literature will be presented outlining the attributes of computer simulation as a learning aid along with the factors which improve the understanding and application of complex scientific information. The affordance of computer simulation on learning will then be discussed. This is followed by a critical analysis of computer simulation as a teaching aid and addressing questions on the robustness of the evidence presented. Finally, the summary will give an overview of principles covered, and how they can be applied to the design of a computer simulation learning experience.

2.2 Current difficulties in learning Anatomy and Physiology

The aim of Anatomy and Physiology education is for students to reach a level of understanding of the human anatomy which enables them to use such concepts in problem-solving situations in their working practice (Södervik, 2016). A common issue for students learning Anatomy and Physiology is their perception of the subject matter being difficult to understand and abstract. This results in students feeling overwhelmed and lacking in confidence to engage (Sturges & Maurer, 2013 p9, Çimer, 2012 p70). Students are often required to complete Anatomy and Physiology classes as part of the Beauty Therapy and Sports Therapy courses, but often they to lack the prerequisite skills required to transfer and build on existing knowledge (Michael, 2007 p38).

Typically, Anatomy and Physiology students collate study material from a variety of static images (often black and white), textbooks, dissection manuals, and lecture notes. Developing a spatial understanding in line with experimenting on real cadavers is not feasible in a typical Anatomy and Physiology learning environment in further education. A common teaching practice of Anatomy and Physiology tends to follow a didactic approach which is syllabus driven and teacher-lead (Olson & Loucks-Horsley, 2000 p15, Osborne & Dillon, 2008 p13). Consequentially students perceive Anatomy and Physiology as being difficult to understand, with the focus on rote learning facts, rather than applying the knowledge to practice through higher-order thinking (Speth et al., 2010 p435). This approach limits students capacity to gain cognitive dissonance, as they find it difficult to connect the topics to existing underpinning knowledge (Çimer, 2012 p70). One of the main factors to learning complex and abstract information is the individual's capacity to utilise working memory in an efficient manner. Quite a number of adult students in FET may have been out of education for a number of years, and the amount of mental effort required to comprehend the material is overwhelming (Falasca, 2011).

2.3 Cognitive load difficulties associated with learning complex curricula

Cognitive load is known as a model for the mental effort required in order to comprehend information. The cognitive load theory relates to the limitations of working memory in the formation of new information, coupled with the capacity to function with long-term memory associating it with familiar information. This process gives humans the capability to acquire highly complex knowledge and skills (Paas & Ayres, 2014 , Sweller, Ayres, & Kalyuga, 2011). This is a fundamental consideration when evaluating human capacity to comprehend complex ideas (Paas & Ayres, 2014). Working memory is a process often combined with short term memory, where information is stored and managed in order to carry out complex cognitive tasks such as learning, reasoning, and comprehension (Cowan, 2009). Working memory enables the processing of information such as encoding, storing, and the retrieval of data from long term memory (Shipstead, Harrison, & Engle, 2016). The load on working memory is reduced through the development of cognitive schemas. This is achieved through the process of storing and organising knowledge by grouping multiple units of information into a single component with a specific function (Kashima, 2000).

Expert skill development is mastered by the construction of higher level complex schemas through encapsulating elements of lower level schemas into higher level schemas (Chi, Glaser, & Rees, 1982). When developed over a long period, higher level schema may incorporate vast amounts of information, and the processing of this information becomes automated (Bassok et al., 2003).

There are many quantifiable differences in cognitive load between a novice and an expert, most noticeably the time to solution when problem solving. This is down to the capacity of the individual to use working memory. These higher-level schemas are stored in related configurations in long-term memory, and the method in which they are stored enables the efficiency of working memory, which in turn improves the rate of comprehension (Gavens & Barrouillet, 2004). When combined, schema construction and automation of information processing results in a reduced load on working memory, which enables the individual to process information in a very efficient manner and formulate procedural knowledge by manipulating existing knowledge structures which have been developed (Fischer, Greiff, & Funke, 2012).

However, studies on cognitive load theory suggest that the working memory capacity which is available for learning is not determined by task and learner characteristics alone. Aspects of the physical environment have been shown to curtail working memory resources by unintentional monitoring of the environment. Environmental effects increase the number of interacting elements which must be processed in working memory simultaneously. This creates high demands on working memory and is known as intrinsic cognitive load. Simulation is a form of instructional design which can facilitate germane cognitive load, which is the process of storing knowledge in long term memory. The instructional design used in presenting learning content affects the extraneous cognitive load and it is imperative to reduce extraneous load when learning complex information (van Merri¨enboer & Sweller, 2005). One effective method of reducing extraneous load is the use of video tutorials (or worked examples) showing step-by-step procedures to students in a structured format. This has been shown to reduce cognitive load and frustration levels in early learners (Wyeld, 2016). Simulation is a form of instructional design known to reduce extraneous load by enhancing information integration using imagery and visual cues to enable schema construction (Reedy, 2015).

From constructionist learning theory, Papert acknowledges that setting and context are important factors for an effective learning environment (Stager, 2013). These factors highlight important design considerations when combining the learning environment with learner characteristics and instructional strategies as memory retrieval benefits from a reduction in the cognitive load. Systemic understanding reduces cognitive load and enables students to become dynamic thinkers, in order to manipulate and apply concepts to various situations (Tanner & Allen, 2005). Teaching students to adapt and manipulate interrelated concepts as opposed to learning unconnected facts can 'facilitate high-level learning of complex scientific phenomena'(Tanner & Allen, 2005). Conception is a related issue for adult students as cognitive load can inhibit the cognition process leading to reduced levels of understanding.

2.4 Concept formation

Having spoken about cognitive load theory, this discussion now moves onto the examination of knowledge conception. Conceptualisation enables cognition and understanding. This thought process involves contriving new ideas or explanations and formulating them mentally (DiSessa, 2007, Zacharia, 2007, Saleh, 2011). Accurate conceptualisation is key when learning about complex scientific systems such as human Anatomy and Physiology. The process involves the reconfiguration of prior beliefs (ontology) in order to create new meaning, which is more specific and accurate to scientific theory (Chi, Slotta, & De Leeuw, 1994). This is a complex task as pre-determined misconceptions can act as barriers to learning. They can often remain throughout the learning experience and hinder the 'systemic learning of complex and multifaceted scientific phenomena' (Södervik, 2016). The reason for this is that prior knowledge is the foundation for "*the assimilation and construction of new knowledge"* and thus may interfere with the learning of new concepts (Tanner & Allen, 2005). It is important that the learner is presented with sufficient ontological concepts of scientific theory to develop their conceptual understanding. One approach to this is creating a learning experience that confronts the student with explicit information which conflicts with their prior conceptual understandings. This phenomenon is known as cognitive dissonance, it involves self-reflection on attitudes and concepts and measures taken to resolve discrepancies within one's own understanding (Festinger, 1957, Aronson, 2000, Ulrich, 1997 P5).

Learning Anatomy and Physiology curriculum is a challenge, even among 3rd level student groups (Tanner & Allen, 2005). Due to the systemic nature of Anatomy and Physiology any misconceptions about central phenomena have consequences for the practical application of the subject matter. Research has suggested that didactic teaching methods constrain students from investigating complex scientific phenomena and is not the most effective method for teaching scientific concepts (Bransford, Brown, & Cocking, 2000 p2-23).

Kolari & Savander-ranne interpretation of constructivist theory is based on learning being a cognitive process unique to the individual. Their hypothesis is that students gain apprehension and comprehension of scientific theory through experimentation, demonstration and visualisation. The visualisation process of viewing models of relevant scientific representations greatly assists the learner in translating more abstract representations into less abstract representations (Kolari & Savander-ranne, 2004 p489-491). Teaching for understanding, including the process of conceptual change, and practical implications of such can be better implemented through the use of simulation in teaching practice (Tanner & Allen, 2005). The use of computer simulation in the teaching of Anatomy and Physiology also facilitates metaconceptual awareness as students can visualise biological events which cannot be seen by the naked eye and they can interact with models that represent various systems in the body. These types of practical experiments have been widely considered essential learning practice in science education but only if the models are linked to scientific fact (Juntunen & Aksela, 2013 p159-161). To exploit the full potential of computer simulation students need to have established fundamental under pinning knowledge. Experiments and simulations do not have the same effects if the learner does not understand what they are doing and why (Lateef, 2010 P348-351). For example, when dissecting a heart, students must understand which anatomical structures to focus on, they must also understand the functions of the anatomical structures and how these structures work within the cardiovascular system.

2.5 A systematic analysis of simulation

Simulation is a technique for practice and learning which can “replace and amplify real experiences with guided ones, often “immersive” in nature, that evoke or replicate substantial aspects of the real world” in a fully interactive environment (Lateef, 2010 P348). McGuire defines simulation as “a person, device, or set of conditions which attempts to present problems authentically”. A simulation exercise requires students to respond to a problems as he or she would under natural circumstances" (McGaghie, Siddall, Mazmanian, & Myers, 2009 p63). A computer simulation (or "sim") is computer generated virtual model of a real-life or hypothetical situation that enables students to study how a system works and virtually investigate the behaviour of a system. Simulation is defined “the imitative representation of the functioning of one system or process by means of the functioning of another” (Merriam-Webster, 2013). The measure of realism in simulation or ‘approximation to reality’ is known as fidelity. In Anatomy and Physiology simulation there are multiple levels of fidelity available. Most medical simulation-based software applications have low-fidelity levels (Talbot, 2013). Computer simulation can enhance students understanding of abstract concepts through the exploration of detailed graphical 3D models (Olympiou, Zacharias, & deJong, 2013).

Computer simulation is popular in high-risk professions such as medicine, and has been used since the 18^{th} century (Bradley, 2006). Literature published on the PubMed database indicates that computer simulation in teaching Anatomy and Physiology falls into three basic categories (Torres et al., 2014).

Category 1 — Simulated Cadaveric.

A simulated cadaveric is a physical model of a human corpse used to show students how anatomical knowledge is useful in medical work practice. Studies have shown how simulated cadaveric dissection provides a 'purposeful and memorable way of learning anatomy', in comparison with conventional teaching methods (Nutt, Mehdian, Parkin, Dent, & Kellett, 2012).

Category 2 — Simulator based education

Simulators have physical controllers which provide input to the simulation through direct manipulation by the user. Often tactile feedback from the physical controllers are incorporated into the hardware to give a heightened level of fidelity. Simulators are typically used in the training of surgical procedures during anatomical classes (Seixas-Mikelus et al., 2010).

Category 3 — Other.

There are many 'other' types of medical simulation, one of the more popular areas is in problem-based learning simulation. This typically involves clinical cases presented to medical students based on computed tomography scans, real patient clinical cases in the form of patient/physician history recordings, and physical examination videos. Students must interact with simulation by answering a series questions based on a predetermined problem.

These types of computer simulations are typically based on radiology images and involve techniques such as image labelling, 3D reconstruction, and multiplanar reformatting (Turmezei, Tam, & Loughna, 2009). The virtual human dissector or the 3D stereoscopic images are used predominantly in modern anatomical curriculum, and has been proven extremely effective in medical education (Donnelly, Patten, White, & Finn, 2009, O'Byrne, Patry, & Carnegie, 2008).

Using Anatomy and Physiology simulation, students can view 3D organs and other anatomical structures in the body where they can magnify and explore the models in detail and view them from a range of perspectives. Anatomy and Physiology simulations have a range of interactive features. Students can filter out and isolate various components of the body, using functions to reveal and hide layers of muscle, bone, and nerves. Virtual dissection tools can also be used which enable students to analyse and experiment with various systems in greater detail. Other features of the software enable students to mark incisions in virtual skin, reveal underlying tissue layers and manipulate these layers from different perspectives, and insert labels or notes to these models for personalisation and reflective practice (Mayer, 2005).

2.5 Affordance of computer simulation in the learning of Anatomy and Physiology

There are many research papers which promote the affordances of simulations to develop deeper conceptual understanding (Olympiou et al., 2013 p587-592, Andrews, Polack, & Sampson, 2010 p4-13). Anatomy and Physiology computer simulators enable the conceptualisation of biological events that are traditionally taught in a descriptive didactic form. Interactive simulation activities enhance conceptualisation by enabling students to view human biological systems through a range of perspectives in a controlled environment, and perform tasks that would not be possible without the use of technology (Dori & Belcher, 2005). Real-time feedback is also available through simulation apps which facilitate the comprehension and application of knowledge when compared to rote-learning activities (De Jong & Van Joolingen, 1998 p192 -195). There is also statistical evidence to suggest simulation significantly improves concept assimilation among science students (Martínez, Naranjo, Pérez, Suero, & Pardo, 2011). Computer simulation improves the comprehension of vast amounts of information through imagery which builds context and visual perspectives of complex systems (Zacharia, 2007). 3D computer modelling develops rich understanding through visualisation when coupled with previously-learned knowledge (Blikstein, Fuhrmann, Greene, & Salehi, 2012 p299). 3D simulations can also animate complex environments in a simplistic form that enables the visualisation of abstract functions of the human body (reducing cognitive load) in order to develop conceptual understanding and the formation of new knowledge (Saleh, 2011 , Kolari & Savander-ranne, 2004).

Engaging in direct manipulation of Anatomy and Physiology using 3D computer simulations is a more effective method of learning than the passive viewing of two dimensional images on a static page (Jang, Vitale, Jyung, & Black, 2016). Anatomy and Physiology simulation software also enables the visualisation of various clinical abnormalities in the body such as disease or genetic disorders. Some applications can even animate the impacts of aging on the body over time. This approach has a distinct advantage for learning, as the immersive nature of computer simulation has greater depth of visualisation and interaction which enables a deeper conceptual understanding of complex information (Hsieh, 2016). Anatomy and Physiology simulation significantly improves assimilation as it enables students to interact with detailed graphical representations of complex biological systems in a more engaging way than classic illustrations and narrative descriptions (Issenberg et al., 1999). Research by (Cai, 2014 p31) revealed evidence to support the use of computer simulation in teaching molecular biology, the results of the study showed the intervention of simulation helped clarify understanding while increasing interest and engagement.

The development of cognitive skills is demonstrated through implicit and explicit learning; implicit knowledge is acquired directly from the environment and has a lower cognitive load during the learning process than explicit learning (Sun, Mathews, & Lane, 2007). It is important to consider environmental factors in the design of simulation exercises as these factors can distract from explicit learning. They may be added in at a later stage in the development cycle as the learner becomes more advanced and has acquired fundamental underpinning knowledge to cope with multiple variables. An example of this would be the use of computer simulation to teach skill based practices such as the operation of an aircraft through flight simulation software.

Piaget’s theory of abstract symbolic reasoning defined the growth of knowledge as “a progressive construction of logically embedded structures superseding one another by a process of inclusion of lower less powerful logical means into higher and more powerful ones" (Silverthorn, 1999 p1). Abstract symbolic reasoning skills can be developed through computer simulation by deconstructing complex systems into less complex minor systems and building up the complexity over time in order to develop higher level cognitive schemas (Psychol- & Psychologist, 2015). Piaget's theory of constructivism is based on the principle that humans produce knowledge from meaning based upon their personal experiences. The two key components of his theory are accommodation and assimilation. Assimilating is the process by which an individual incorporates new experiences into the old experiences and uses the new experience to formulate a new outlook, and change their perceptions. Accommodation involves conceptualising the new experiences into the mental capacity that is already present. The "experience" offers a different context which the learner must accommodate and set new expectations with the outcomes (Piaget, 1970). Computer simulation develops conceptual and experiential practices necessary for complex skills development while maintaining a safe and controlled environment for the learner. This facilitates operant conditioning which enables students to experience consequences for their actions in a controlled setting (Skinner, 1988). Feedback from computer simulation can "reward" or "punish" students depending on the situation and the inputs they give.

There is a great deal of research supporting the effectiveness of computer simulation in the classroom (Falcon, 2010 p3). There are also a number drawbacks identified. Research has shown where computer simulation is counterproductive if implemented incorrectly (Ferguson, 2005 p2). In the past it was argued that biological 3D models had low fidelity and the approximation to reality was poor in truly reflecting the scale and perspective of the real organ or system being shown. Quite often these early versions required browser plugins or emulators to be pre-installed on the computer. This is no longer the case as advancements in computer-generated imagery (CGI) development tools and computer hardware have enabled high resolution simulations to be accessible via a web browser on a range of devices (Duff, 2016).

It is argued that for inexperienced learners computer simulation leads to information overload as users experience cognitive difficulties with the additional task of developing the skills that enable them to use the software effectively (Shrivastav & Hiltz, 2013). Fraser, Ayres, & Sweller claim simulated learning environments are beyond the zone of proximal development due to the complexity and tactile skills that are required to operate the models and carry out simulated investigations (Fraser, Ayres, & Sweller, 2015). Others argue that simulations are prone to being over simplified with a focus on specific procedures to be learned, and giving students free reign to experiment is not sufficient without prior knowledge (Alessi & R.Trollip, 2001). For these reasons, it is critical to contextualise the setting in which computer simulation is used to enhance the learning experience. If the audience is inexperienced in using technology or they do not have underpinning subject matter knowledge the load on working memory will be too great for the learner to achieve the learning outcomes. Likewise, if the scaffolding is too much and the technology is assisting the learner the consequence will have a negative impact on the learning experience (McKenney, 2013 p4-8).

2.6 Evaluating the effectiveness of simulation software.

With so many Anatomy and Physiology software simulations on the market it can be difficult to evaluate each one individually as they all have merits and weaknesses. High resolution graphics and proportionate 3D models with high fidelity are not the most important features of a successful Anatomy and Physiology simulation. Achieving learner engagement requires a sense of immersion, appropriate visuals, responsiveness, and a good narrative (Munshi, Lababidi, & Alyousef, 2015). The decision to use computer simulation must be determined by the educational objectives (Wang, 2010). In choosing computer simulation software, educators often find that the level of fidelity required is lower than expected (Talbot, 2013). Currently the predominant use of technology in Anatomy and Physiology teaching is in the form of presenting information to students in a didactic manner rather than engaging them in an active learning experience. Evidence suggests a small minority of Anatomy and Physiology teachers in third level use computer simulations and animations to engage students and develop conceptual understanding (Osborne & Dillon, 2008 p20). This is not the case at 2nd level or in further education. The role of technology in learning is an important affordance that requires a strategic vision and support from management in order harness and develop deeper meaningful learning experience (Means, 2010 p302, Osborne & Dillon, 2008 p23-27, (Wang, 2009).

2.7 Software evaluation and lesson development

For this study, the researcher evaluated 10 commercially available Anatomy and Physiology simulation software applications. An evaluation criteria was derived, and the task of finding the most appropriate package was undertaken. The evaluation criteria was derived from Gagne's 9 Events of Instruction design model (Gagne, 2008) (Appendix B). The simulation application needed to have key pedagogical attributes to implement the design principles. Several key elements were evaluated in each application, table 2.1 outlines the criteria used in the simulation software selection process.

Attribute	Criteria	Weighting %
Fidelity levels	How accurate are the models and human systems to reality regarding scale, size and appearance? Can models be animated?	15
Design	How intuitive is the user interface? Are the functions clearly labelled to inform students? Can models be viewed from a range of perspectives? Does it have a zoom function? Can the systems in the body be isolated? Can students save their work for retrieval? How well does the application provide guidance to students? Does the software have on line tutorials/streamed videos/ YouTube channel?	25
Compatibility	What platform can the simulation be run on? How much RAM/computer memory does it require? Can it run over a web browser? Can students log in and retrieve/saved work?	20
Cost	What is the cost of the software? Are there trial demos available? Is there a group/class licence available?	15
Level of interaction	Does the software enable the students to carry out/practice virtual experiments on the models? Does the application provide learner feedback? What is the range of interactive tools available? Can learner's record notes/label the models? Is there an assessment / quiz instrument incorporated into the application?	25

Figure 2-1 Software Evaluation Criteria

Software was measured against set criteria and an overall score for each given. A breakdown of the scoring is detailed in Appendix A. With an overall score of 90, the BioDigital human https://www.biodigital.com/ simulation software was selected as the primary resource for the simulation lessons. Biodigital was developed by BioDigital Systems in collaboration with the NYU School of Medicine, and is a custom-built 3D simulation tool delivered in HTML5 and WebGL platform which can run via a web browser or as a standalone application. The application is highly interactive and intuitive. Students can get feedback on their models from online communities through the knowledge base, while the quiz feature allows students to test their knowledge. The dissection and exploded view tools aid conceptual understanding through visualisation and the YouTube demonstration videos can be used to reduce cognitive load and improve the efficiency of working memory.

2.6 Summary

This chapter has outlined the difficulties students face in understanding the complex information in the Anatomy & Physiology curriculum. Syllabus-driven didactic classes were shown to compound the difficulties in the formation of new knowledge (Olson & Loucks-Horsley, 2000 P15). The concept of cognitive load theory was discussed and the limitations of working memory was identified, and how this impedes the formation of new knowledge and the comprehension of complex information. A strategy supporting the implementation of instructional design in the form of computer simulation was then suggested as a method to reduce cognitive load and improve conception and understanding of complex curricula. The use of video tutorials and worked examples was found to be an effective method to introduce students to complex and abstract curricula. Cognitive load factors were then outlined, and how environmental factors add to cognitive load and the importance of visual stimulus and how this affects cognition. The comprehension of abstract information was then defined as a grouping of a series of information nodes together in a structured form (Paas & Ayres, 2014). Rounding off the key issues facing students the process of knowledge conception was discussed and how ontological structures are formed.

Literature was then presented highlighting the affordance of computer simulation to enable students carry out virtual dissections on models as a means of conceptualising abstract information. The principle of teaching students to adapt and manipulate interrelated concepts using computer simulation was presented as a method of learning complex scientific phenomena (Tanner & Allen, 2005). The chapter then goes on to outline the challenges of incorporating 3D simulation and constructivist activities into a conventional classroom setting and the fundamental measures that need to be considered before implementing this technology into teaching practice. The chapter concludes with a detailed breakdown of the learning experience and the criteria used for evaluating various simulation software applications that were measured against the design specification. The criteria for evaluation was based on Gagne’s instructional design model (Gagne, 2008). The next chapter will propose a framework which aims to address the students needs when conceptualising, visualising and comprehending complex information.

Chapter 3: Design

3.1 Introduction

The previous chapter reviewed literature which dealt with cognitive load theory and concept formation difficulties encountered by students in the comprehension of Anatomy and Physiology curriculum. Computer simulation was proposed as a means of improving the comprehension of complex of information through imagery which builds context and perspective (Cai, Y. 2014). Simulation was also shown to promote the application of knowledge through virtual investigations of the system and organs in the human body. This chapter describes the design of computer simulation lesson plan based on the principles of instructional design to address the reported difficulties associated with learning Anatomy and Physiology.

3.2 The Topic

The subject matter covered in the lesson plan is based on the International Therapy Examination Council (ITEC) level 2 component award in Anatomy and Physiology. ITEC is a leading international specialist examination board, providing quality qualifications in Beauty & Spa Therapy, Hairdressing, and Complementary Therapies. Anatomy and Physiology is a mandatory module required on the ITEC Beauty and Sports therapy diplomas. Computer simulation is not widely used for the teaching of Anatomy and Physiology to adult students in Further Education and Training (FET).

3.3 Design factors

The design factors drawn from the literature review are summarised in table 3-1 below.

Lit Review theme	Design principle	Implementation
Cognitive Load Theory (Sweller ,1988, Paas F, 2003)	Worked examples used to reduce cognitive load in students.	Students view a series of videos demonstrating the use of the simulation software. These videos will show various systems in the body from the perspective of an end user of the simulation software giving the learner a visual perspective on how to carry out the activities in the lesson plan.
	Cognitive load testing - Task Load Index	At the end of the lesson students were given a cognitive load test known as a Task Load Index (TLX) to investigate the cognitive load on students (NASA, 1986).
Conceptualisation/ Ontology (Obitko, Marek (2006 2007). Constructivism (Piaget, 1970)	Simulation (Rich Learning in realistic and relevant learning environment) This principle involves students making observations, doing research to find out what information is already recorded, collecting, analysing, and interpreting data and formulating anatomy and physiology concepts.	Students were asked to carry out a dissection on a given human organ. Computer simulation facilitates manipulation and interaction with variables and parameters. Virtual dissection and animations illustrate conceptual ideas in a simplified graphical form. A series of lessons that engage students in conducting simulations that promote the application of knowledge for problem solving.
Constructionism (Papert, S. & Harel, I. eds, 1991).	Create an artefact The process of learning by creating artefacts that develop a cognitive level of understanding.	Tasks are given to students where they identify a part of the body or system to investigate using computer simulation and present the findings to the class.

Table 3-1 Design Factors

3.4 Outline of the learning experience

The five lesson plans were developed by the researcher and implemented by the course tutor and the technical hardware/software required was sourced and managed by the researcher. Classes were tutor lead and the researcher started off by outlining the goals and context at the start of each lesson. Throughout the lesson delivery the researcher was observing and recording the activities of students and providing technical assistance when required. The top 6 topics identified by students in the pre-survey were used to inform the lesson plans and establish a list of topics to cover using computer simulation see table 3.2.

Topics identified	**Frequency**
Endocrine System	14
Nervous System	14
Lymphatic System	15
Muscular System	19
Digestive System	11
Cardiovascular system	9

Table 3-2 Lesson Topics

The lesson plan was set for 5 lessons in each venue. The lessons ranged from 1- 2 hours in duration over a 7-week period. The initial lessons for both groups was developed in line with the profile of the students. The topics for each lesson are outlined in table 3.3.

Lesson Number	Topics
1	Lesson orientation • Show demonstration videos on YouTube • Login and investigate the various systems with Biodigital software • Explore different viewing angles and isolate various organs in the model
2	Explore and investigate the Lymphatic System record and label various parts and save to your portfolio. If you have time continue to the Cardiovascular system and record and label various parts and save to your portfolio.
3	Explore and investigate the Muscular System record and label various parts and save to your portfolio. If you have time continue to the Nervous System and record and label various parts and save to your portfolio.
4	Explore and investigate the Endocrine System record and label various parts and save to your portfolio. If you have time continue to the Digestive System and record and label various parts and save to your portfolio.
5	Finalise your portfolios and do a TLX cognitive load test. Present portfolios to the class Participate in a focus group session

Table 3-3 Lesson Plan

Orientation

During orientation students were given an informed consent form to sign (see Appendix M). Once this was complete, students were shown a demonstration in class which provided information on how to access and use the BioDigital simulation software (VLE). Students were then showed several animated videos (worked examples) on the BioDigital YouTube channel demonstrating the Biodigital software and its features (see fig 3-1).

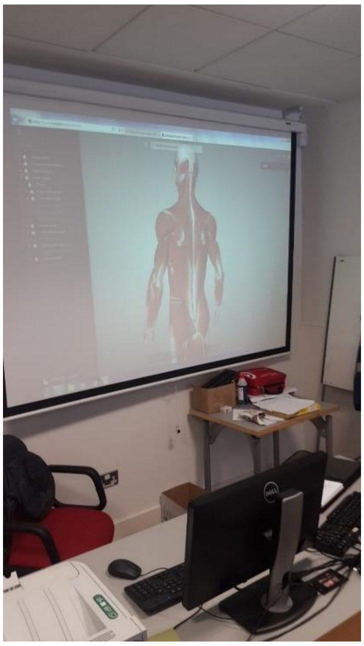

Figure 3-1 Lesson Orientation

After this, students were given the YouTube channel link and various other online tutorials. This method was used to reduce cognitive load while introducing simulation technology to the class. The chosen examples demonstrated in class were in line with the topics that students identified in the pre-surveys. Since most students used the web on a frequent basis, YouTube was chosen as the most appropriate medium for showing these worked examples. Once the demonstrations were complete, students were encouraged to search for other related YouTube tutorials on the Biodigital YouTube channel (Fig 3-2). A full breakdown of the worked examples shown in the lesson orientation are detailed in Appendix E.

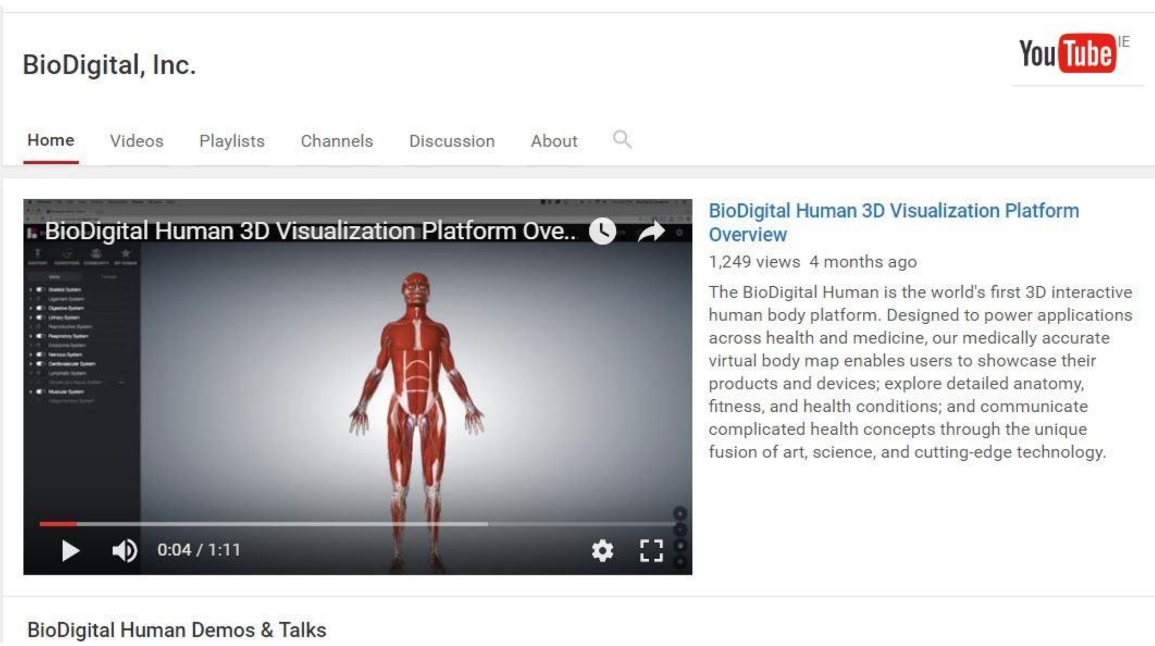

Figure 3-2 BioDigital YouTube Channel

Once the demonstration was complete, students were given login details for the BioDigital application (see fig 3.3) in order to start engaging with the software via the VLE (see fig 3.3). Students were encouraged to use the software to make observations, analyse, and interpret models and conceptualise Anatomy and Physiology once they were deemed competent to work on their own. This gave students greater depth of information than that gained by passively viewing two dimensional images on a static page (Gog & Elsevier, 2006).

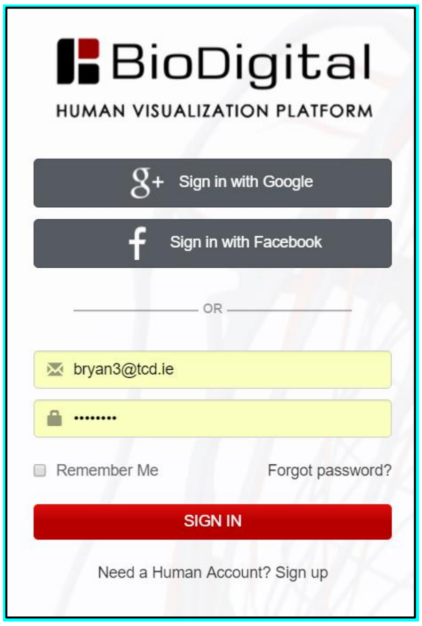

Figure 3-3 BioDigital Login Screen

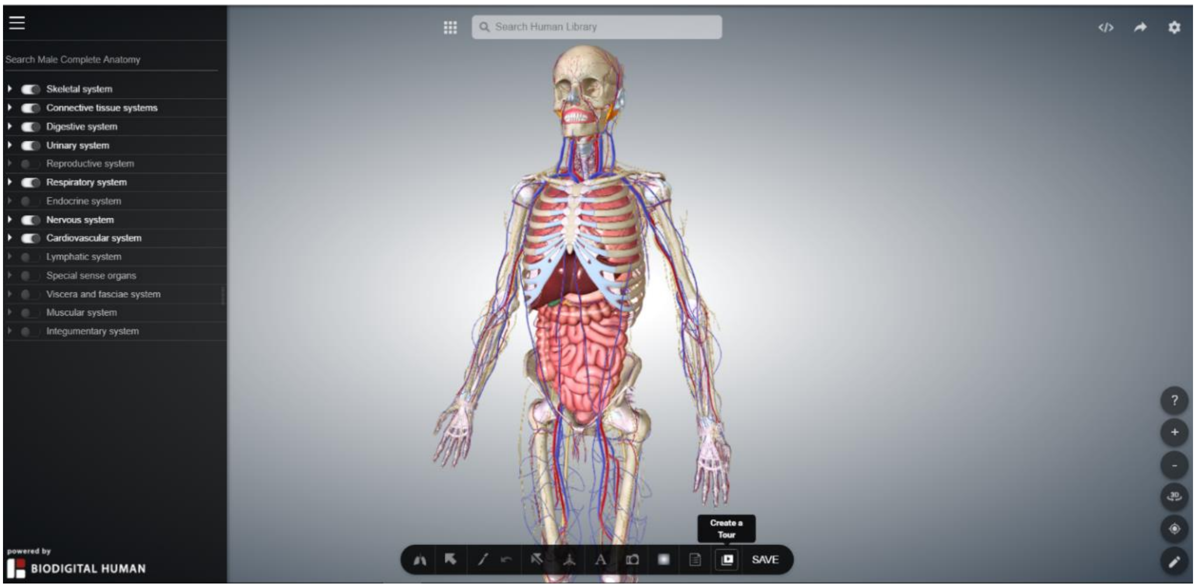

Figure 3-4 BioDigital VLE

After the second lesson, whereby students developed their skills and competency in using the Biodigital software, the class was instructed to carry out a series of virtual dissections on organs of their choosing. This task was chosen to address the research question relating to the effectiveness of computer simulation in the conceptualisation of biological events which cannot be seen by the naked eye. This method of learning helps to develop apprehension and comprehension of scientific theory through experimentation, demonstration and visualisation (Reedy, 2015). Simulated experimentation also facilitates operant conditioning; students can examine the function of a system by altering individual components within that system and observing the consequences. At the end of the second lesson, a class assignment was given out. This task required students to capture screen images of their 3D investigations and prepare a portfolio of work for presentation.

3.4.1 Academic Support

Students had academic support from their tutor throughout the course, students were expected to be in classes no less than 25 hours per week. Students could also contact the researcher at any stage of the project. There was also direct support for students on the tutor lead sessions, and observation of student activities was carried out by the researcher throughout the classes offering guidance and help to those who were experiencing difficulty. Students were encouraged to view the online tutorials of the BioDigital software as a knowledge base for key information pertaining to the use of the application. Sample models were also available through the Biodigital application via the search function. Students could also access the on-line community via the BioDigital support center.

3.4.2 Task load index test

In the final classes both groups (n = 14) completed the NASA Task Load Index (TLX) questionnaire. This instrument was developed by NASA to assess total cognitive load in humans. The matrix used combines the sum of intrinsic load (how complex the task is), extraneous load (how the task is presented) and germane load (how the learner processes the task for learning) (Nasa, 2010 ,Martin, 2014). The NASA-TLX instrument is a widely used, subjective, multidimensional assessment tool used to quantify perceived workload to assess a task effectiveness or other aspects of performance. The test is conducted on line via the TLX portal (see fig 3-5), available on http://www.nasatlx.com/.

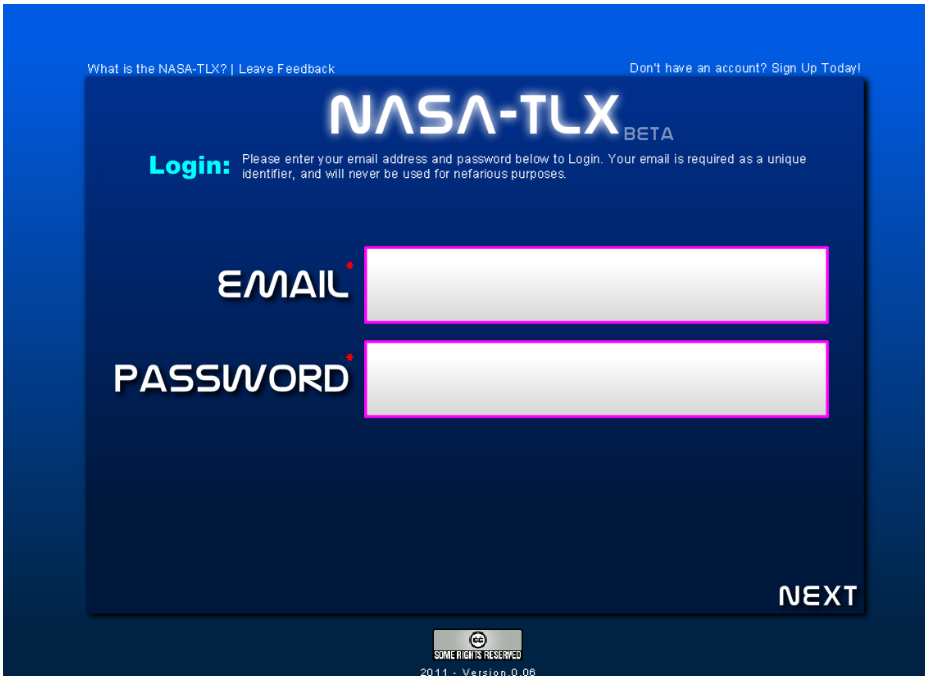

Figure 3-5 NASA TLX Login

For this study the researcher set up 2 classes on the TLX website. Each class was given login instructions and a brief presentation was given beforehand outlining the format of the test (see Appendix N). The is a series of self-reflective questions divided into 2 parts. The first part relates to the total workload and is divided into six subscales see (fig 3.6).

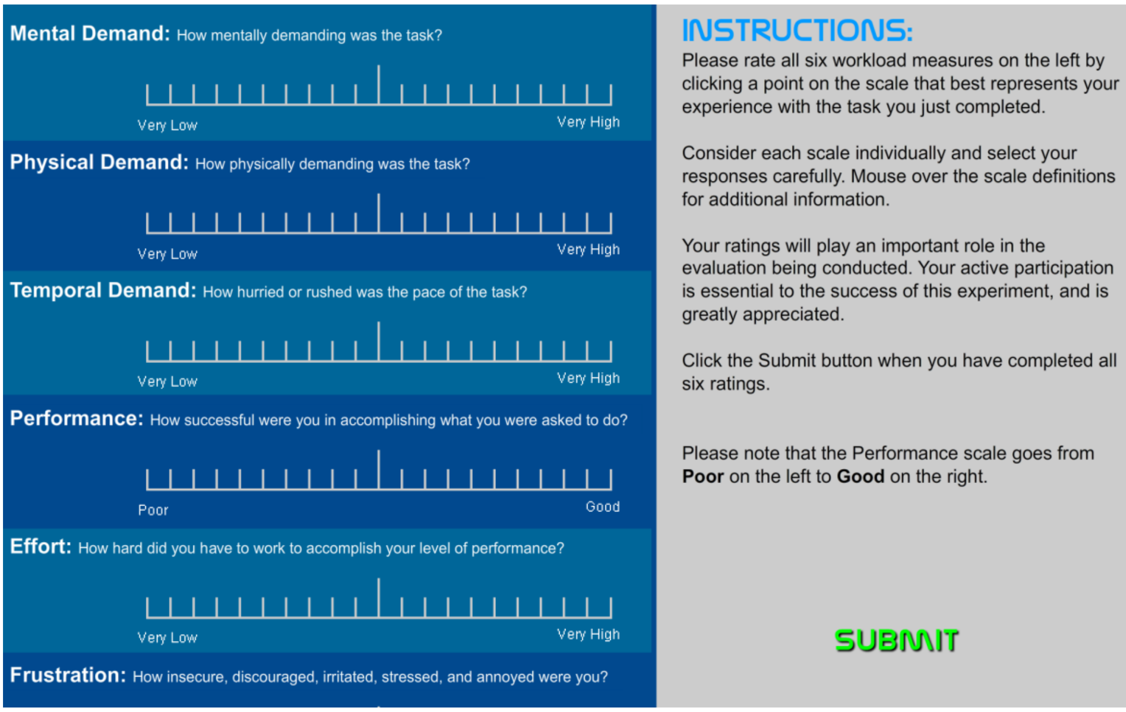

Figure 3-6 TLX Six Workload Measures

There is a description for each of the six subscales that students can read before rating each. Each workload measure is rated *for* within a 100-points range with 5-point steps see fig 3.6. These ratings are consolidated to give to the task load index. The second part of TLX test sets out to create an individual weighting of the subscales by asking students to compare the workload categories against each other based on their perceived importance. This requires the student to choose which measurement is more relevant to workload. The number of times each is chosen is the weighted score. This is multiplied by the scale score for each dimension and then divided by 15 to get a workload score from 0 to 100, the overall task load index.

3.5 Lesson Design ADDIE

The design model used to develop the lesson plan was the ADDIE model (fig 3-7). The five-phase instructional systems design model "ADDIE" is an acronym for Analysis, Design, Development, Implementation and Evaluation. Each phase of the model has an outcome that feeds into subsequent phases. The analysis phase is where the instructional goals and objectives are established and the learner profile is defined. The design phase related to the learning objectives and the specific exercises and learning activities to be carried out. The development phase is where the content is assembled and prototyping is carried out to refine the learning procedures. The implementation phase is where the lesson plan is executed and the conditions for learning are checked to ensure they meet the needs of students. The evaluation phase is usually in 2 parts formative and summative, the formative evaluation takes place at each stage of the process where as summative evaluation is domain specific and criterion related that enables students to provide feedback on the learning experience.

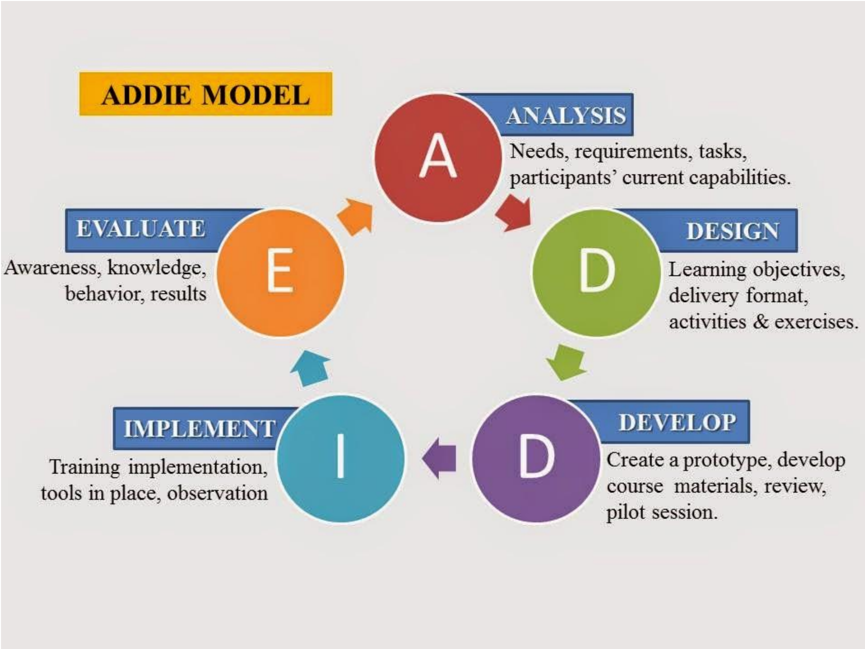

Figure 3-7 ADDIE Model

3.5.1 Analysis

The pre-survey instrument was used to set the parameters for the lesson design, it was also used to inform the scoring on the software evaluation. A series of questions on the topic of I.T usage and aspects of the Anatomy and Physiology curriculum was asked. This was carried out to determine the general frequency of I.T usage and to identify specific Anatomy and Physiology topics for the simulation lessons (see Appendix C). This information was used to inform the lesson design. The design principle used to investigate these themes was taken from the 9 events of instructional design (Gagne, 2008) see Appendix B. Simulation is a form of instructional design that enables the acquisition of knowledge and skill more efficiently, effectively, and in a way, that is more appealing to students. A detailed breakdown of the results acquired from the pre-survey can be found in Appendix D.

3.5.2 Design

The learning objectives were derived from the syllabus and the pre-survey instrument. Consultation with teaching staff on the class time available and the lesson delivery methods was conducted. A blended learning approach was taken whereby students would engage in the computer simulation activities in class conducting exploratory exercises using the BioDigital software. These exercises were designed to engage learners in direct manipulation of A&P models and exploratory learning which is known to improve concept formation and assimilation (Olympiou et al., 2013). Each lesson was between 1-2 hours in duration and learners were guided by a lesson plan for each class, this was not strictly enforced as to allow for self-directed learning in instances where students wanted to explore a specific area of interest or difficulty. A cognitive load test was also incorporated into the lesson plan with students carrying out the test during the final lesson. The learning objectives for each lesson are detailed in table 3-3.

3.5.2 Develop

Two pilot classes were conducted as part of the development cycle, one in each college. The specific aims of the pilots were:

- To determine the compatibility of the simulation software with the computer hardware and internet connection available in each college. This was done to select the most appropriate simulation software to use.
- To stress test the duration for each lesson and establish the boundaries of complexity (scaffolding) for the lesson plans and determine which application was most aligned to the needs of students.
- To gather feedback from tutors and students to refine the lesson plans and set out the milestones to be achieved in the classes that followed.
- To refine the data collection methods and inform the discussion for the focus groups.

The purpose of the pilot study was to critique the lesson plans and review the design process identifying areas for clarification prior to implementation.

3.5.3 Implementation

The implementation of the design was carried out on a phased basis, following the action research lifecycle. In the first phase, 2 pilots were conducted to refine the lesson plans. An evaluation of the teaching facilities took place prior to the investigation. Both colleges had computer facilities in place and the BioDigital software was compatible with the web browsers and hardware available in both locations. At the point of introducing computer simulation, students completed approx. 100 hours of the curriculum delivered through didactic teaching methods. Thus, students had developed a foundation of underpinning knowledge of the Anatomy and Physiology curriculum. During each class student activities were observed by the course tutor as well as the researcher and a formative assessment rubric was used to capture the behaviour of students when conducting the exercises. At the end of the final lesson students were given a TLX cognitive load test and asked to reflect on the portfolio exercise when completing the test.

3.5.4 Evaluate

The evaluation process of the design was conducted during the pilot phase. Feedback was gathered from students and tutors during the pilot based on extrinsic themes. Other methods used in the design evaluation were class observations, data logs that monitored engagement, and analysis to the literature. A survey instrument was derived from the ECAR Study of Undergraduate Students and Information Technology (Brooks, 2016). This instrument consisted of two sections. Section 1 consisted of 20 questions on a Likert scale. Section 2 consisted of 7 questions in open ended descriptive form that asked about specific details of the learning experience and the strengths and weaknesses of using computer simulation to learn about Anatomy and Physiology.

3.6 Participants

The participants in this study were recruited from the Sports Therapy class in a College of Further Education and an Education and Training Board (ETB) Training Centre. The class size in both colleges was 15 students, and participants were adult students (over 18 yrs) who were undertaking one of the aforementioned courses, and who agreed to volunteer as a participant in the project. The main issues identified by tutors relate to the complexity of various systems within the human body and information being abstract. FET students are often out of education for several years or they may not be academically inclined. These factors lead to students feeling overwhelmed by the volume of material on the syllabus and they find the complex curriculum confusing. (Community College Research Center, 2014). The current teaching approach is quite disjointed from the other practical sessions on the courses, and students struggle to adapt to the change in lesson delivery. These issues are leading to poor learner engagement and non-completions (Those achieving full certification). The sample groups had varying levels of qualifications and experience. Students were actively involved in the learning activities as part of their regular curriculum hours.

3.7 Ethical Considerations

Ethical considerations limited the study in some ways as the class were working through certified course which limited the time available in which to carry out the research. Prior to commencement of the research, consent was granted from the Board of Management in each college. Consent and information forms were also circulated to all teaching staff involved in the study and signed sheets were collected. Students were informed about the project at a presentation by the researcher in class, the researcher explained the purpose and the use of data collected in the project. Students were also given information forms detailing the purpose of the study prior to signing consent forms. Electronic audio was used to record the responses from the participants in the focus group discussion and the teacher interviews. Throughout the surveys / focus group sessions participants were offered the opportunity to refuse to answer any questions if they wished to do so. Ethical approval for this project was granted by Trinity College Dublin Ethics Board. The Information Sheets and Consent Forms for the board of management, Students and Teachers are available to view (Appendix. M).

3.8 Summary

This chapter has described the design process drawing from the literature. The ADDIE instructional design model was used to develop the learning experience. The implementation of the simulated learning activities was then described as a method of addressing the learning difficulties identified in the literature review. The task load index test was then outlined as an instrument to measure cognitive load in students. The evaluation process of this design lifecycle was then outlined detailing how extrinsic methods were used to implement design principles which aimed to address learner’s needs. The aim of the research is to examine how computer simulation can impact on the cognitive load of students and the effects on conceptualising complex systems in the human body. The next chapter will describe the research methodology and the data collection process for the study.

Chapter 4: Research Methodology

4.1 Introduction

A mixed methods approach was chosen for this investigation; studies were carried out on a series of computer simulation lessons that were designed to engage students to conduct various investigations on human anatomy using the BioDigital simulation software. Observations of the classes were recorded using a formative assessment rubric and a focus group was conducted with each group at the end of the lessons. Post-activity questionnaires were also given to students and teacher interviews were conducted to measure the impact of the lessons. This chapter will now discuss the methodology in further detail, outlining the advantages and disadvantages of each approach and the data collection and analysis that took place.

4.2 Research Question

The research questions focus on the on the effects of using simulation software in the teaching and learning of complex abstract information, in particular Anatomy and Physiology for adult students engaged in further education and training courses.

This topic is broken down into a series of sub questions:

- How can computer simulation address the difficulties associated with learning complex information?
- How effective is computer simulation in learning biological concepts which cannot be seen by the naked eye?
- What features of computer simulation best facilitate the comprehension and application of abstract knowledge?

4.3 Setting & Time

The study was conducted in two separate colleges of further education to improve the validity and reliability of data. Lessons were delivered in classrooms with appropriate IT equipment to run the computer simulation apps. Each class consisted of 15 students and there were 5 lessons delivered in each college over a 7-week period. Each lesson was approximately 2 hours in duration and the first lesson took place on Tuesday 28th February 2017, and the final lesson was concluded on Monday 10th April 2017. Each student had the use of an individual computer and screens were no smaller than 19'. The rooms also had interactive whiteboards and audio equipment that was used to instruct students on the use of the app and the features/resources available. Students were given login details of the BioDigital software during the first lesson where they could engage in learning on their own time.

4.4 Pilot Investigation

Two pilot investigations were conducted to identify areas of improvement and to identify possible difficulties the students may encounter before the lesson plan was implemented. This process helped to determine the threshold of the lesson plans and to stress test the duration and boundaries of complexity for each group. The pilots were conducted in each location to determine the compatibility of the simulation software with the computer hardware available. System compatibility tests were also conducted to establish the network speed to determine the load time of each 3D VLE on each computer. Early feedback from tutors and students helped to refine the lesson plans and set out pace of the lessons and the milestones to be achieved over the weeks that followed. Some technical issues were also identified with such as the availability of headphones for the students, login details for the students and set-up times. The process of getting the demonstration PC to play audio on the classroom speaker system was also addressed during the pilot sessions. The difficulties which were highlighted during the pilot test phase were rectified prior to the data collection phase. The main logic for using action research methods was to develop converging lines of enquiry from different data sets to produce a quality formative evaluation that would lead to a more robust learning experience.

4.5 Research design model

Data was collected over a series of 5 lessons with 2 groups over a 7-week period. The data was in both structured and unstructured form and a series of coding exercises was carried out to prepare the data for analysis. The research model was broken down into specific domains to ensure the data addressed the research questions and each stage was informed by outputs from prior stages. The methodology followed action research techniques where an iterative process of investigation occurred and action was taken to solve a problem (Mills, 2000). Without a control group, the construct validity was strengthened through multiple converging lines of enquiry. Student engagement was captured using a formative assessment guideline FAST SCASS (Heritage, 2012). After the pilot stages, a series of computer simulation lessons were conducted and the researcher observed learner activities and recorded the data using a formative assessment rubric (see Appendix F). On the final lesson, a focus group lead by the researcher was conducted with each class. A TLX cognitive load test was also given during the final lesson to students who participated in the study. This test provided a dataset that measured cognitive load categorised under several sub headings (see Appendix N). A post-lesson survey was also given to students, which gave significant qualitative information that identified various strengths and weaknesses of computer simulation. Teacher interviews were also conducted after the lessons which gave insights into the timing of the lessons and suggestions on the implementation of computer simulation on future courses.

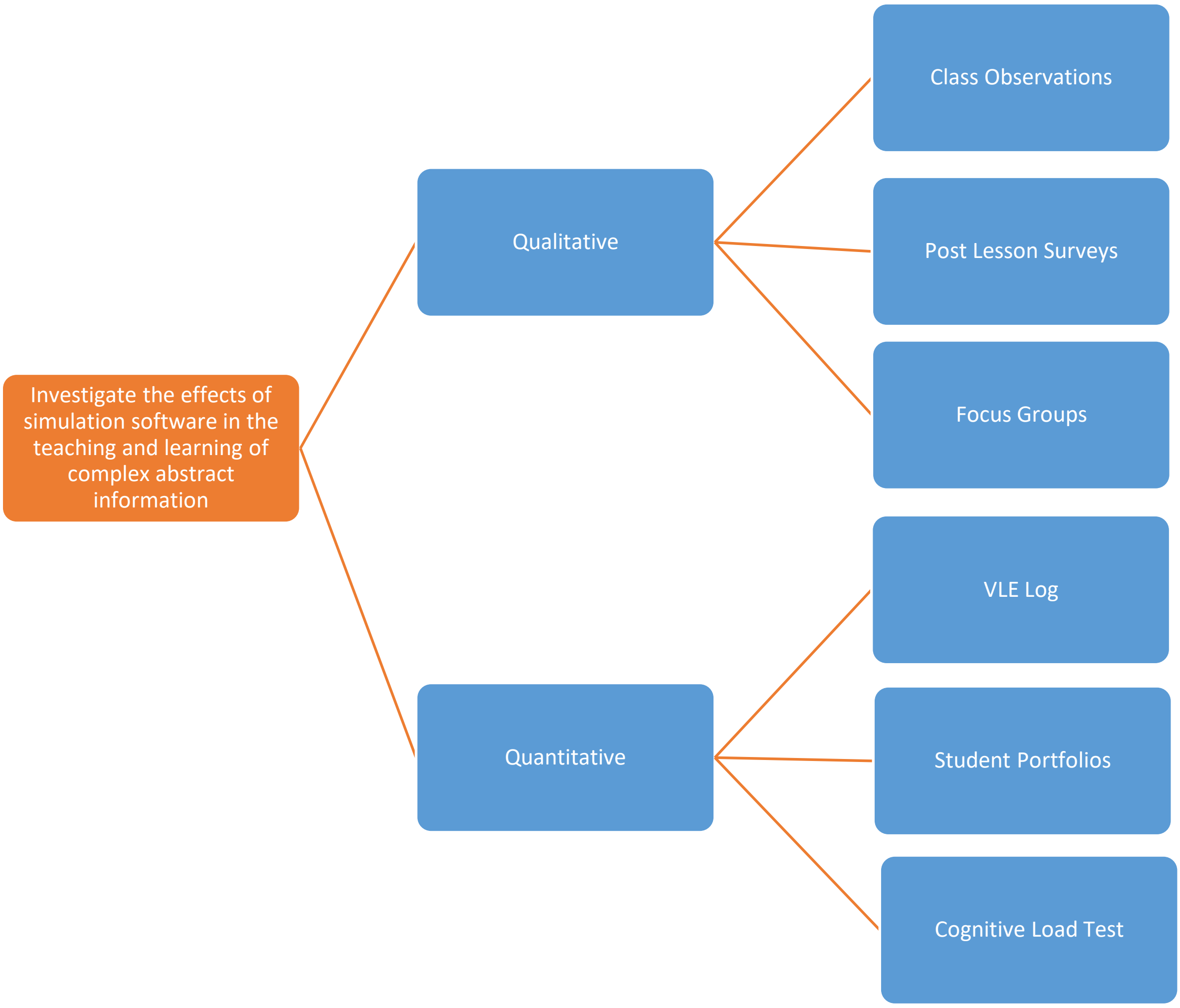

Figure 4-1 Research Design Model

A detailed breakdown of the research activities is listed below:

- Classes were tutor-lead, the researcher observed and recorded the sessions providing technical assistance when required.
- Students created portfolios of work using computer simulation software.
- Post lesson student survey- This survey was derived from the 2016 ECAR student study, (Brooks, 2016).
- At the end of a series of lessons a focus group lead by the researcher was conducted. These focus group sessions were semi-structured discussions around the effectiveness of computer simulation on addressing the difficulties (topics) identified.
- Cognitive load testing was conducted on students using the NASA Task Load Index instrument (Nasa, 2010).
- One-to-one interviews with tutors also took place after the final lesson.

4.6 Collection of Data: Qualitative and Quantitative Methods

A description of the data in each of the fields is shown in table 4-1 below.

Instrument	Data Sets	Purpose
Activity reports from VLE	Reports on the content that was viewed in each class and time spent working on portfolio.	Measure of behavioural responses to using simulation software and indicators of motivation and engagement.
Class Observations	Discussions with students during class activities, researcher's notes recorded in formative assessment rubric.	Qualitative evidence to validate and triangulate data.
Student Portfolios	A series of models taken by students that reflect the learning experience.	To collect evidence of concepts that students identified as having effect on their knowledge formation. Portfolio images display the visual impact of the software on students.
Focus groups	Transcript of focus group discussion (Audio recording) and coding of topics covered.	Qualitative data to confirm findings and determine the strengths and weaknesses of simulation software for learning complex information. Subjective opinions of the used students to address the research question.
Post lesson survey	Responses students measured using a likert scale and open ended survey questions.	Measures learner interest and enjoyment, perceived competence, strengths and weaknesses of simulation. Qualitative evidence to strengthen integrity of data.
Cognitive load test	TLX test Scores	Measures cognitive load index
Teacher interviews	Informal interviews with teaching staff who deliver A&P to the sample groups.	Teaching perspective on computer simulation. Qualitative evidence to strengthen integrity of data.

Table 4-1 Data Collection Methods

All data was anonymised and treated using the qualitative techniques. All data collected was stored on an encrypted and password protected USB device throughout the learning experience to insure confidentiality.

4.6.1 Class Observations

Classroom observations were carried out by both the teacher and the researcher, the observer in each instance was the non-participatory party in the class. Having delivered 10 weeks of classes to students prior to the simulation lessons the course teacher could quickly identify any unusual reactions from the students while using the software. Video recordings were not used in this research instead classroom observations were carried out taking notes during the sessions. After each class, the researcher populated the formative assessment rubric based on the notes accumulated in class. Appendix F details a populated formative assessment rubric. The main advantages and disadvantages of classroom observation are detailed below.

The advantages of classroom observations:	The disadvantages of classroom observations
• A detailed account of classroom activity • Greater insight into student activities and the context of the phenomenon • Can capture what people do as opposed to what they say they do • Allows the researcher to record information pertinent to their research questions • Combined with VLE records to strengthen the integrity of the data	• There is a possibility of bias from the recordings as information is recorded in a subjective manner. • A conflict in recording or distraction if the researcher is engaged in classroom activities • There can be an impact on results in the presence of an observer.

The advantages of classroom observations:

To overcome the disadvantages, both researcher and teacher combined notes and had open discussions at the end of each class in order to reflect on the outcomes and accurately record the classroom observations.

4.6.2 Activity reports from VLE

Students were logged on their activities with the VLE and the quizzes they took were measured and later analysed for the research. The VLE generated reports for each class, the information on these reports was limited, participant engagement with learning activities were measured by the time spent on each activity. This was coupled with the observational data to inform conclusions and address the research question. A sample activity log is shown in Appendix G.

The main advantages of a VLE logs	The drawbacks of a VLE logs
• Measure learner activity to inform lesson design • Non-invasive methods of measuring learner activities • Can record a multitude of activities simultaneously and produce quantitative data sets	• Does not connect with students lacks the depth of observational data. • 'Activity' does not translate into understanding or learning • Validity of data – login details can be shared no way of telling (without using biometrics) who logged the data outside the classroom.

4.6.3 Student portfolios

Throughout the series of classes students produced various models captured from the BioDigital VLE. These models were from the learner investigations and were saved under the student profile on the BioDigital app. The artefacts are a very rich source of data which were examined by the researcher to measure the level of competence demonstrated by students in using the Biodigital application. This evidence informed the response to the research question. This task was given to identify the features of computer simulation which enables students experience greater interaction and engagement with complex biological systems. The portfolio was unique to each learner as the images and videos taken were specific perspectives or angles of the 3D models that captured their concept of new information. Extracts from students portfolios are provided (see Appendix L).

The main advantages of a portfolio	The drawbacks of a portfolio
• Individualised artefacts that represent students work • Portfolios promote student communication during classroom sessions • Offers students the opportunity to showcase their achievements • Measures a wide range of skills	• Time consuming to complete and may distract students from other areas of study • Difficult to grade/mark • Validity of work outside of class time

4.6.4 Post-lesson survey

A post-lesson survey derived from the ECAR Study of Undergraduate Students and Information Technology (Brooks, 2016). This was given to students at the end of the last lesson in order to evaluate the perception of computer simulation and identify the effects simulation had on learning Anatomy and Physiology. Questions were developed and phrased in language that was familiar to the audience and the number of questions was kept under 25. The survey was designed in 2 parts. Part 1 consisted of 20 questions on a Likert scale. The range of the scale was from Strongly Disagree up to Strongly Agree (see Appendix H). Part 2 consisted of 7 questions in open-ended descriptive form that asked about specific details of the learning experience and the strengths and weaknesses of using computer simulation to learn about Anatomy and Physiology. Once complete, the results of both surveys were recorded by the researcher and transferred into a spreadsheet for analysis. Assistance was given by the course tutor on each class to validate data captured from each questionnaire to that in the spreadsheet.

The main advantages of a post-lesson survey	The drawbacks of a post-lesson survey
• Practical, cost effective solution to gathering information from students. • Allows information to be gathered from large groups efficiently • Students can remain anonymous and without pressure (unlike interview)	• Misleading/dishonest information provided by respondents who may have hidden agenda • Students may misinterpret the questions • Clinical approach – lack of personalisation

4.6.5 Focus Groups

At the end of the final class each group was asked to participate in a semi structured focus group interview that was conducted by the researcher. These sessions were held in the classroom and were 20-30 mins in duration. Each focus group was recorded by the researcher and the group were made aware of the audio recording, the transcript was stored on a password protected device. The themes for the focus group were derived from the research questions and the transcript from the recordings was coded to formulate analysis. A detailed list of questions asked on the focus group can be found in Appendix J. The purpose of the focus groups was to triangulate data and receive detailed information from the students on the learning experience that was not captured from the post lesson surveys. Prior to holding the focus group the formative assessment logs were also analysed to identify potential gaps in the data that could be achieved through focus group topics. One of the aims set out on the focus group sessions was to assess whether the participants felt that the instructional design elements of computer simulation addressed the difficulties they faced in learning.

The main advantages of a focus group	The drawbacks of using focus groups
• Minimal cost to implement • Short time-frame involved • Rich dataset of detailed information • Allows for a range of topics to be covered in a single event with multiple users	• Results can be influenced by dominant participants • Participants may not be representative of population • The group dynamics can be an issue as class norms may exist.

In this instance the focus groups provided rich qualitative feedback that informed the research and provided evidence to strengthen integrity of data. Both directed coding and open coding were used (Saldana, 2012). A transcript sample of the coding can be seen in Appendix K.

4.6.6 Teacher interviews

Post lesson informal interviews with teachers to get insights into the best method of implementing simulation technology for A&P teaching. Teaching insights on computer simulation was used to support the integrity of the data.

The main advantages of a teacher interview	The drawbacks of a teacher interview
• Good personal contact and level of understanding • Can elicit opinions that may not be appropriate in a group setting • High level of detail/honesty • Questions can be planned in advance	• Time consuming and can be inefficient • Arability of the teacher to conduct the interview • Anonymity of the interviewee

4.6.7 Cognitive load test

The NASA TLX test (Nasa, 2010) was given to students in the final class to measure the cognitive load index. Students were instructed to reflect on the portfolio task in answering the questions posed in the test. The results of the tests were measured against typical TLX scores using the scoring matrix provided on the NASA website. This information was used as a proxy for investigating the nature of the workload imposed by the task.

The main advantages of a TLX test	The drawbacks of a TLX test
• Quick and easy method of estimating workload on the working memory of the end user • Used to inform instructional design and improve VLE • Benefits designers and end users	• Post hoc measurement – the measure is after the event relying on the learner to reflect their practice • Subjective ratings of the learner – a heightened sense of self awareness is often required to carry out the test effectively • Sub-scale ratings could be repetitive

4.7 Data Reliability and Validity

The reliability and validity of data from this study was ensured by the triangulation of convergent data collected from a variety of sources. In this context, a process whereby the results of one research instrument were compared against the results from another instrument. This process improves data validation and helps explain the complexities of human behaviour. This strategy of using two or more research instruments was increased the overall reliability and validity of the data.

4.8 Data Analysis

Various approaches were taken to analyse the data taken from various perspectives to ensure a complete book of evidence was formed to address the research question.

Quantitative data

- VLE logs – Logs of student activity using the BioDigital software was recorded to measure engagement and evaluate the duration it took students to carry out the activities.
- Student portfolios – Student portfolios were studied to determine the evidence of concepts that students identified as having effect on their knowledge formation. Portfolio models display the visual impact of the software on students.
- Cognitive load test – TLX scores were analysed to establish the cognitive load scores and get a breakdown of the workload index for each learner.

Qualitative data

- Classroom observations – Both the researcher and teacher took observational notes for each TEL class. The main purpose was to monitor and record the levels of engagement and identify the strengths and weaknesses of the technology. At the end of the study the classroom observations were compared to the post lesson feedback surveys as a method of ensuring the validity of the data.
- Post-lesson surveys – The post-lesson survey was used to gather information on learner’s attitudes, engagement and educational experiences, the survey also collected information on a range of objective and subjective outcomes. This data was used to investigate the specific effects of using simulation

software in the teaching and learning of Anatomy and Physiology. Questions also asked students to identify the features of computer simulation that best facilitated the comprehension and application of abstract knowledge.

- Focus groups - Both focus groups were conducted on the last lesson of each group with over 40 minutes of discussion recorded. The transcripts of the focus groups were hand coded using open and directed coding. The open coding drew themes from the transcripts, 6 categories emerged from the directed coding.
- Teacher interviews – The purpose of the teacher interviews was to capture deeper insights into student behaviour and behavioural changes within each group. The teachers could give perspectives from the class based on their experience with each group. This information was used to measure the effects of the lessons and identify specific teaching methods that could be used in conjunction with the software.

The final phase of the data analysis involved investigating correlations between the quantitative and qualitative data. This was carried out to triangulate findings and to ensure the validity of data and identify areas for future research.

4.9 Researcher Bias

In order to conduct this research, the researcher operated in an FET College and an ETB (Education and Training Board) Training Centre. The researcher is employed (circa 2006) by SOLAS the Further Education and Training (FET) authority of Ireland. The area of simulation is of personal interest and the researcher is an advocate of the use of technology in learning.

4.10 Summary

This chapter detailed the research methods used and data collection instruments implemented to address the research question in this study. The qualitative and quantitative data collection methods were also discussed and the rationale was outlined for this approach. The next chapter will present and discuss the analysis of each data set in the context of addressing the research question.

Chapter 5: Findings and Discussion

5.1 Introduction

This chapter presents the findings of the research methods outlined in the previous chapter. The analysis of the observational data is first discussed, and extracts from the formative assessment rubric are then presented. The chapter goes on to discuss student portfolios and the cognitive load test scores. The post-lesson survey is then presented. The chapter then examine the results from the focus groups, showing samples of open and directed coding of transcripts and the findings are discussed. The next section discusses the teacher interviews and unexpected findings. The chapter concludes by highlighting limitations of this study, and possible areas of future research.

5.2 Class Observations

The researcher observed two tutor lead classes prior to the simulation pilot sessions (See Appendix F). This was carried out to determine the teaching methods, resources used and to observe the class dynamics. The TEL observations were carried out by both the researcher and the tutor on each course. From the outset students appeared engaged and excited to use the simulation technology in class. Several students in both groups had never undertaken an E-Learning lesson before. Every student had a basic knowledge of I.T, and was engaged in web activities on a frequent basis. Once students had developed a basic competency in using the Biodigital application the engagement levels rose. For the most part the learning was self-directed with tutor guidance, and at various times throughout the classes, students would comment on the effectiveness of the simulation for learning. From the start students were focused on creating their portfolios and were sending each other links (share feature in the app) to models they had created. There were occasions where some students appeared distracted and were browsing irrelevant websites, playing games and watching peripheral YouTube videos. These distractions were a consequence of the learning environment and reflected the inexperience of students or lack of motivation to engage in self-directed learning. There were also observations of collaborative learning taking place. Some students were asking their peers for opinion and advice as they were putting together their portfolios. On several occasions students were sharing their portfolio images with each other using the share tool in the BioDigital interface. In one of the groups, a competitive atmosphere was evident near the end as students became more proficient in using the software and exploring the advanced features. When presenting the portfolios students were articulating the details about the models they created and the class were engaged in asking questions and sharing experiences during the intervals.

From observing both groups, it was evident that there were higher levels of engagement in the classes which used the simulation technology. There are several suggested reasons for this detailed below:

- Simulation technology is conducive to learning the A&P syllabus by means of interaction and feedback.
- These learning activities enabled more dynamic collaborative work among students
- Classes were less structured and the open to self-directed learning.
- Students could construct models which developed skills and deeper understanding through enquiry based learning and the application of knowledge.
- Students showed more signs of excitement and motivation to learn during the computer simulation classes.
- Students were more confident about speaking to the class about their models, and how they related to the syllabus and what they learned from the activity.

It was clear from the observational evidence that computer simulation was of benefit in the learning of Anatomy and Physiology among adult learners in FET. In general, the responses from students was very positive and there appeared to be a consensus among the group that computer simulation gave a greater perspective on human Anatomy and Physiology.

5.3 VLE activity

Logs of student activity using the Biodigital software were recorded to measure engagement and evaluate the duration it took learners to carry out the activities. In both instances, these VLE logs were limited as the systems were not designed to monitor user activity in detail. Web browser logs were used to identify the Biodigital web pages each learner visited and the duration spent on each page. Specific mouse clicks or key inputs were not recorded but the individual artefacts which students created were stored under the user profile. In general, most students produced 2-3 models varying in detail from highly descriptive notes to basic views of anatomy from a specific perspective. There were also internet logs for email and gaming websites from a minority of students, these sites were outside of the prescribed list and were evidence of the distractive environmental factors with on line learning. These issues were minimal and no major time was logged in these domains. The log times showed the average time spent for each student constructing the portfolio was between 2-3 hours. 3 of the students were recorded as saving models outside of class time but most students worked on the software during the scheduled class hours. An extract from a student's VLE log is available in Appendix G.

5.4 Student Portfolios

Student portfolios were examined to determine the models which learners identified as influencing their knowledge formation. Portfolio images displayed the visual impact and perceptions of the software on learners. In every case students took discrete views and angles of models they had created for their own reference. There was quite a variance in the systems chosen. For example, the sports therapy students tended to have more examples of musculoskeletal systems as this featured a lot in their syllabus. The cardiovascular system was another system which many students chose to investigate. There were also examples of dissections, cross sections and exploded organs in many of the portfolios which demonstrated advanced levels of interaction and exploratory learning activities. When presenting the portfolios, students were confident and descriptive in the details of their work. They articulated the anatomical terms and systems to the class demonstrating knowledge, application and understanding. At the end of the classes many students were printing off the models to add to their notes. In most cases students had their own labels or notes detailed on the models for further reference. (See Appendix L)

5.5 TLX Cognitive load test scores

The cognitive load test results are broken down into six subscales. The details on the results for each category are listed below:

- Mental Demand - The average score across both groups was 50.1%, the highest score recorded was 81% and there were 3 students who scored this between 60-65%. These scores indicate that there was quite a high perceived mental effort in using the BioDigital application to create portfolios.
- Physical Demand - The average score across both groups was 25.8%, this score indicates that the physical demand was not very strenuous on learners.
- Temporal Demand - The average score across both groups was 41.7%, this indicates that students were not under any pressure to carry out the investigations. Due to the voluntary nature of this study, students were not subjected to stringent deadlines on their work. The portfolios were not graded or had no bearing on the overall marks. For this reason, students were not under any pressure to complete tasks.
- Overall Performance - The average score across both groups was 37.9%. This result indicates that students did not complete the lesson plans as anticipated. There were 6 students who scored this below 20% which may indicate motivational issues or satisfactory ratings of their own work at the end compared to that of others.
- Frustration Level - The average score across both groups was 42%, the mode score on this rating was 37% however 2 students had a score of 88%. This indicates that while most students were complacent, a small minority of students were stressed or annoyed in carrying out the activity.
- Effort - The average score across both groups was 54.2%, this was an unexpected result considering the physical scores however students may have a preconceived idea of performance, and this may have set ambitions targets among the groups. With that said, it appears the task was challenging but not overwhelming for learners to achieve expected outcomes.

The overall TLX score average was 46.5% among the group. The mode score was 38% indicating that the burden on working memory was below 50%. In isolation, this score is quite subjective, however the breakdown gives interesting insights on the perceptions of learners. The full table of results from the TLX tests can be seen in Appendix N.

5.6 Post lesson learner survey

A post lesson survey instrument was used to capture learner's feedback and opinions of the computer simulation lessons. Learners were given 10 mins at the end of the final class to complete the survey. 21 of the questions were in Likert scale format and the remaining 7 questions were descriptive open -ended questions. In addition to a range of questions designed to capture information on learner's attitudes, engagement and educational experiences, the survey also collected information on a range of objective and subjective outcomes.

Objective outcomes

Objective outcomes included details around making connections with previous knowledge and levels of understanding, number of tasks completed and overall ratings. Table 5-1 outlines the objective responses from the survey.

	Don't know	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Technology helped me engage in the learning process	13%			29%	58%	
Technology helped me investigate topics outside class time	7%		11%	32%	36%	14%
Technology helped me reflect on course materials (e.g., readings, videos, etc.)				30%	57%	13%
Technology used in my class enriched my learning experiences	12%			25%	46%	17%

Table 5-1 Objective Responses

It was clear from the responses that the simulation software improved learner engagement levels and lead to a more enriched learning experience. The strongest objective outcome reported was in learner reflection with over 70% of learners agreeing that the software helped in this regard. There was a wide disparity in responses to using the simulation technology outside class time. 50% of learners felt the technology helped them to work in their own time. This evidence suggests that not all students were enthusiastic about engaging in the software outside of class time. Even though every student said they access the web daily in the pre-survey, they did not choose to access the Biodigital software. There were more positive responses on the worked examples, when asked in what way did the videos help to gain a clearer understanding students responded by saying; *'I found it useful it was like a manual to instruct step by step'* and *"Excellent very informative showed in depth how human body works"*. Others said *'I could see how to use it better'* and *'There were lots of different examples to see and this gave me ideas for my* portfolio'. Other students explained: 'I don't use technology much but I liked the videos, it showed me the various systems in the body' and 'I *was able to view extra features which I wouldn't have found out on my own*'. Worked examples are known to reduce cognitive load this was evident from one student's comment "*I could just watch the videos instead of using the app to understand the A&P systems*".

Subjective outcomes

Subjective outcomes included how leavers reflected on their educational experience, the attitudes to learning, their satisfaction with using the application, and areas for improvement. Table 5-2 details responses to subjective questions on the post survey.

	Don't know	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Technology helped me conduct research for class assignments				27%	68%	5%
Technology helped me document class work or projects		8%	8%	46%	43%	4%
Technology helped me examine human anatomy in greater detail				14%	68%	18%
Technology helped me learn through interactive activities				22%	52%	26%
Technology helped me get a clearer image of organs and systems in the human body.				35%	65%	
Technology used in my class was relevant to my achievement of course learning objectives			12%	46%	42%	
Technology used in my class connected course materials and real world experiences	8%			25%	50%	17%
Technology used in my class helped me understand fundamental concepts				41%	42%	17%
Technology used in my class built relevant skills that were useful in the workplace	8%		8%	17%	67%	
Technology used in my class helped make connections to knowledge obtained in other classes			16%	17%	67%	
Technology used in my class helped me understand hard-to-grasp concepts or processes			9%	27%	55%	9%
Technology used in my class was appropriate to the content being delivered			8%	23%	69%	
Technology used in my class helped me think critically	8%		8%	17%	67%	
Technology used in my class helped me focus on learning activities or course materials			16%	17%	67%	

Table 5-2 Responses to Subjective Questions

In general, the subjective responses were very positive; over 85% of students felt the application helped them to examine human anatomy in greater detail. 65% said simulation gave them a clearer image of organs and systems in the human body. 64% agreed that the software to understand hard-to-grasp concepts or processes, and 67% felt it helped to focus on learning activities. Most learners felt simulation technology helped to build new knowledge based on previous learning. This is another point of evidence in the concept formation and many learners felt they made connections with previous information. It also appeared from the responses that computer simulation encourages critical thinking, with over 80% of responses claiming the technology helped in critical thinking. This is an important attribute in the comprehension and application of knowledge. Most learners felt the technology was appropriate to the content they were studying. Over 65% of learners felt the simulation classes enabled the application of knowledge in workplace activities. Almost 60% of learners agreed that the simulation technology helped them to understand fundamental A&P concepts, however over 40% felt neutral on the matter. This was an interesting finding as underpinning knowledge is a prerequisite to exploit the potential of the technology for advanced learning (Wang1 & Cranton, 2013). Although more than half of learners reported the computer simulation helped them focus on learning activities, there was a minority which expressed disagreement or neutral opinion. This may have been down to the interpretation of the question or the technology having a negative effect on the learning. More than 65% of learners felt the simulation technology connected course material and real world experiences, and this is an important factor in the application of knowledge.

Students reported feeling more engaged and claiming to have developed a better understanding than didactic classroom teaching. When asked how effective they felt simulation was as a method of learning students said it was *'Very effective as it brings a method of dissecting human body and how systems connect'* and *'It helped me understand by seeing the models and being able to click on them for information'.* Others mentioned how they got more enjoyment and pleasure from the experience *'More interesting and fun', 'I found it interesting and a change from normal classes' and 'It was much better than the book'.* One student joked about how it *'Brings the book to life!'* It wasn't all fun and games though, some students had genuine concerns on the use of I.T for learning saying *'It's good if you know how to use it or get help from others, it's too much for me on my own'* and *'It would be good for people who are computer savvy'.*

Learners were asked about the strengths of computer simulation in the teaching of Anatomy and Physiology and they responded saying; *'It's interactive and better to see a 3D version'* and *'The visual effects were excellent for learning'.* The visual aspect was a key attribute for a lot of learners with others saying; 'The 3D models can be split apart and you can see more detail' and *'Seeing the 3D model and each section in detail this I wouldn't get from the book.'* Others commented on the visual perspectives; *'Seeing different angles of the body on the BioDigital website'* and *'I can see more up close and deeper than the book'.* Personalisation and reflection were also mentioned by some of the students; *'Being able to see the systems we have been talking about in class'* and *'Interactive to use, clearer images, pathology notes, I liked how I could add my own notes into the models and see different systems at the same time'*

When asked how the learning could be improved, learners commented on the timing of the lesson saying; '*If the classes were done at different times in the year not at the end'* and 'Start at the beginning of the course and it would work really well'. Others felt some of the descriptions and questions in the quiz were too advanced; *'The quiz questions were too hard and not related to our exam'* and *'The descriptions are too complicated'.* One learner had feedback on the instructional design saying 'If it had a way to activate the muscles when you clicked on them to watch how they move.' Another student explained how it could be used to incorporate more into the curriculum saying *'If we could do assignments using the BioDigital app'.* A full breakdown of the post learner survey including responses can be found in Appendix H.

5.6 Focus group interview

The transcripts from the focus groups were coded using directed coding (seeking examples from predetermined themes) and open coding (no preconceptions). In the first instance the categories for the directed coding process were set out as follows:

- ➢ The features of computer simulation
- ➢ How effective is computer simulation in learning complex and abstract information.
- ➢ The perceptions with regards to ease of use.

These categories were broken into themes, for example under the category of 'Ease of use' the themes used were; design, navigation, intuition. A breakdown of the categories and themes are listed in table 5-3, codes were assigned based on positive and negative scale.

Category	**Theme**	**Code Positive/Negative**
Features of computer simulation	• Interactivity • Collaboration • Creating models • Personalisation	A1δ / A1δ– A2δ / A2δ– A3δ / A3δ– A4δ / A4δ–
Effectiveness of computer simulation	• Visual Perception • Timing of lesson • Engagement • Cognition	B1δ / B1δ– B2δ / B2δ– B3δ / B3δ– B4δ / B4δ–
Ease of use	• Design • Navigation • Intuition • Experience	C1δ / C1δ– C2δ / C2δ– C3δ/ C3δ– C4δ / C4δ–

Table 5-3 Directed Coding Themes

Hardcopies of the focus group transcripts were used for the directed coding. A coded extract from of one of the focus group transcripts is listed in Appendix K. Once coded frequencys were then recorded into table 5.4 below.

Category	Code	Frequency
Features of computer simulation	A1δ	32
	A1δ–	0
	A2δ	5
	A2δ–	0
	A3δ	12
	A3δ–	0
	A4δ	9
	A4δ–	0
Effectiveness of computer simulation	B1δ	41
	B1δ-	0
	B2δ	6
	B2δ-	12
	B3δ	26

	B3δ- B4δ B4δ-	0 17 5
Ease of use	C1δ C1δ- C2δ C2δ- C3δ C3δ- C4δ C4δ-	26 2 6 1 14 0 33 4

Table 5-4 Directed Coding Frequencies

It is clear from the results that there was very positive feedback overall from the groups. The effectiveness category B1-4δ was the most topical, with the highest frequency being the positive visual impact of simulation on the learning experience and the engagement attributes of the application. With that said, there were some negative comments about the timing of the lesson B2δ- and the cognition factors B4δ- from some learners. Another topical category in the focus groups was the positive opinions on the interactive nature of the software and the capacity to create individualised models which could be saved for reference. There were no negative comments about the features of the application but not everyone explored the full capacity of the features available, as just 5 comments were made about the collaborative features. The ease of use category also scored well with 33 positive comments on the learning experience C4δ-, and the enjoyment learners got from using the software. It appeared that the intuitive design C1δ was enjoyed by most and the BioDigital application was easy to use and navigate the various systems in the body.

The second phase of coding was carried out using open coding techniques. This iterative process involved grouping keywords which relate to an emerging theme from group conversation. This was done by firstly reading the transcripts to identify a series of keywords. This was followed by conducting a word search on the transcripts in Microsoft word, and recording the frequency of each keyword. The table below shows the frequencies of occurrence of the top 15 keywords from the open coding process.

Keyword	Frequency
Book	11
Difficult	10
Learn	16
Models	15
Systems	10
Seeing	19
Dissect	12

Activities	11
Helped/helpful	15
Groups	9
Fun	7
Like	17
Enjoy	12
Doing	15
Interaction	11

Table 5-5 Open Coding Results

From the open coding process, new convergent themes emerged. Student's personal experiences were more explicit in the open coding, and statements such as 'I found it enjoyable.' and 'It was fun' and 'I liked how it was different from class' were considered positive experiences from the activity. Another theme which emerged was the interest in 'doing', comments such as 'It was helpful to be able to carry out the dissections' and 'The interactive activities were better than going through the book'. The visual aspect of the experience was also very prevalent as the word 'seeing' was counted 19 times from the transcripts. Students also commented on the engaging learning experience and how the models helped them to visualise the constructs more than in the books.

5.8 Teacher interview

The teacher interviews gave deeper insights into student behaviour, as both teachers had experience with the students and an awareness of the class dynamics. There were some instances where the teacher observed high order thought processes from questions they asked students during the simulation classes. Other insights from the teacher included instances where students worked in pairs in peer-to-peer learning. This was not as prevalent in the didactic classroom setting. In one of the classes when students were presenting their portfolios, the teacher commented on the articulation of the students in naming the parts of the model and the confidence the activity inspired in the students. In both instances the teachers explained the constraints of using technology in the classroom, the availability of suitable classrooms and contact hours with students would limit the capacity to deliver workshops using simulation software. One of the tutors suggested an incremental approach to use BioDigital in class at various stages throughout the course. Another suggestion was to develop assignments for students to investigate topics using the Biodigital application. A point was made about the quiz feature in BioDigital being useful to engage learners to test their knowledge, however it was pointed out that the questions would need to be more aligned to the level of the ITEC assessments.

5.9 Relevance of the findings in relation to the research questions.

The investigation identified various attributes of computer simulation which are relevant to the research questions. The following discussion will be framed around each of the research questions:

- How can computer simulation address the difficulties associated with learning complex information?
  Student feedback during classroom observations showed signs of cognitive dissonance (Cooper, 2012) and reduced cognitive load. Also from comments in the post lesson survey, students described how they "dissected organs of the body that I didn't know in detail". Students also found the worked examples of benefit with comments like "I like the step by step approach showing how to use the application". The cognitive load testing was used as a proxy to evaluate the effectiveness of instructional design and the capacity of working memory among students. The TLX cognitive load test scores showed a range of scores across 6 categories. The test results showed the effects of simulation on working memory and the workload imposed on students by the tasks. The results revealed the mental effort was involving for most learners but not to a point where it inhibited student's capacity to comprehend information. The fact that students had access to worked examples may have been a factor in this outcome. Student feedback also supported the use of simulation for improved concept assimilation in the learning of abstract information, this was found to be consistent with the literature (Issenberg et al., 1999). Comments around the visualisation of complex organs giving greater perspective than the books showed students felt the detailed 3D images improved the concept formation and assimilation of human anatomy. The variance on perspectives and rotational features in the 3D environment gave a greater depth of visual perspective than static 2D images on a page.

- How effective is computer simulation in learning biological concepts which cannot be seen by the naked eye?
  The overall findings support the use of computer simulation in clarifying understanding of Anatomy and Physiology curriculum while increasing student interest and engagement. The reports from VLE show positive behavioural responses with high levels of activity and engagement recorded. In most cases, the data logs showed high frequencies of website activity (BioDigital/YouTube) during the lessons. This indicated students were motivated and engaged in the learning activities. This was also evident from the post lesson feedback as 58% of students reported the technology helped them engage in the learning process. The findings of the class observations also showed simulation to be learner focused as students developed portfolios based on their own perceptions and the investigations were carried out on specific areas they had difficulty with. This approach is a very effective method to learn scientific principles and the informal approach is more in line with adult learning theory (Knowles, Holton, & Swanson, 2015). The student portfolios also showed evidence of analysis evaluation and design, and teachers observed an increase in student confidence and articulation when presenting their work. The portfolios also gave insights into the perspectives of students as to how they used images/models to display the visual impact of the software on their own concept formation. This method facilitates the comprehension and application of knowledge through discovery learning(Hai-jew, 2008). The timing and environmental distractions are important considerations when delivering to a new target group as learners may become

frustrated or distracted if they are not familiar with using technology for learning. Another factor to the success of computer simulation for learning is the students underpinning subject knowledge. A foundational level of subject matter and emotional intelligence are necessary to promote self-directed learning (Çimer, 2012, Fragouli, 2009).

- What features of computer simulation best facilitate the comprehension and application of abstract knowledge?
  The coding exercise on transcripts from the focus groups identified a series of features of computer simulation that aided learning A&P subject matter. These features included: Intuitive design, Creating artefacts, Visualisation, Immersion. The open coding revealed several convergent themes with other data collected throughout the investigation. The frequency of occurrence in keywords were highest for themes in visualisation and application of knowledge in constructing the portfolios. Other emerging themes included satisfaction, interest and engagement. Post lesson feedback on the 3D imagery with low/moderate fidelity levels showed students got greater visual perspectives of complex A&P systems. The interactive features such as the dissect tool and the explode function enabled students to investigate and view in detail the inner workings of complex organs and surrounding systems in the body. Worked examples were found to be a key feature in the comprehension of the abstract information; these examples reduced cognitive load and facilitated operative conditioning. The predominant feature of that was reported by students was the high level of interactivity. By creating portfolios that were unique to their own learning students captured personal insights through the models they aerated. By adding in labels and study notes the students personalised the material which improved motivation (Mayer, 2005).

Overall, the results of the data analysis are consistent to support the hypothesis that simulation is a more visually engaging learning experience. The strands of research in totality combined to address the research questions. The synthesis of results support the plausibly of developing a framework to implement the use of simulation technology in the teaching of Anatomy and Physiology to adult students on Beauty Therapy and Sports Therapy courses. The findings also highlight features of computer simulation that facilitate the comprehension and application of abstract knowledge. These features are evidenced by the production of the portfolios. The findings of the post learner survey and teacher discussions also reveal improved concept formation and cognitive dissonance through abstract symbolic reasoning (Psychol- & Psychologist, 2015).

5.9.1 Comparing results between the two groups

When comparing the results between the two groups, there were subtle differences noted. The Sports Therapy group had specific occupational interests, and were quite focused on the skeletal and muscular systems from the outset. Sports Therapy students also investigated the injuries catalogue in more detail, whereas the Beauty Therapy students were taking a more general approach to their investigations with some exploring the skin conditions library. In terms of portfolios both groups produced detailed models and demonstrated high levels of engagement and interactivity from their work. In terms of expected outcomes, Sports Therapy students would generally look to progress to HE courses whereas the Beauty Therapy group would generally progress directly into employment.

5.9.2 Unexpected outcomes

One of the features of BioDigital software enables students to share their work with the online community, some students posted their work and received positive feedback from peers. This activity improved learner's confidence as receiving positive feedback from a stranger was reassuring and motivating. Other aspects of the investigation that were unexpected emerged in the focus groups where some students said the activity was memorable and having positive feelings on the activity. This suggests that there was a psychological impact on learners in the way they felt about the subject having produced portfolios which they had a personal connection with. There were some instances where students appeared distracted with the technology and were observed browsing other websites and playing games. This indicated the potential for distraction due to the learning environment and the habits of students when using the web. The motivation for students to fully participate in self-directed learning was limited as portfolios were not formally assessed.

5.10 Summary

This chapter has presented key findings from mixed method data collections and analysis on the results. The findings were produced from 7 different research instruments, and each data set had nuances unique to this target group. The next chapter will discuss the implications of these findings and draw conclusions from the investigation. A strategy to implement computer simulation will be outlined as a mechanism to enhance adult students comprehension of Anatomy and Physiology.

Chapter Six: Conclusion

6.1 Introduction

This chapter presents conclusions based on the findings from the study in relation to the research question and sub-questions. A framework to implement best practice is then proposed outlining key considerations based on the results of this study. The chapter concludes by outlining the limitations of the research and recommendations for future areas of research.

6.2 Conclusions drawn from study

This investigation has presented evidence to support the benefits of computer simulation as a learning aid for adult students in the comprehension of Anatomy and Physiology curriculum. Student portfolios showed the application of knowledge through active learning exercises. This was found to be consistent with the findings from the literature (Martínez et al., 2011). Students reported improved apprehension of Anatomy and Physiology in getting a "clearer understanding" through the visual cues of the software this was also consistent with the literature (Kolari & Savander-ranne, 2004). Classroom observations showed that computer simulation improved student engagement and comprehension of the Anatomy and Physiology curriculum. Feedback from the worked examples, revealed some evidence of concept formation and a reduction in the extraneous cognitive load. However, students did not articulate this explicitly in the focus groups, it was revealed through consultation with the tutors when discussing the portfolio presentations. There was evidence to support a mixed learner focused, syllabus driven approach to teaching A&P to adult learners. Simulation software can assist the learner to carry out investigations based on a set syllabus. The software is a scaffold and the learner is in control of the activity. This approach utilises self-directed learning but within the structure and constrains of the syllabus. In order to implement this strategy learners must have fundamental underpinning knowledge to enable cognitive dissonance (Cooper, 2012). Emotional intelligence is another key factor when determining self-directed learning readiness (Fragouli, 2009). It was evident from both groups that not every individual was prepared for self-directed learning. There were instances where some learners became frustrated with the technology and needed one to one teaching assistance, others commented in the post survey on the reliance of the teacher for emotional support in class. This problem is compounded when the syllabus is complex and there is a degree of apprehension and pre-existing attitudes to learning (Sticklen, Urban-Lurain, & Briedis, 2009).

6.3 Recommendations on best practice

Based on the findings the results indicate a framework to implement best practice as follows.

- Adult learning theory places emphasis on the importance of self-directed learning. Simulation can facilitate this through problem solving/goal orientated activities such as simulated dissections and virtual investigations.
- Teaching staff must be cognisant that the preconceptions of adult learners might not be aligned to scientific fact. Simulation facilitates comprehension through abstract symbolic reasoning through visual cues which can resolve discrepancies in understanding among adult learners.
- A key factor to the success of computer simulation is the importance of underpinning knowledge as a prerequisite to learner engagement. Students must have foundational knowledge for simulation to be

effective as a learning aid.

- Collaborative working can be an effective solution to address the I.T skills deficits among students. Longer class time is also needed to allow for peer-to-peer and collaborative working
- Teacher guidance and support is crucial; well-planned orientation and worked examples are key factors to the success of computer simulation lesson plans.
- The tasks/exercises need to be aligned to the needs of the student, incorporating a more dynamic approach to teaching which is aligned to the teaching of other modules on these courses.
- Learning outcomes need to be set higher on Blooms taxonomy scale on the understanding and application layers, students can demonstrate the application of knowledge through simulation activities.
- Motivation is key – low steaks yield mixed results at times. Linking student motivation to the personalisation of learning is an effective motivation strategy (Bartle, 2015 P4).
- Implementation needs to be incremental; a blended approach building activities into the lesson plan in the form of assignments and online quiz/assessments can be an effective approach.

6.4 Research limitations

The sample size was one of the drawbacks to this study, the timeframe for users to engage with the computer simulation software (less than 8 weeks) was also limiting. This type of research could yield richer datasets if it were to run over a longer period with more activities as a longitudinal study. Participation was optional for students this meant the audience had some level of motivation or interest in technology. There were also no consequences if students did not complete the portfolio which meant that motivation was intrinsic. It would also have been beneficial to obtain the CAO points of those who participated in the study to determine the baseline academic levels of the sample group. Aptitude tests and IQ tests were considered but were not implemented for ethical reasons. The cognitive load test is subjective and the results could be interpreted in several ways. The Hawthorne effect (Macefield, 2007) may also be an issue in terms of increased learner motivation and other the outcomes of the study. The focus groups can be a blunt instrument measuring opinion and learner satisfaction ratings. The drawbacks to this type of model is that it measures subjective opinions in a snapshot of time and often comments are fluid and reactive.

6.5 Recommendations and further areas of research

A further area of research could be in exploring the generalisability of simulation on a variety of complex subject matter. The TLX test could be used to evaluate the effectiveness of different simulation software applications to inform best practice for instructional design. The application of physiological methods, and electroencephalography (EEG) to measure continuous cognitive load, detecting subtle fluctuations in instantaneous load, could also be used to investigate the effects of computer simulation for a more objective measure of overall cognitive load of students. This approach could be used as method to evaluate the effectiveness of simulation technology as a learning mechanism. Further study into measuring cognitive load can be framed on the model detailed below. This dual-task approach (fig 6.1) measures cognitive load in multimedia learning using the modality effect as an example (Brünken, Plass, & Leutner, 2003).

TABLE 1
Classification of Methods for Measuring Cognitive Load Based on Objectivity and Causal Relationship

	Causal Relationship	
Objectivity	*Indirect*	*Direct*
Subjective	Self-reported invested mental effort	Self-reported stress level
		Self-reported difficulty of materials
Objective	Physiological measures	Brain activity measures (e.g., fMRI)
	Behavioral measures	Dual-task performance
	Learning outcome measures	

Figure 6-1 Dual Task Cognitive Load Testing

6.6 Summary

This investigation has produced findings that address the key research questions. Conclusions were drawn from a synthesis of research methods that formed converging outcomes that support the use of computer simulation among adult learners. In particular, classroom observations and learner feedback outlining key features of computer simulation that improved student engagement and comprehension of Anatomy and Physiology curriculum. Further conclusions on the effects of computer simulation were made, and the ways in which computer simulation can be used to reduce cognitive load and concept formation were outlined. Key recommendations outlining the methods for implementing computer simulation to address the difficulties in the comprehension of the Anatomy and Physiology curriculum were then made. The limitations of the research were then made, acknowledging the subjective nature of the TLX scores and the Hawthorne effect simulation may have on learner engagement. Lastly suggestions on further areas of study were made outlining the generalisability of simulation on a variety of complex subject matter and taking a dual task approach to cognitive load measurement.

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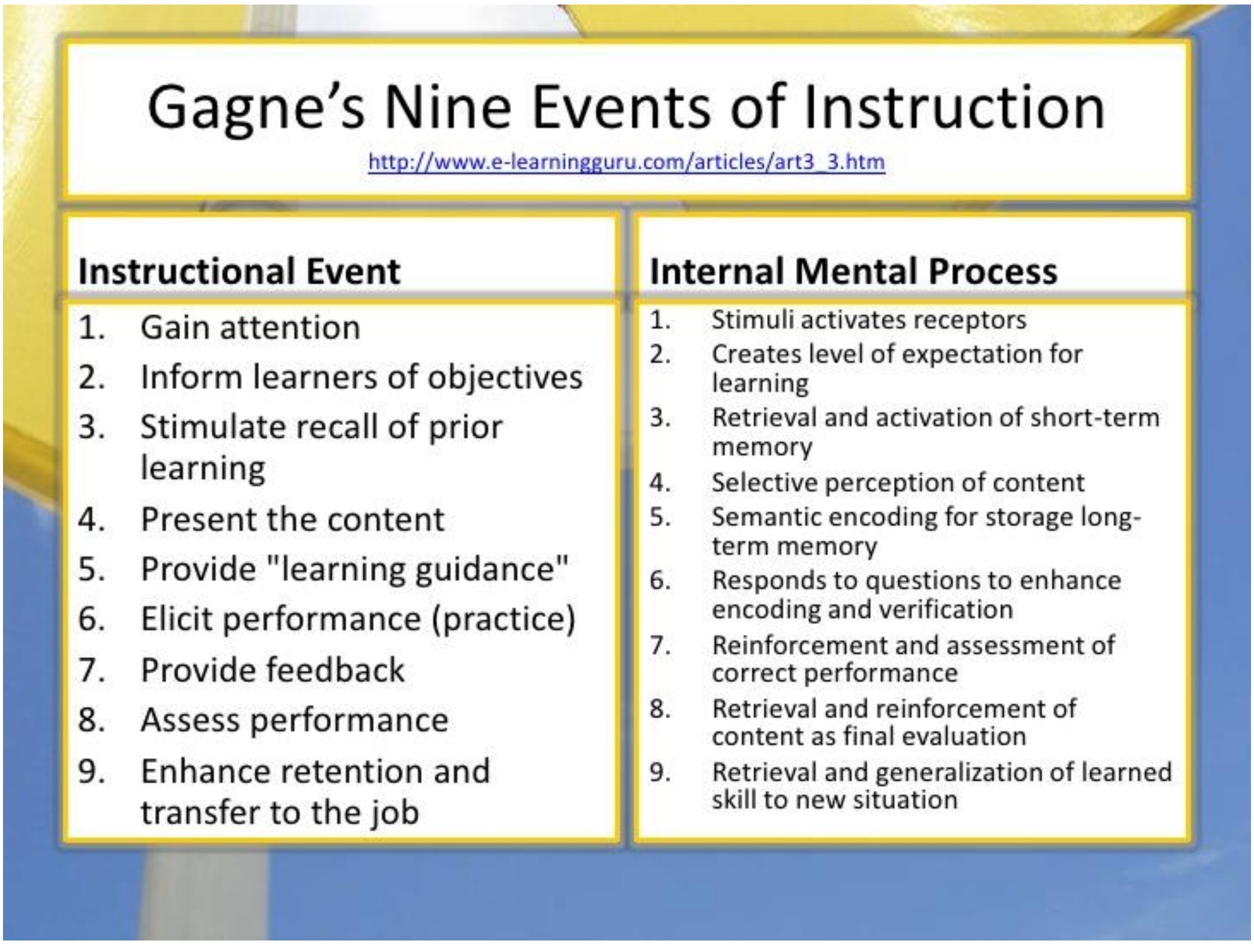
Appendix A Simulation Software Evaluation

Simulation Software:	***Attributes***	***Overall score***
Human Bio-digital: https://human.biodigital.com/	***Positive:*** • Cross platform compatible available as a download app or via a web browser • Very intuitive and easy to use. • Low cost – trial licence available. • Detailed descriptions of organs/systems available via the user interface. • High level of interactivity and tools available. • Multiple viewing angles and zoom features. • Embedded tools for capturing images/video • Capacity to filter systems and isolate organs for dissection. • Capacity to share content and interact with other learners. • Use of audio and phonics to help with pronunciation of systems/organs. • Animations of moving parts in the body. • Quiz feature to allow learners test their knowledge. • Has YouTube channel as a resource for learners ***Negative:*** • Descriptions of systems and organs are quite advanced. • A good level of I.T competency is needed to use all the features available • Medium to low fidelity simulation • Quiz questions are quite advanced.	90
3D Medical Essential **http://applications.3d4medical.com**	***Positive:*** • Very intuitive and easy to use. • Can animate the workings of various system. • Medium to high fidelity with cross sections of models. • High level of interactivity and tools available. • Animations of moving parts in the body. • Quiz feature to allow learners test their knowledge. ***Negative:*** • Cannot layer various systems in the body. • A good level of I.T competency is needed to use all the features available • Needs to be pre-installed on a high spec machine. • No quiz feature or user login to manage work.	75
Ikonet: Virtual Human Body: Http://www.ikonet.com/	***Positive:*** • Low cost – trial licence available. • Animations of moving parts in the body. • Simple and easy to use user interface • Has various video tutorials available on YouTube • Cross device compatible • Multi views and transparency feature to merge systems. • Vast library of anatomical structures ***Negative:*** • Heavy on system resources (RAM/CPU) • Low fidelity and level of detail in models.	70

	• Requires download and instillation • No testing or quiz function	
Zygote body: https://zygotebody.com/	***Positive:*** • Low cost – trial licence available. • Works in browser no instillation required • Simple and easy to use user interface • User logins to allow models to be saved. • Can save screen images of models via interface. ***Negative:*** • Expensive subscription/very limited trial functions • Limited tutorials/no YouTube channel • Medium to Low fidelity and level of detail in models. • No testing or quiz function	80
Virtual Autopsy http://www.le.ac.uk/	***Positive:*** • Easy to use website that details • Free resource available via a web browser ***Negative:*** • Limited to 6 systems in the human body • Low fidelity and graphical content • Static web pages with limited interaction • Lots of text on screen and no test/quiz function • No learner resources available (tutorials/videos/worked examples)	50
Get Body Smart: http://www.getbodysmart.com/	***Positive:*** • Low cost – trial licence available. • Runs in a browser and no install required • Quiz function available • Simple easy to use interface ***Negative:*** • Limited interaction and user resources • Low fidelity and graphical detail • Lots of text on screen and limited animations • 2D images with one viewing angle	60
Human Body Maps **http://www.healthline.com/human-body-maps**	***Positive:*** • Free resource via website. • Video tutorials available • Cross platform/browser compatible • Covers related health conditions on various systems in the body ***Negative:*** • Limited viewing screen size for models • Low to Medium fidelity on images and graphics • Limited views and levels of interaction • No quiz function available	70
Build a Body	***Positive:***	70

http://www.spongelab.com	• Low cost – trial licence available. • Built in learning management system • Quiz features available • Easy to use interface • Cross browser multi device compatible/no install required • Good level of interaction and collaborative learning environment ***Negative:*** • Low fidelity graphics • Static images and limited views • No tutorials/videos available • Limited to 7 systems in the body	
https://www.visiblebody.com/	***Positive:*** • Highly Interactive 3D learning environment • Medium to high level fidelity models • Built in tutorial videos and YouTube channel • Animated functions of 3D models • Integrated quiz functions • Available in Multible languages ***Negative:*** • Have to pay for basic and premium to access the simulation. • Each application/system needs to be pre-installed separately • No dissect function • Advanced material aimed at health professionals	85
E-Skeletons **http://www.eskeletons.org**	***Positive:*** • Free available on the website • Detailed imagery of human skeletal system • Glossary of terms available • Quiz function available ***Negative:*** • Limited to skeletal system • Low fidelity and limited graphical images • Limited interaction and model descriptions • No video tutorials • Load time for each model is high	55

Appendix B Gagne’s Nine Events of Instruction



Appendix C Learners Pre-Survey

Using Technology for Learning

Have you used technology for learning in the past?

- ○ Yes
- ○ No

What device/s do you use most to access the internet? *

How frequently do you access the internet? *

Have you ever completed an e-learning lesson/module?

- ○ yes
- ○ no

From the following list of IT devices, indicate your weekly hours of usage.

	0 hrs	1-5 hrs	6-12hrs	12-20hrs	21+ hrs
Smartphone	○	○	○	○	○
Digital Camera/Video	○	○	○	○	○
Tablet	○	○	○	○	○
PC	○	○	○	○	○
Other IT device	○	○	○	○	○

List the topics in ANATOMY AND PHYSIOLOGY that you found most difficult

List Topic	**Extremely Difficult**	**Very Difficult**	**Moderately Difficult**	**Explain how you found it difficult?**
	○	○	○	
	○	○	○	
	○	○	○	
	○	○	○	

Sample response

Learners Pre Survey

Using Technology for Teaching and Learning

Have you used technology for learning in the past?

- Yes
- ✓ No

What device/s do you use most to access the internet? *

phone

How frequently do you access the internet? *

everyday

Have you ever completed an e-learning lesson/module?

- ✓ yes
- no

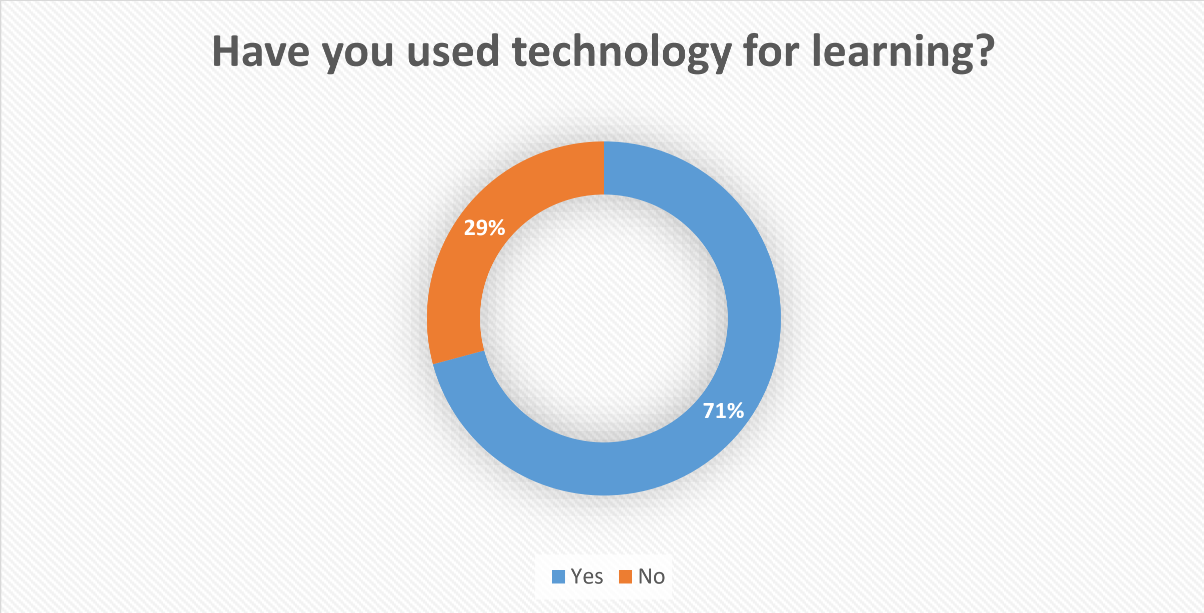
From the following list of IT devices, indicate your weekly hours of usage.

	0 hrs	1-5 hrs	6-12hrs	12-20hrs	21+ hrs
Smartphone				✓	
Digital Camera/Video	✓				
Tablet		✓			
PC		✓			
Other IT device	✓				

List the topics in A&P that you found most difficult

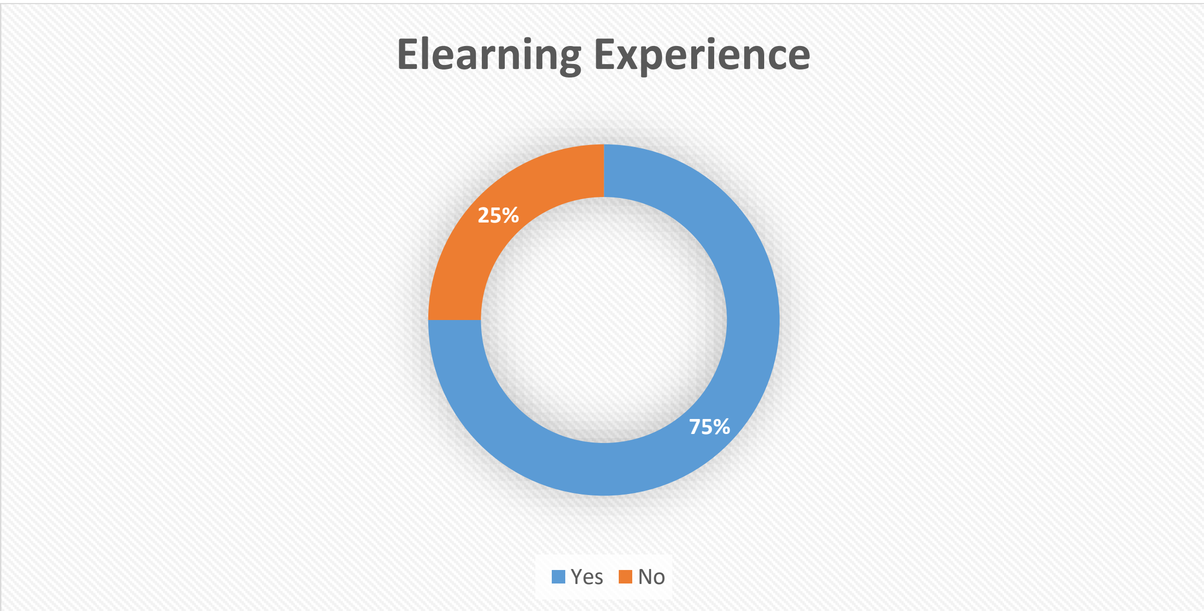
List Topic	Extremely Difficult	Very Difficult	Moderately Difficult	Explain how you found it difficult?
nervous system		✓		alot of learning
muscles			✓	loads of different muscles hard to learn them all
lymphatic			✓	don't think we spent enough time on it for me to understand it all.

Appendix D Pre-Survey Results



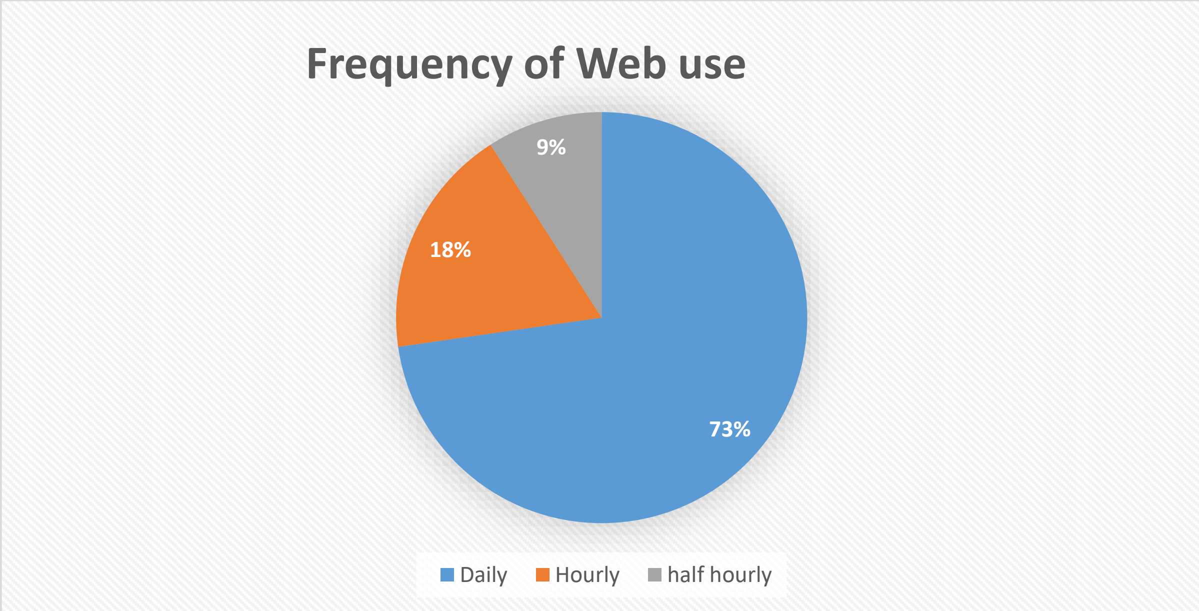
Pre Survey 1

Over 70% of participants said they have used technology for learning.



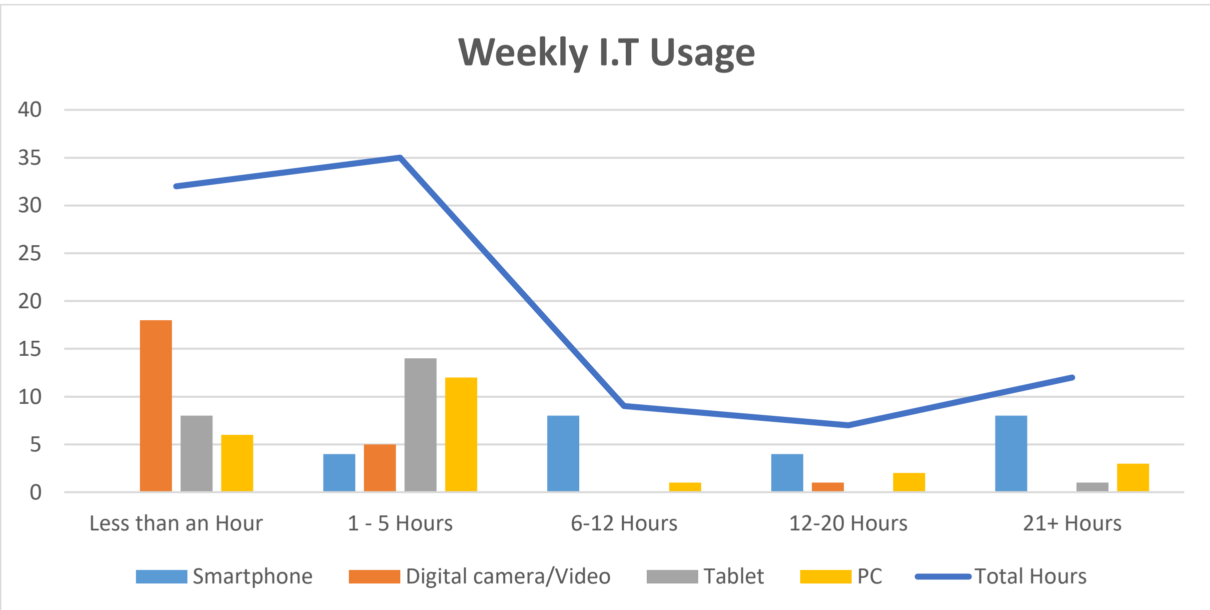
Pre Survey 2

75% of students said they had experience in using E-Learning lessons, however that did not imply they were familiar with simulation software.



Pre Survey 3

The frequency of web use was very high within both groups, all students claimed to use the web daily (73%). This was useful information as it was reasonable to expect most students to be able to access the Biodigital App or website on a frequent basis to develop a portfolio for the class. This response also meant students were highly engaged in web based activities and would be comfortable with accessing information on line. With over 70% of students saying they access the web daily there was good evidence to suggest there was a high level of on line activity within each group. There was a range of devices used by the groups to access the web, the survey showed a divide between PC and mobile device web usage. This had an impact of the selection criteria for the simulation software as it needed to be cross browser compatible and needed to operate on a variety of platforms.

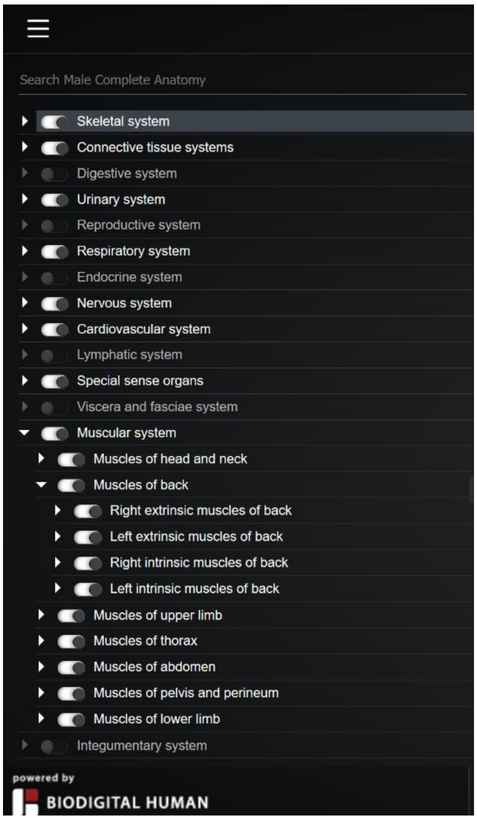


Pre Survey 4

The most used device in the group was the smartphone, followed by tablet devices. This information set the criteria for the simulation software. Another factor in the design considerations was the issue of drive storage and version control on portfolio work. The software needed to allow students to work on their portfolio in class but also at other locations on other devices. Ideally students would have a login to the software and can access prior work in order continue working on the portfolio. Once the pre-survey was concluded the results were used to inform the software evaluation and a series of lessons were derived.

Appendix E Lesson Orientation

Students were given various assignments in class. In the first lesson, they were asked to isolate various systems in the body using the control panel on the left-hand side of the user interface. This feature allowed students to select and investigate specific areas of anatomy which that they had found difficulty with, and layer systems in parallel to view the interrelating attributes. Each system had a toggle "switch" that could be turned on to view in isolation and multiple systems could be turned on simultaneously.

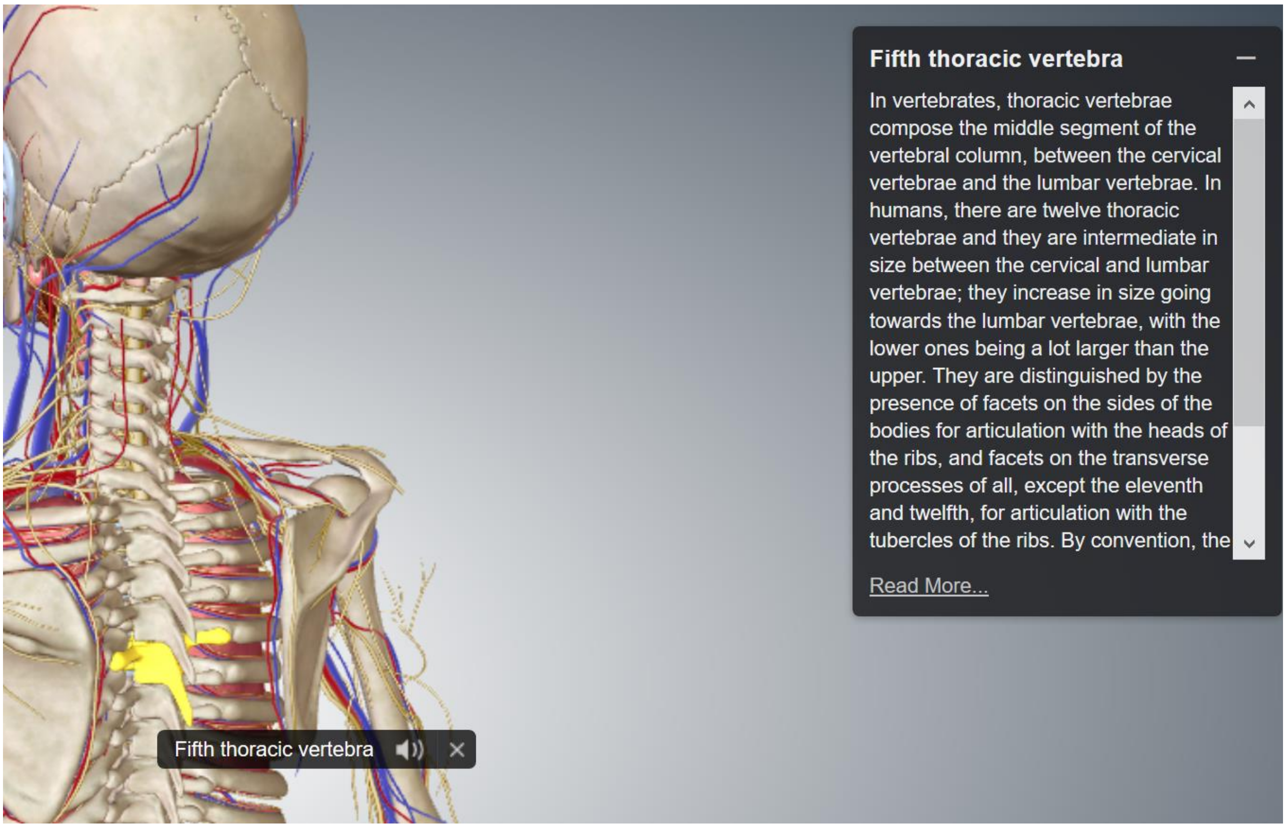


User Control Panel

User Control Panel

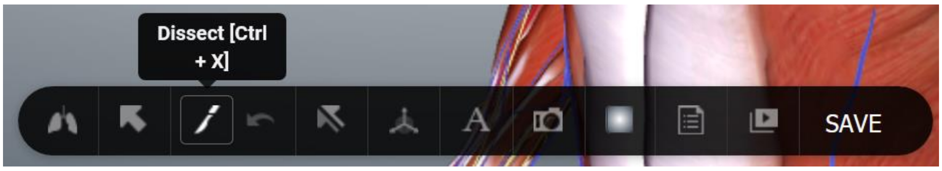
The second feature which students were shown how to use was the toolbar at the bottom of the user interface. This feature had several functions that enabled users to interact with the 3D model. One of the most fundamental features was the 'pick tool'. This function allowed users to select a specific component of a system or organ and view a description and listen to the audio of the name of the component they had selected.

Biodigital toolbar

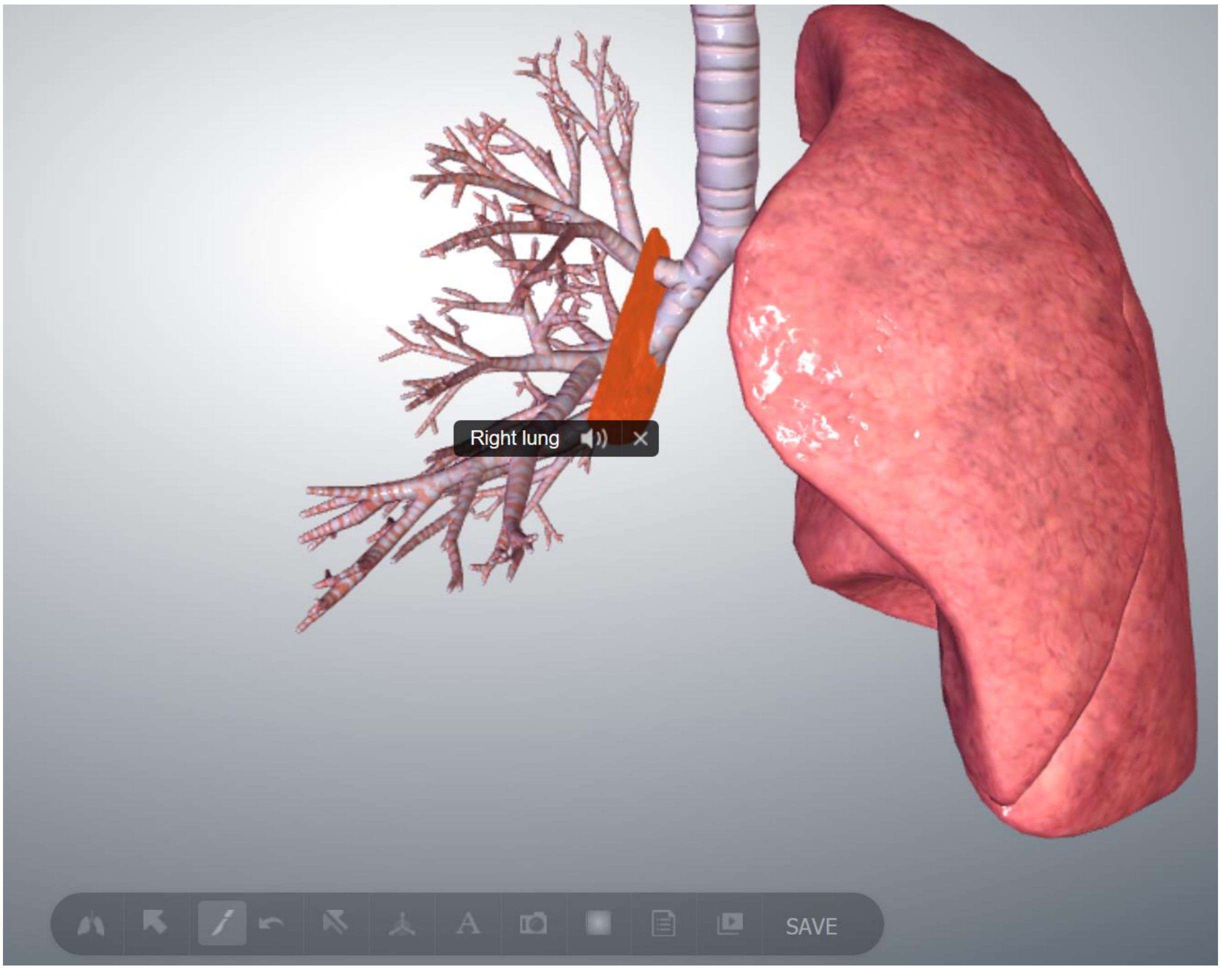


Pick tool function

The next tool learners were shown taught them how to use the dissect tool on the toolbar. This tool enabled learners to carry out dissections on selected areas of anatomy. Once selected users can click on the selected area to be dissected and layers would be removed to give greater perspective on the structures.

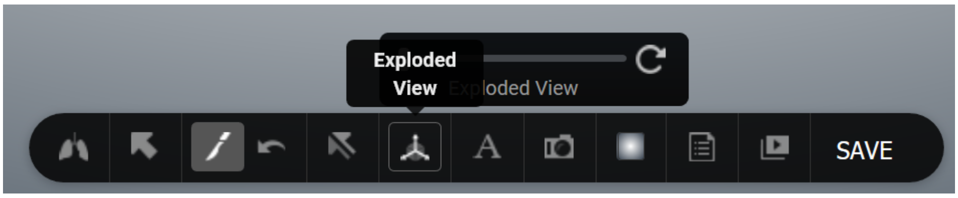


Dissect Tool

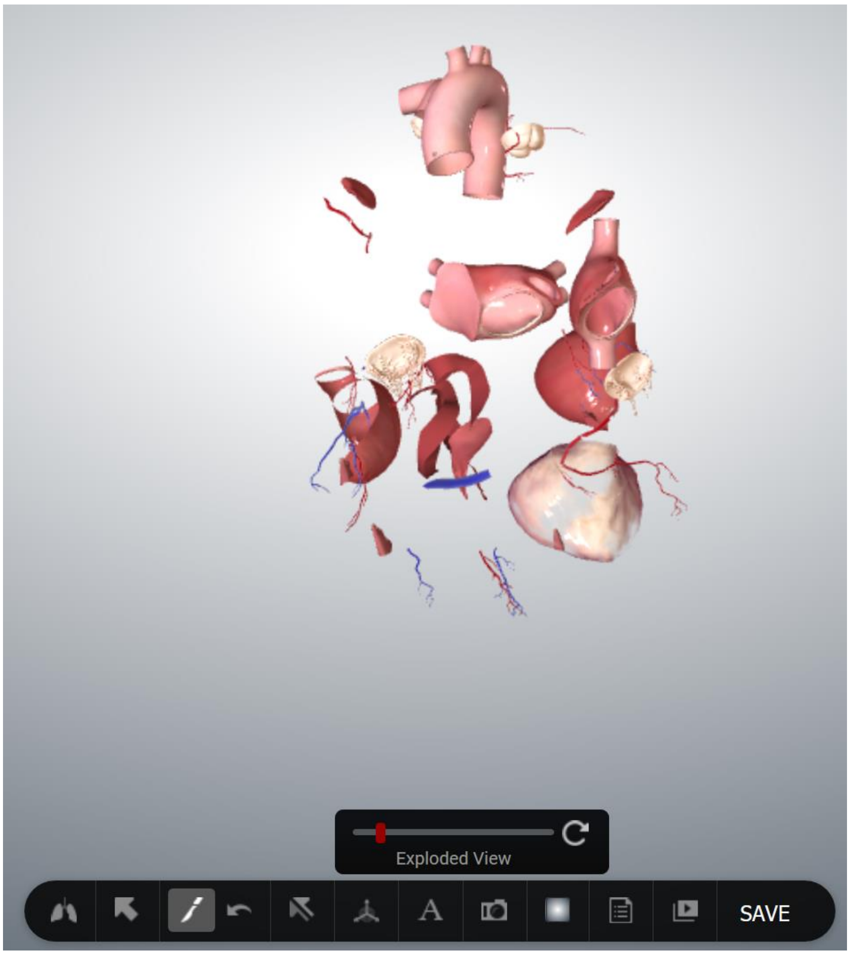


Right lung dissection

Once learners were shown the dissection tool they were then shown an advanced tool known as “exploded view” tool. This tool enabled users to toggle animations of the selected organ being broken apart and isolated the various structures that it was comprised of. This feature built on the concept of dissection in a more controlled format. Each component of the organ was broken apart in segregated form and the user had control of the animation and was able to toggle and view the separation from 360 degree angles.

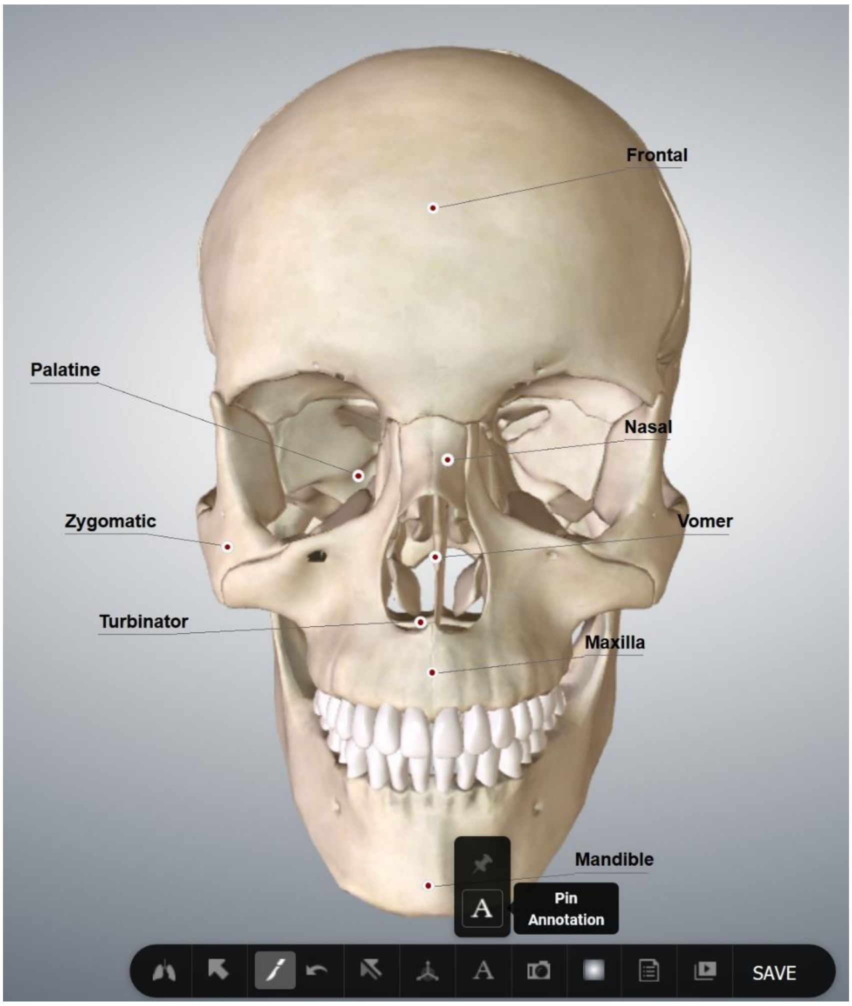


Exploded view tool



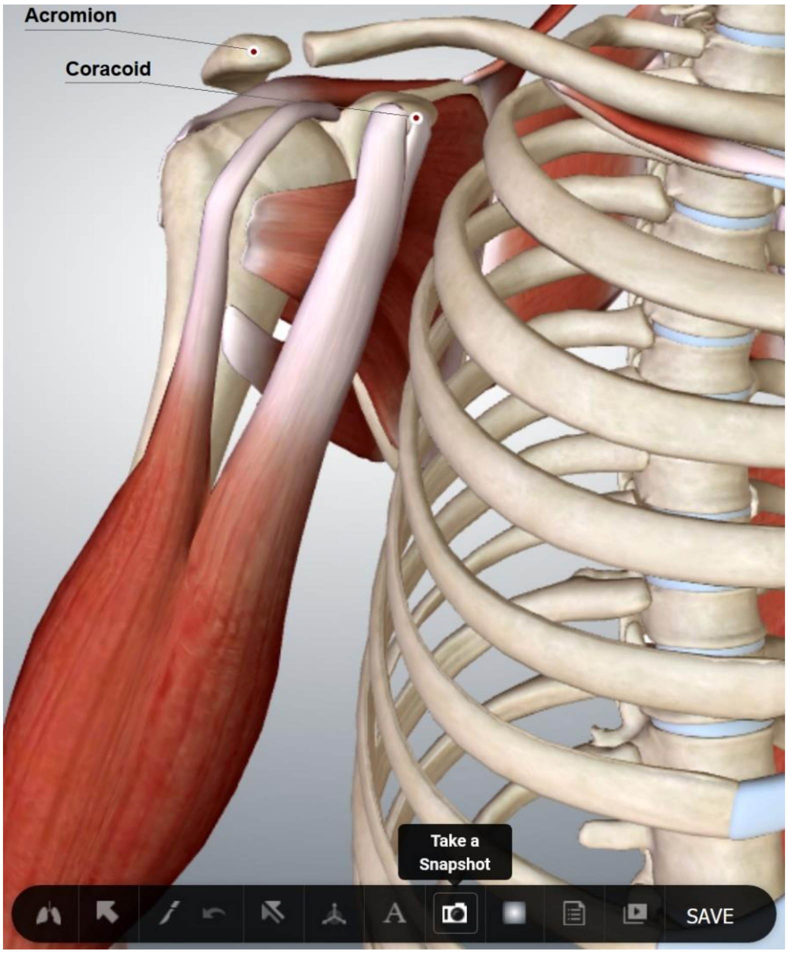
Exploded view of the heart

The next tool that was shown to learners was the annotation tool. This tool enabled users to pin notations to specific areas on a selected model. These notations could range from short labels to descriptive notes that students took from their books or study notes. Once saved these annotations were available for printing or later reference via the BioDigital personal bookmark feature.



Annotation tool

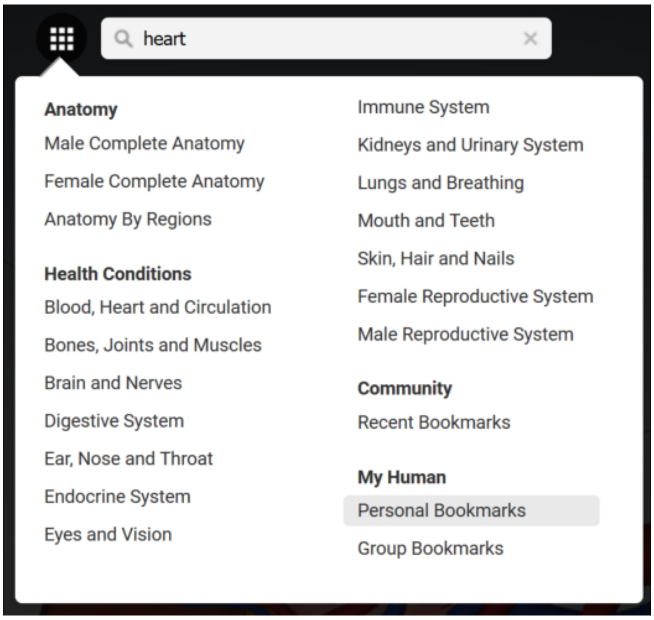
The next feature learners were shown was the "take a snapshot" tool. This was used by all learners to create a portfolio outlining the roles and functions of various systems within the human body. This was done using a combination of tools mentioned. Images were generated from screen captures and videos recorded of aminations using the toolbar functions. The graphical media was developed from learners own investigations, and was presented to each class in the final class. Learners were asked to investigate specific systems/organs in the body that they found difficulty in learning, and reflect on their experience.



Snapshot function

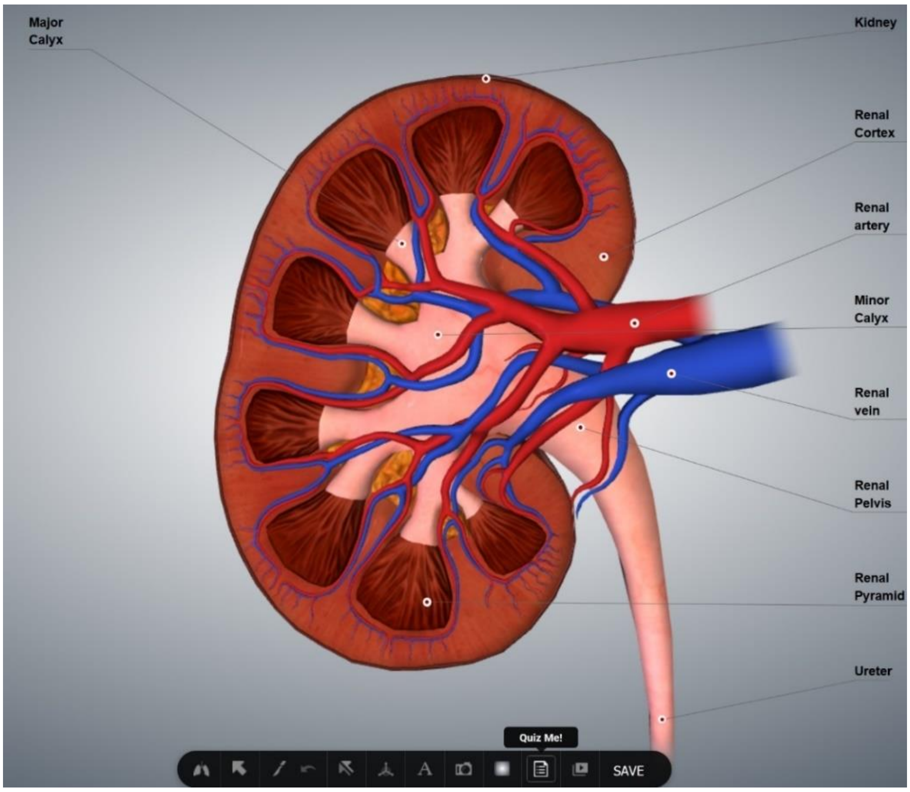
The portfolio was unique to each learner as the images and videos taken were specific perspectives or angles of the 3D models that captured their concept of new information. Observations of these lessons were measured by the researcher using a formative assessment matrix FAST SCASS (Heritage, 2012).

Once they had completed their model students were asked to save their work in the "Personal Bookmarks" section where they could retrieve it later.

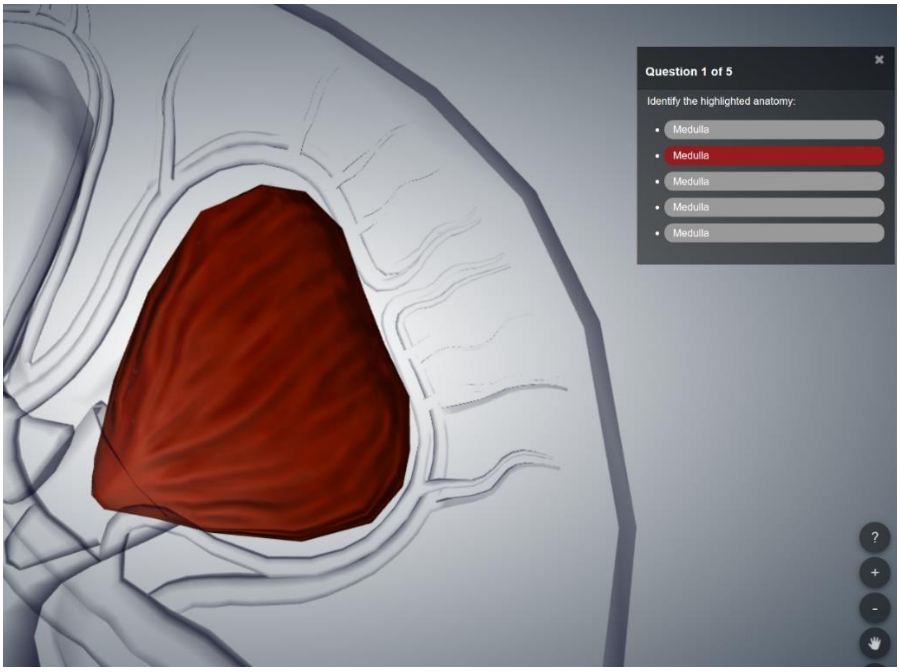


Save to personal bookmarks

Students were also encouraged to test their knowledge by taking quizzes through the BioDigital interface. Multiple choice questions were presented which tested knowledge on the specific area chosen to investigate, and answers were given at the end of the quiz.



Quiz tool



Multiple choice questions

Students were informed beforehand that the questions in the BioDigital quiz screens were not directly aligned to the ITEC syllabus, and that the level of difficulty was higher than in the actual exam. Nonetheless students got great enjoyment and assurance from going through the quiz screens and seeing their results at the end of each quiz. At the end of the final lesson, students volunteered to present their portfolio to the class and explain the slides/videos they chose to present.

Appendix F Classroom observations

Pre-TEL Lesson Class Observations

College of Further Ed

Date: Feb 27th 2017

Course: Sports Therapy

Topic - Lymphatic system

Class time 10am -1130

Gender balance 50/50

Punctuality - average

Delivery

- Didactic/ trans missive syllabus driven
- Some use of IBL and Q&A discussions to interact and engage with learners.
- Descriptive/narrative of curriculum Lymphatic system descriptions
- Some students described specific conditions relating to lymphatic system disorders with personal experiences.
- Pace of lesson/rate of speech reduced as the topic was being introduced for the first time and students were not familiar with terminology.
- Use of whiteboard – tutor used blank tables with headings to engage with learners (fill in the blanks)
- Information was contextualised in narrative form to the related discipline of sports therapy
- System was explained giving perspective to other systems (already covered) and how the system operates and where it is positioned in the body (narrative description) and how proportionate it is to other organs/surrounding systems in the body.

System	Functions	Disorders

Example of classroom activity

Pre-TEL Lesson Class Observations
Training Centre
March 7th 2017

Topic Cardio Vascular system

Course: Beauty Therapy

Class time 830am-10am

Gender balance 100% female

Punctuality good – 1 person late for class

Resources

- Hand-outs
- Use of images/pictures of labelled organs
- Image extract from past exam paper.
- Book – Heavily used in class
- There are posters on class wall have illustrations of various anatomy and physiology systems (Hair & Nails)
- Medical Dictionary Tutor uses as a reference anatomy and physiology topics

The tutor made reference to book quite frequently in class, the book is prescribed by ITEC and has images and descriptions of anatomy and physiology systems.

Delivery of lesson

- There were a number of ailments covered in class that highlighted medical conditions that relate to the role of a beauty therapist.
- This was a revision class and the pace was fast, this pace of delivery primed students for the exam conditions, the class also covers curriculum from 2 separate awarding bodies which adds to the volume of information covered.
- The delivery of the lesson invited student discussion and Q&A with the tutor.
- Sample test questions were covered in class which familiarised students with the testing process and the format of the exam paper.
- When explaining the septum in the heart the tutor made the connection to the septum in the nose)which was covered previously) in order to illustrate the similarities to learners.
- The learning environment is very open and social environment where students have a collective interaction with the tutor and they discuss difficulties/challenges they have with curriculum in class. Students discussed personal experiences in class to relate to syllabus experiences such as having a baby / high blood pressure/ diabetes etc was discussed in class.
- Tables were used to illustrate structure and categorise systems.

Formative Assessment Rubric

The table below was derived from the Formative Assessment guidelines set out by the FAST SCASS (Heritage, 2012) for use in observations and reflections on formative assessment practices.

Dimensions of Formative Assessment		Poor Evidence	Average Evidence	Good Evidence
Learning Goals	Learning goals were achieved and milestones were met.		*Exploration by most group members demonstrated relatively accurate understanding of A&P principles.*	
Tasks and Activities to Elicit Evidence of Learning	Tasks and activities were carried out as evidence of student understanding		*Students accurately followed the instructions but 3-4 details could have been refined.*	
Questions & Strategies to Elicit Evidence of learning	Questioning strategies were used to collect evidence of student thinking to illicit understanding.		*Questions were answered appropriately with accurate information and systematic reasoning.*	
Construction Materials	Students produced 3D models using the Biodigital application outlining what they had added and why.		*Careful and accurate techniques used for the most part but some details could have been explained in more detail.*	
Self-Assessment	Self-Assessment provided students an opportunity to think metacognitively about their learning.			*Accurate information was taken from several sources in a systematic manner.*
Collaboration	A classroom culture was established in which students are partners in learning.			*Strong evidence of collaborative learning with peer to peer learning and sharing of information.*

Appendix G VLE Log

A typical student VLE log taken on March 15th 2017 at ETB Training Centre.

Name	Location	Visit Count
BioDigital Human: Anatomy and Health Conditions in Interactive 3D	https://human.biodigital.com/signup.html	1
BioDigital: 3D Human Visualization Platform for Anatomy and Disease	https://www.biodigital.com/enroll/mode/group/mrkt/academic	1
BioDigital: 3D Human Visualization Platform for Anatomy and Disease	https://www.biodigital.com/human-case-studies/nyu	1
BioDigital: 3D Human Visualization Platform for Anatomy and Disease	https://www.biodigital.com/human-case-studies/smiletrain	1
BioDigital: 3D Human Visualization Platform for Anatomy and Disease	https://www.biodigital.com/human-case-studies/yamuna	2
BioDigital Human - 3D Anatomy - Android Apps on Google Play	https://play.google.com/store/apps/details?id=com.biodigitalhum...	1
Sign in - Google Accounts	https://accounts.google.com/ServiceLogin?service=googleplay&p...	1
play.google.com/store/apps/details?id=com.biodigitalhuman.human...	https://play.google.com/store/apps/details?id=com.biodigitalhum...	1
BioDigital Human - 3D Anatomy - Android Apps on Google Play	https://play.google.com/store/apps/details?id=com.biodigitalhum...	1
BioDigital Human: Anatomy and Health Conditions in Interactive 3D	https://human.biodigital.com/signup-thank-you.html	1
Your BioDigital Human Premium Subscription - bryan3@tcd.ie - Trini...	https://mail.google.com/mail/u/1/#inbox/15a915c3752e459b	1
BioDigital Human: Explore the Body in 3D!	https://human.biodigital.com/user-account.html	0
BioDigital Human: Health Care Provider Demo - YouTube	https://www.youtube.com/watch?v=dW4JSMlBhWQ	1
BioDigital Human Tutorial: How To Use The Anatomy Explorer - You...	https://www.youtube.com/watch?v=qMwLf3p4LSk	1
BioDigital Human Tutorial: Tour Of Animated Conditions - YouTube	https://www.youtube.com/watch?v=eOo80AJW1el	1
BioDigital Human Tutorial: Finding 3D Anatomy Models - YouTube	https://www.youtube.com/watch?v=ncj82yEaK_I	1
BioDigital: 3D Human Visualization Platform for Anatomy and Disease	https://www.biodigital.com/education	4
biodigital - YouTube	https://www.youtube.com/results?search_query=biodigital	1
BioDigital, Inc. - YouTube	https://www.youtube.com/user/biodigitalsystems	1
BioDigital, Inc. - YouTube	https://www.youtube.com/user/biodigitalsystems/videos	1
www.google.com/search?q=biodigital&ie=utf-8&oe=utf-8&client=fi...	https://www.google.com/search?q=biodigital&ie=utf-8&oe=utf-8...	1
biodigital - Google Search	https://www.google.ie/search?q=biodigital&ie=utf-8&oe=utf-8&c...	1
www.google.com/search?q=biodigital&ie=utf-8&oe=utf-8&client=fi...	https://www.google.com/search?q=biodigital&ie=utf-8&oe=utf-8...	1
biodigital - Google Search	https://www.google.ie/search?q=biodigital&ie=utf-8&oe=utf-8&c...	1
BioDigital: 3D Human Visualization Platform for Anatomy and Disease	https://www.biodigital.com/	4
BioDigital Human: Anatomy and Health Conditions in Interactive 3D	https://human.biodigital.com/signin.html	6
BioDigital Human: Explore the Body in 3D!	https://human.biodigital.com/index.html	6
BioDigital Human: Explore the Body in 3D!	https://human.biodigital.com/widget/?be=1mi0&uaid=2li4v	2
BioDigital Human: Explore the Body in 3D!	https://human.biodigital.com/widget/?be=1mhr&uaid=2li3C	1

Appendix H Post Questionnaire

Post-Lesson Evaluation Survey

All questions are optional:

1.1 Thinking about your course within the past year, to what extent do you agree with the following statements, specifically considering the role technology has played in learning Anatomy and Physiology? Technology helped me…

	Don't know	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
…engage in the learning process						
…investigate topics outside class time						
…reflect on course materials (e.g., readings, videos, etc.)						
…conduct research for class assignments						
…document class work or projects						
…complete case studies						
…examine human anatomy in greater detail						
…learn through interactive activities						
…get a clearer image of organs and systems in the human body.						

1.2 Thinking about your course within the past year, to what extent do you agree with the following statements, specifically considering how technology has contributed to your learning of Anatomy and Physiology? Technology used in my class…

	Don't know	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
…enriched my learning experiences						
…was relevant to my achievement of course learning objectives						
…contributed to the successful completion of my course						
…connected course materials and real world experiences						
…helped me understand fundamental concepts						
…built relevant skills that were useful in the workplace						
…helped make connections to knowledge obtained in other classes						
…helped me understand hard-to-grasp concepts or processes						
…was appropriate to the content being delivered						
…helped me think critically						
…helped me focus on learning activities or course materials						

2.1 How well did you understand the topics **before** the experience?

	1	2	3	4	5	
Poor Understanding	○	○	○	○	○	Excellent Understanding

2.2 What is your overall rating of the Biodigital app?

	1	2	3	4	5	
Poor Rating	○	○	○	○	○	Excellent Rating

2.3 How many anatomy and physiology systems/topics did you cover on the Biodigital app in the classes?

○ 0-1 ○ 2-4 ○ 5-6 ○ 7+

2.4 Did working with the Biodigital Youtube channel help you to gain a clearer understanding of how to use the app?

If yes, explain in what way were you able to gain a clearer understanding?

2.5 How effective do you feel computer simulation is as a method of learning?

2.6 What did you like best about this learning experience?

2.7 In what way could this learning experience be improved?

Sample response

2.1 How well did you understand the subject **before** the experience?

1 2 3 4 5

Poor Understanding ○ ○ ⊘ ○ ○ Excellent Understanding

2.2 What is your overall rating of the Biodigital app?

1 2 3 4 5

Poor Rating ○ ○ ○ ○ ○ Excellent Rating

2.3 How many anatomy and physiology systems/topics did you cover on the Biodigital app in the classes?

○ 0-1 ○ 2-4 ⊘ 5-6 ○ 7+

2.4 Did working with the Biodigital YouTube channel help you to gain a clearer understanding of how to use the app?

If yes, explain in what way were you able to gain a clearer understanding?

used it at home as a Study aid

2.5 How effective do you feel computer simulation is as a method of learning?

it helped me understand better

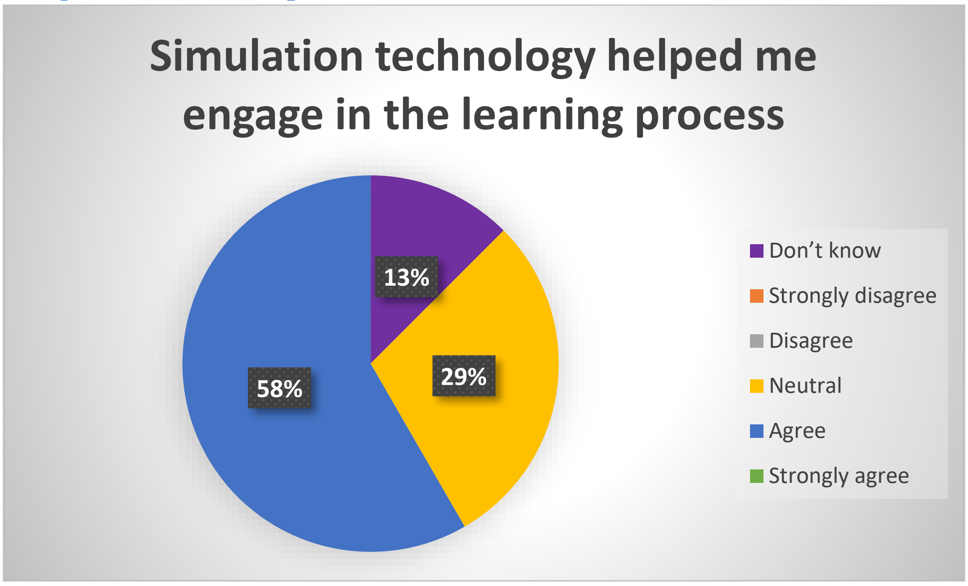
2.6 What did you like best about this learning experience?

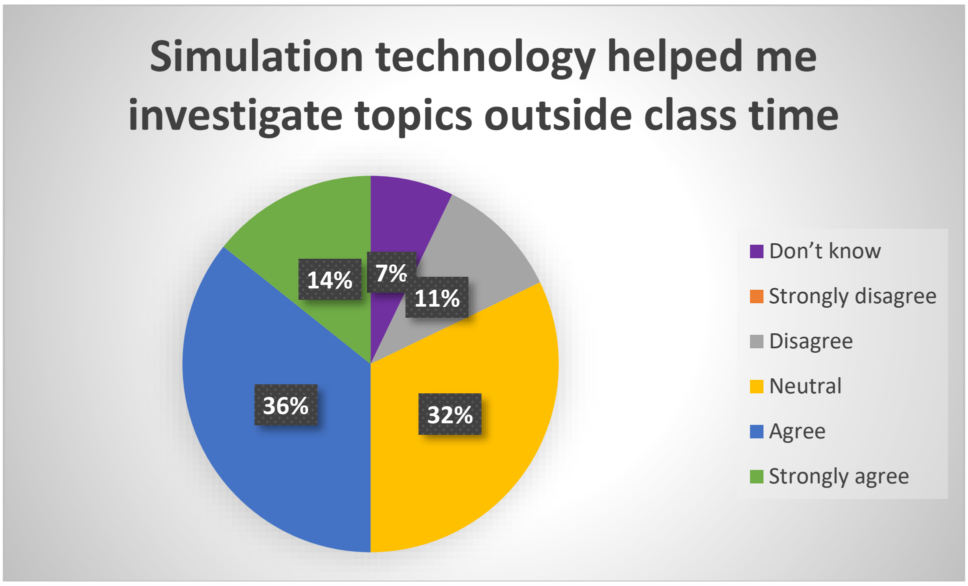
Seeing the 3D modle and each Section in detail I wouldn't get from the book

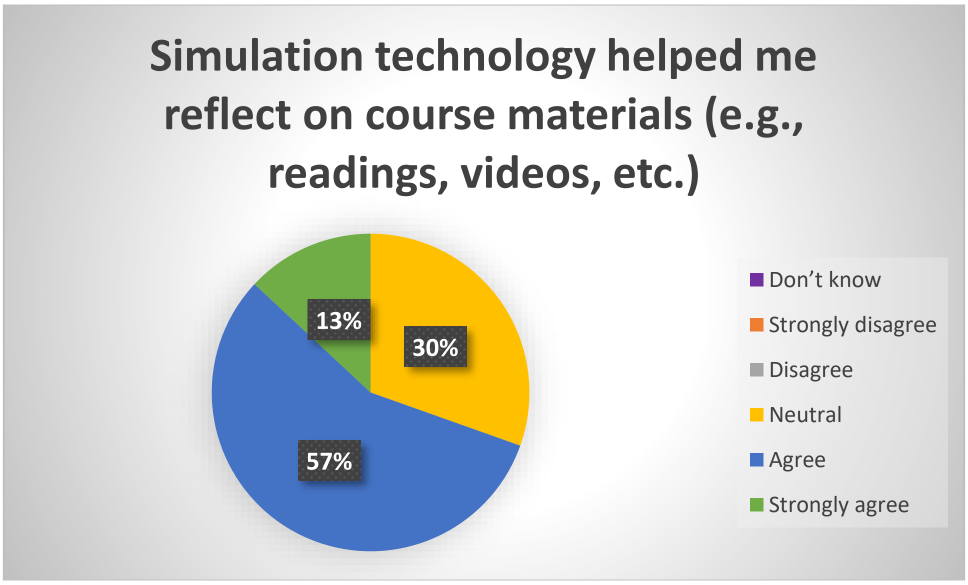
2.7 In what way could this learning experience be improved?

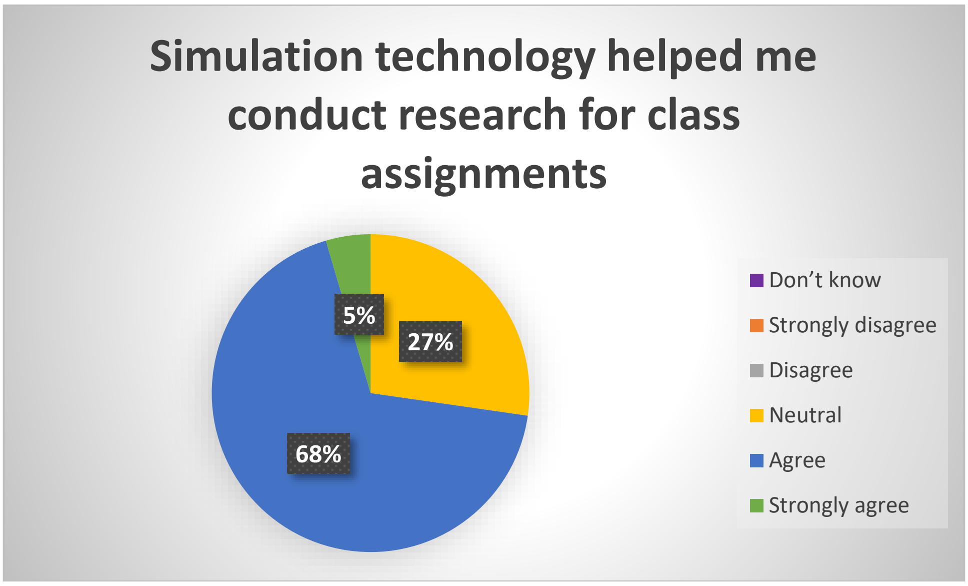
making it easier to use on the iphone.

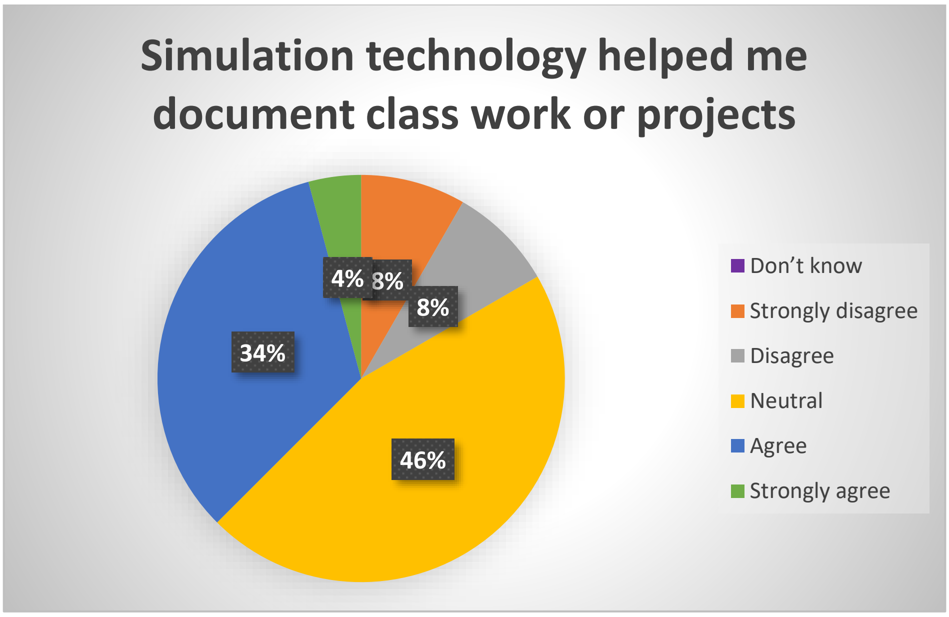
Appendix I Post questionnaire response

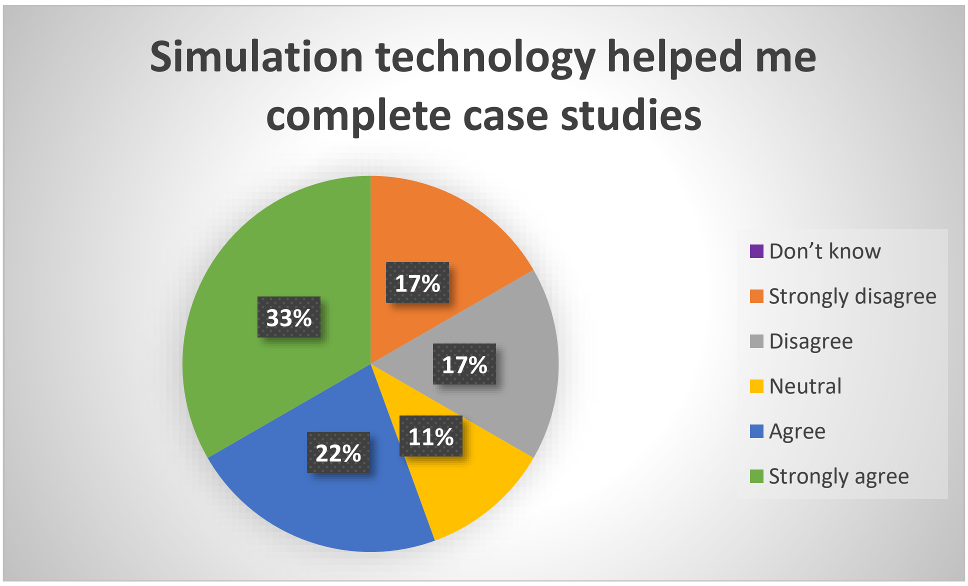


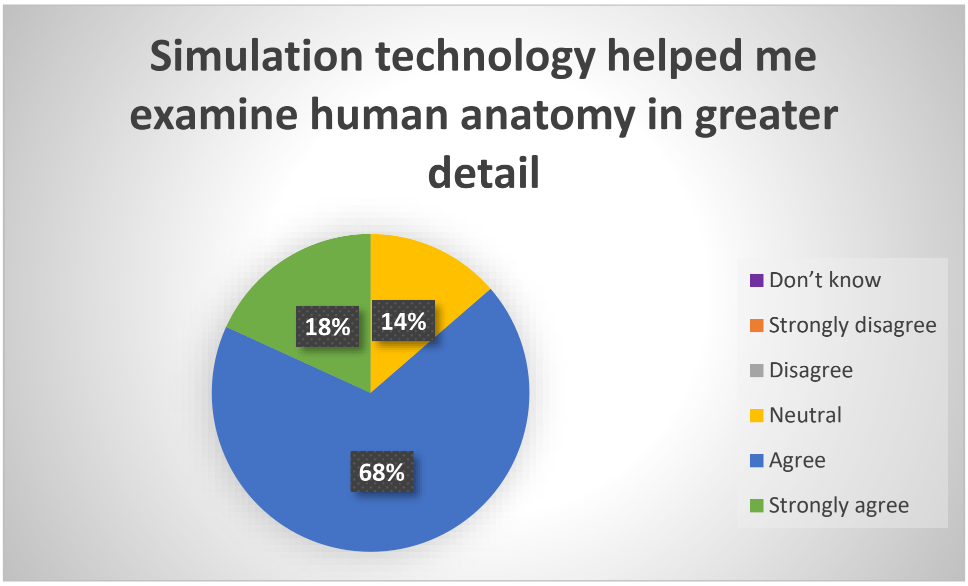


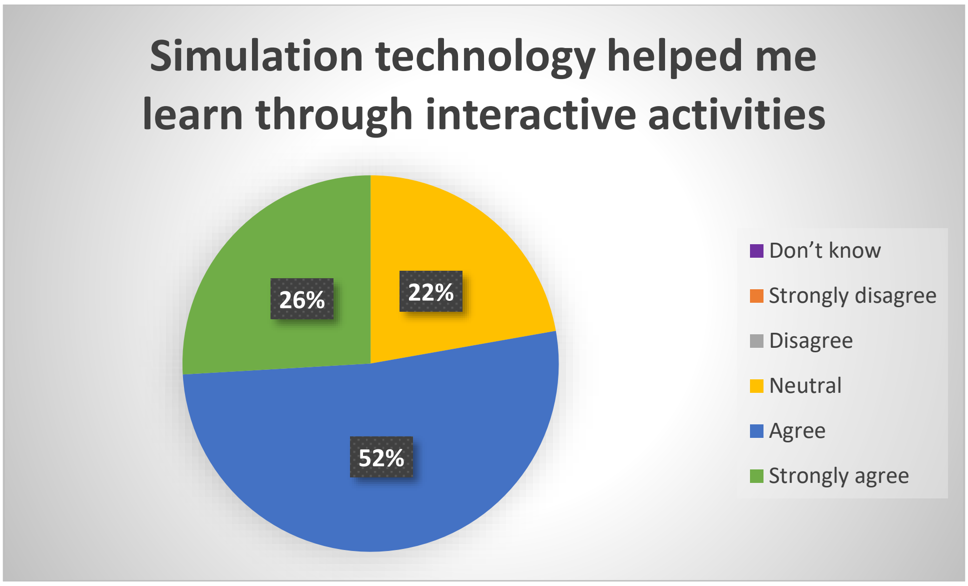


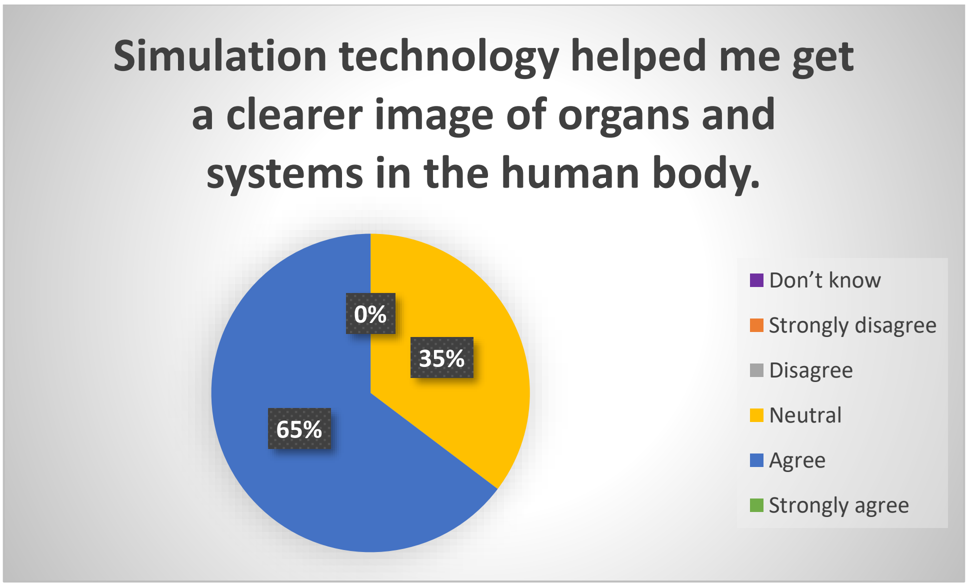

Simulation technology helped me conduct research for class assignments
5%
27%
68%
Don't know
Strongly disagree
Disagree
Neutral
Agree
Strongly agree

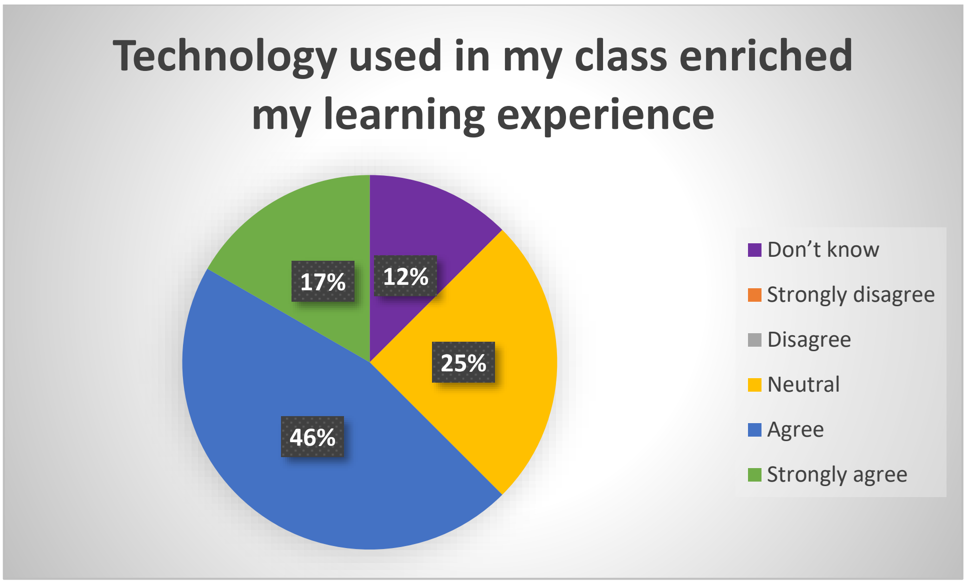

Simulation technology helped me document class work or projects
4%
8%
8%
34%
46%
Don't know
Strongly disagree
Disagree
Neutral
Agree
Strongly agree

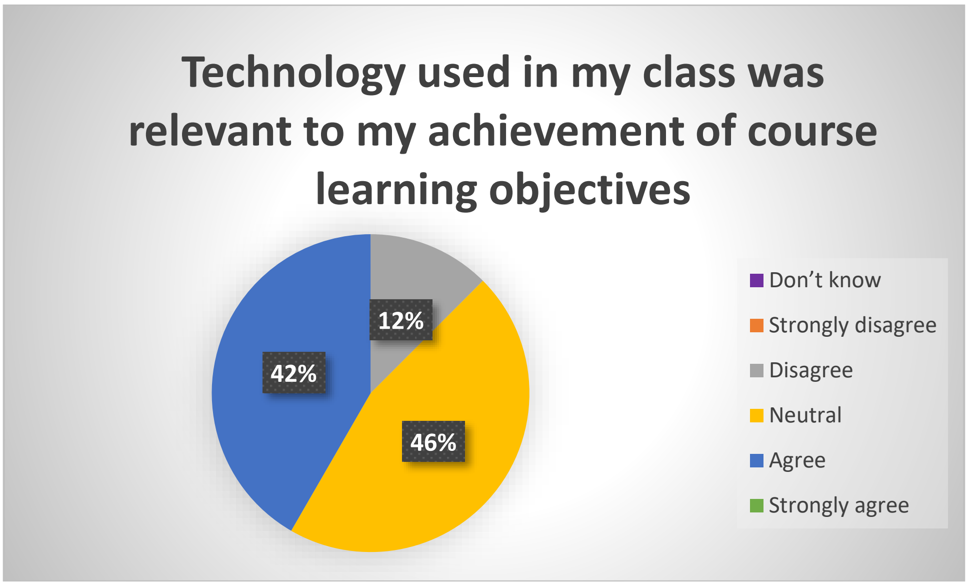

Simulation technology helped me complete case studies
17%
33%
17%
11%
22%
Don't know
Strongly disagree
Disagree
Neutral
Agree
Strongly agree

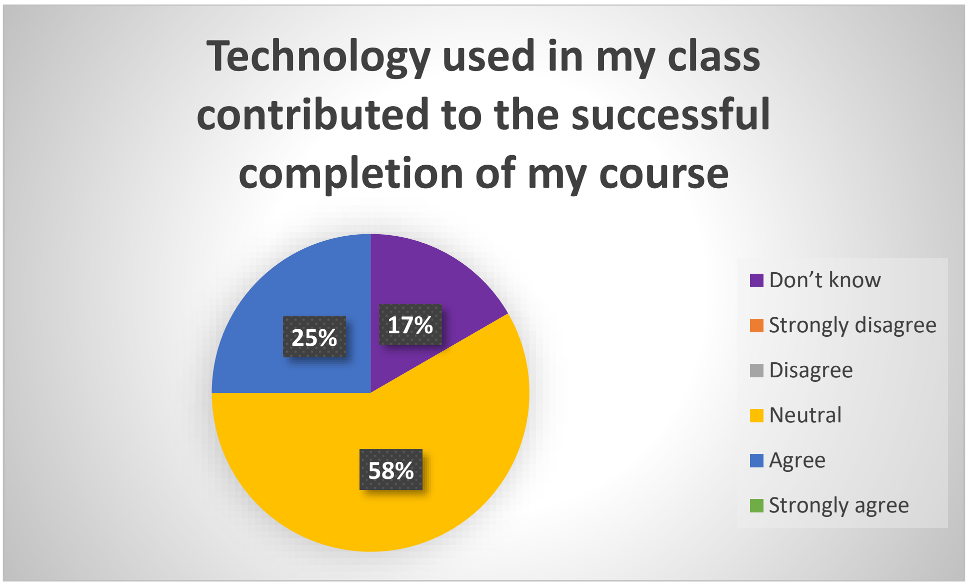

Simulation technology helped me examine human anatomy in greater detail
18%
14%
68%
Don't know
Strongly disagree
Disagree
Neutral
Agree
Strongly agree

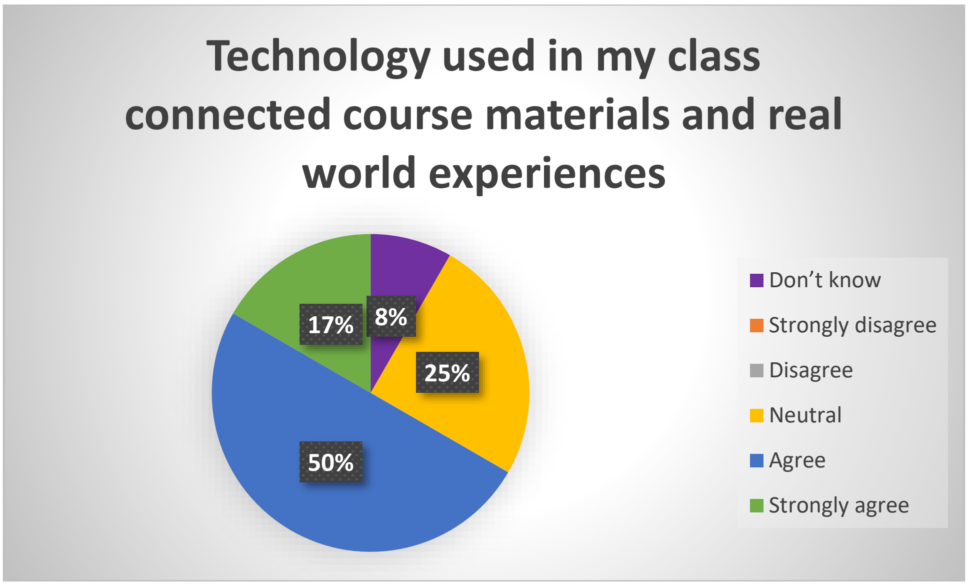

Simulation technology helped me learn through interactive activities
26%
22%
52%
Don't know
Strongly disagree
Disagree
Neutral
Agree
Strongly agree

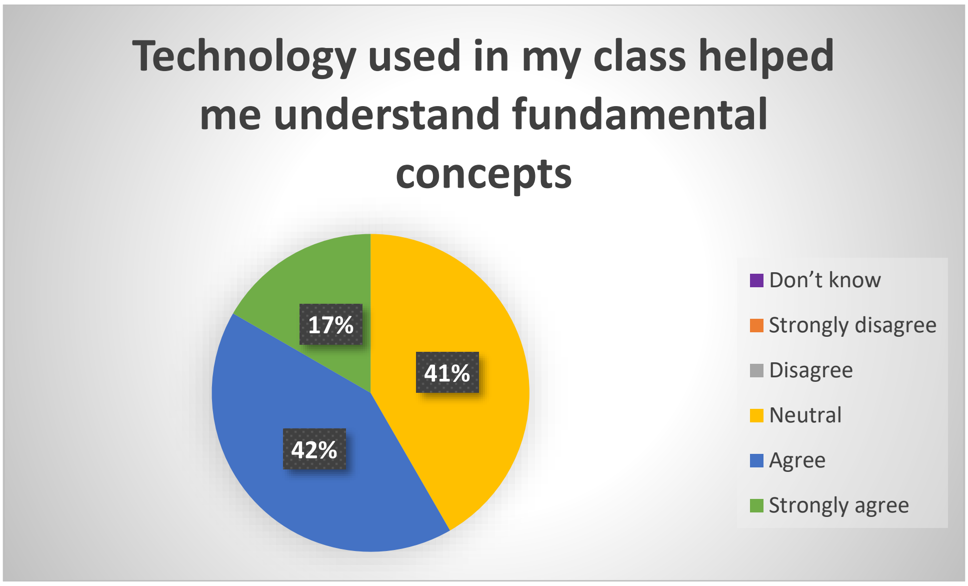

Simulation technology helped me get a clearer image of organs and systems in the human body.
0%
35%
65%
Don't know
Strongly disagree
Disagree
Neutral
Agree
Strongly agree

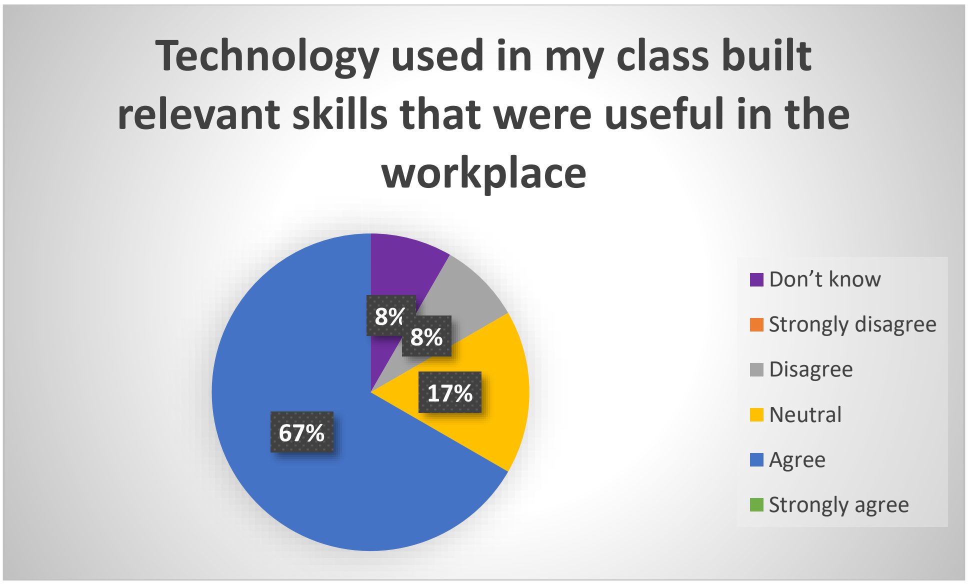

Technology used in my class enriched my learning experience
12%
25%
46%
17%
Don’t know
Strongly disagree
Disagree
Neutral
Agree
Strongly agree

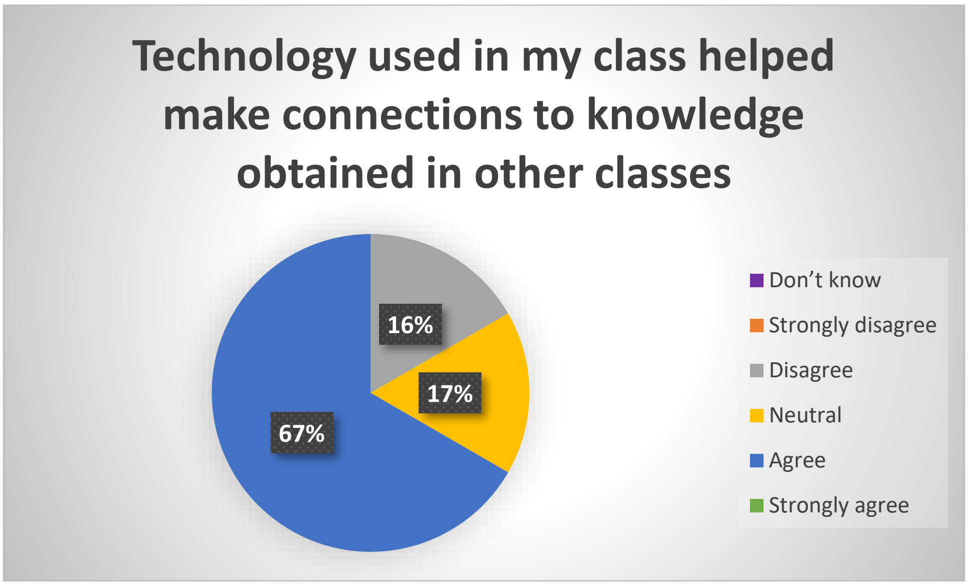

Technology used in my class was relevant to my achievement of course learning objectives
12%
46%
42%
Don’t know
Strongly disagree
Disagree
Neutral
Agree
Strongly agree

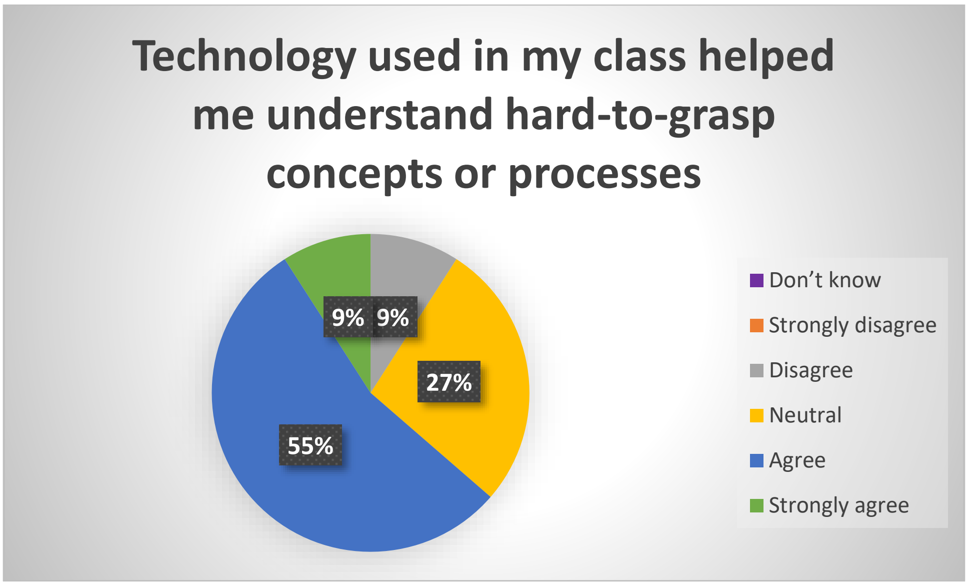

Technology used in my class contributed to the successful completion of my course
17%
58%
25%
Don’t know
Strongly disagree
Disagree
Neutral
Agree
Strongly agree

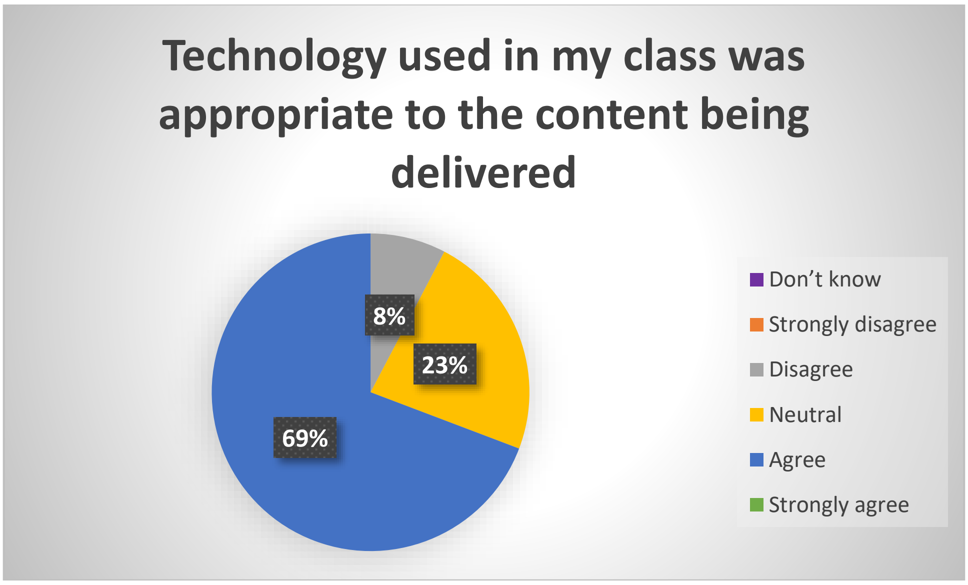

Technology used in my class connected course materials and real world experiences
17%
8%
25%
50%
Don’t know
Strongly disagree
Disagree
Neutral
Agree
Strongly agree

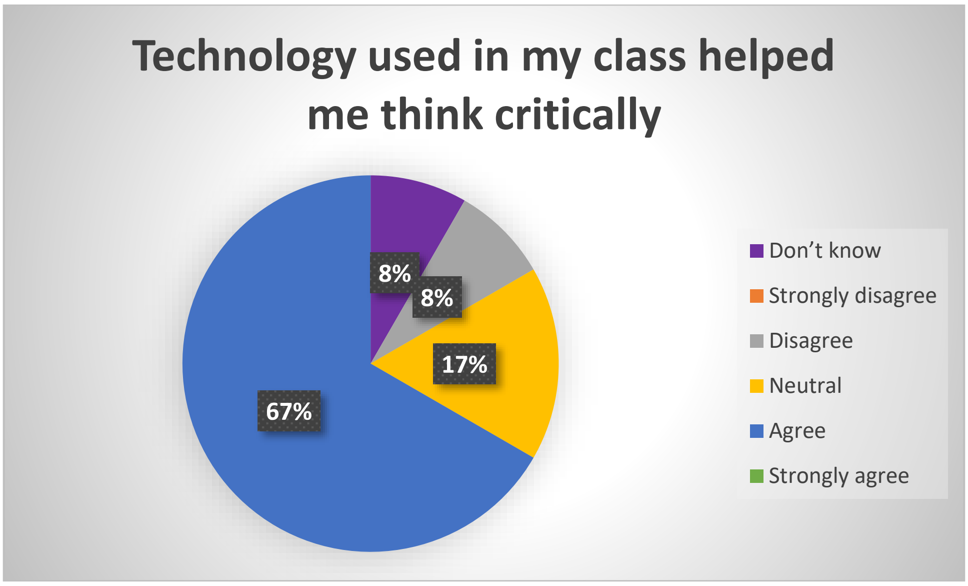

Technology used in my class helped me understand fundamental concepts
17%
41%
42%
Don’t know
Strongly disagree
Disagree
Neutral
Agree
Strongly agree

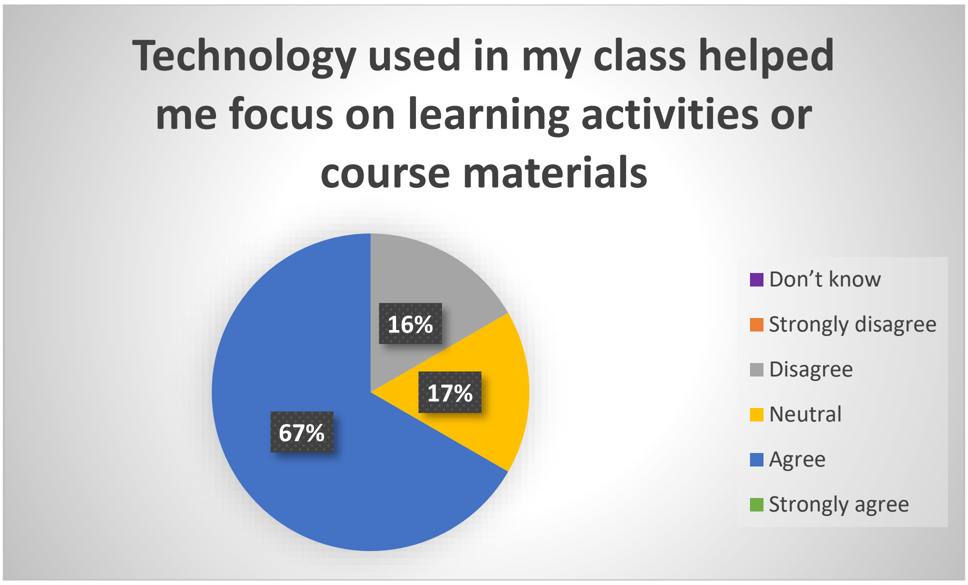

Technology used in my class built relevant skills that were useful in the workplace
8%
8%
17%
67%
Don’t know
Strongly disagree
Disagree
Neutral
Agree
Strongly agree


Technology used in my class helped make connections to knowledge obtained in other classes
16%
17%
67%
Don't know
Strongly disagree
Disagree
Neutral
Agree
Strongly agree


Technology used in my class helped me understand hard-to-grasp concepts or processes
9%
9%
27%
55%
Don't know
Strongly disagree
Disagree
Neutral
Agree
Strongly agree


Technology used in my class was appropriate to the content being delivered
8%
23%
69%
Don't know
Strongly disagree
Disagree
Neutral
Agree
Strongly agree


Technology used in my class helped me think critically
8%
8%
17%
67%
Don't know
Strongly disagree
Disagree
Neutral
Agree
Strongly agree


Technology used in my class helped me focus on learning activities or course materials
16%
17%
67%
Don't know
Strongly disagree
Disagree
Neutral
Agree
Strongly agree

Responses spreadsheet

Q2	Don't know	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Technology used in my class enriched my learning experience	3			6	11	4
	Don't know	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Technology used in my class was relevant to my achievement of course learning objectives			3	11	10	
	Don't know	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Technology used in my class contributed to the successful completion of my course	4			14	6	
	Don't know	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Technology used in my class connected course materials and real world experiences	2			6	12	4
	Don't know	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Technology used in my class helped me understand fundamental concepts				10	10	4
	Don't know	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Technology used in my class built relevant skills that were useful in the workplace	2		2	4	16	
	Don't know	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Technology used in my class helped make connections to knowledge obtained in other classes			4	4	16	
	Don't know	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Technology used in my class helped me understand hard-to-grasp concepts or processes			2	6	12	2
	Don't know	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Technology used in my class was appropriate to the content being delivered			2	6	18	
	Don't know	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Technology used in my class helped me think critically	2		2	4	16	
	Don't know	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Technology used in my class helped me focus on learning activities or course materials			4	4	16	

Subjective question responses.

2.4 Did working with the Biodigital YouTube channel help you to gain a clearer understanding of how to use the app? If yes, explain in what way were you able to gain a clearer understanding?

Responses from learners

- *Yes it was like a manual to instruct step by step*
- *Understanding diagrams in detail*
- *Explained how to use the app*
- *Yes it explained how to use each feature*
- *Yes, gave extra information. However I grasped the use of the app without the need to watch the youtube channel*
- *Used it at home as a study aid*
- *Excellent very informative*
- *Yes, showed in depth how human body works*
- *No not really*
- *No I didn't view this*
- *Didn't get a chance to view this properly and effectively*
- *Yes I liked how it went through the use of the app and demonstrated its features*
- *I got to see how dissections were done*
- *I don't use technology much but I liked the videos, it showed me the various systems in the body*
- *I could see how to use it better*
- *I was able to view extra features that I wouldn't have found out on my own*
- *Some of the videos were not relevant to the course*
- *I could just watch the videos instead of using the app to understand the A&P systems*
- *The videos explained how to use the app (audio)*
- *There were lots of different examples to see and this gave me ideas for my portfolio*
- *I found it helped when we were not in class*

2.5 How effective do you feel computer simulation is as a method of learning?

Responses from learners

- *Very effective*
- *Very as it brings a method of dissecting human body and how systems connect*
- *Good*
- *Its good for me personally*
- *It would be good for people who are computer savvy*
- *Very effective as it helps virtual learning with book learning*
- *V.Good gives 3D version of what we learned in the class*
- *It helped me understand better*
- *Very good, (for those who can use computers) Some struggled. I found it fairly easy*
- *It can be effective when the content is clear*
- *That's very helpful for studying will help more at the beginning of the course*
- *More interesting and fun*
- *It was much better than the book*
- *I liked how I could switch between systems this helped me see how it all works together*
- *On its own its OK but if used by the teacher this could be the best way to learn*
- *I like to see the models and how the systems link together this helped me learn more detail.*
- *A great study aid I liked that I could use it from anywhere in my own time*
- *Very effective compared to the classroom and books*
- *Brings the book to life!*
- *Its good if you know how to use it or get help from others, its too much for me on my own*
- *I found it interesting and a change from normal classes*
- *It helped me understand by seeing the models and being able to click on them for information.*
- *It could be useful if used with the books.*

2.6 What did you like best about this learning experience?

Responses from learners

- *Its interactive and better to see a 3D version*
- *Learning new things about the body and cover more topics*
- *That you can see all organs and body parts in 3D views*
- *Being able to see the systems we have been talking about in class*
- *Interactive 3D effects was useful in learning*
- *Seeing the 3D model and each section in detail this I wouldn't get from the book.*
- *The visual effects were excellent for learning*
- *How in depth you can learn the anatomy and physiology of the body*
- *Seeing different angles of the body on the biodigital website*
- *Not sure.*
- *Can see more up close and deeper than the book*
- *Interactive to use, clearer images, pathology notes*
- *Examine items in more detail than books*
- *It helped me understand more about the body and gave me a clearer insight to anatomy and physiology*
- *I liked how I could add my own notes into the models and see different systems at the same time*
- *Being able to see more detail and save the model for study notes*
- *I could see organs for different perspectives and interact with them*
- *The 3D models can be split apart and you can see more detail*
- *Seeing the models move helped me understand how the body works.*

2.7 In what way could this learning experience be improved?

Responses from learners

- *If it was used as a regular teaching tool*
- *If it had a way to activate the muscles when you clicked on them to watch how they move.*
- *Not sure*
- *Start at the beginning of the course and it would work really good*
- *Its perfect!*
- *Used throughout the course/ needs to be put in place*
- *Making it easier to use on the phone*
- *If our course curriculum (exam papers) were on the app and if irrelevant information in regards to our exams was removed. (extensive details there which we do not need to know)*
- *It could have been improved if we had started it earlier and not 6 weeks before our final exams.*
- *More realistic 3D view etc live video*
- *Start at the beginning of the course and not at the end it would have helped or been more appropriate.*
- *The quiz questions were too hard and not related to our exam*
- *If the classes were done at different times in the year not at the end*
- *The descriptions are too complicated*
- *If we could do assignments using the biodigital app*
- *Use it in class more instead of books*

Appendix J Focus group themes

Introduction:

- Do you enjoy learning A+P?

Learning Experience:

- Did you like the methods used in this project? If so Why/Why not?
- What did you think about the structure of the learning experience? Did you like/dislike it, if so why and how?
- Did you find the project interesting? If so Why/Why not? Could you give me an example what you found the most/least interesting in the project?
- Do you think you learned any new info relating to A&P or any new Skills from this series of lessons?
- Do you think how you learned using this technology was different? If so why/why not? What did you think about learning this way?
- What did you find difficult/easy in using the technology and why did you find these difficult?
- Did you find this approach beneficial to your learning of anatomy and physiology? If so why/why not, what parts of the project did you find/not find beneficial or useful?
- Did this project improve your observation, inquiry, and critcal-thinking skills. If so how/ why/why not? Dicsuus?
- Do think the exercises enable you to present, create work? If so how?
- Do you consider this use of technology in teaching to be an innovatiove and creative approch? If so how? In what way was this innovatiove and creative?
- Do you think you described, illustrated and identified patterns in this project? If so can you give example?

Technology:

- Did you use the technology much in this project? If so which technology did you use? What did you like about the technology?
- Do you think the technology helped you to learn in this project? If so why/why not and How? Could you give me examples of how the technolgoy helped/hindered you?
- What aspects of the technology did you enjoy? Do you think these featues effected how you learn? If so why/why not?
- What technology did you use the most? Was this technology difficult or easy to use and explain why?
- Did you like using technology in the classroom? If so why/why not? Do you think teachers should use more technology in the classroom?
- Would working with the technology in groups be a better approch to A&P Simulation? if so how?

DISCUSSION THEMES

- Gives more interest / in topic.
- Disadvantage to people who are not used to computers
  underpinning knowledge is a must.
- aspects enjoyed most:
  a little frustration initially to get used to it.
  differences between mobile/tablet app v's computer.
- Group work preferred / as some were not confident in using computers.
- Liked email / share option – were able to help each other by forwarding on.
- Could be used with book very well as to keep you close to the syllabus as possible.
- Most would see it as an added aid / + used throughout the course.
- Group licience / would be an option

Appendix K Focus Group Transcript Coding Samples

Due to the environment in which the focus group took place (classroom) the audio recordings were not entirely audible. In both classes, there were sections of the recording where learner comments were not picked up by the recording device. To maintain the validity of the data, gaps were put in place in the transcription.

feedback on Portfolios

Svetlana – Very impressed with app, felt it would be better at beginning of course, used it to isolate muscles + was able to label underneath muscles

Nicole – very impressed with app, again felt / it would be better at beginning of course, was able use it easy enough. Use of seeing /visual aspect of body diagrams helped her work.

Chloe – Skeletal System -> found app very useful tool, created labels on skeleton to aid learning. to help her memory.

Dissection tool used / to dissect heart so as to view heart chambers.

SARAH -> Dissected Body down to the components that she didn't know, found it useful + would use it again

RASILA -> muscular System -> used to point out muscles, would use in future, very interactive / visually helped with learning helped memory.

Open Coding - keywords identified

It was really good, there was a variety of activities that related to the classes and it was good to be able to see the models from different angles. I liked it. The class time went really quickly. I was able to look up the youtube videos for help on how to do stuff. I think using it from the start of the course would be a better way to do it.

Yeah the demos helped me to grasp the idea, I enjoyed using the app I used it to print off my models and use for study notes. I think there could have been more time allowed to get the work done. It was good to see other people's work and see how others were doing.

I think the same stuff could be learned in class but this was more fun, I liked how interactive it was being able to filter the systems and do the dissections on the organs. I really enjoyed labelling the models and doing the activities. I think the questions in the quiz are very difficult and if they were more like the ones in the exam it would be better.

I think it was very helpful, I was able to see the organs and body in more detail and isolate the different parts of the body. I think it would have been better if we used this from the start as we have exams coming up now and theres not much time left on the course.

Ive never used computers for learning like this before, I liked how the models gave more views on the anatomy than the books but I was frustrated at times trying to use the mouse and get the functions to work. I would still prefer a teacher to deliver the lesson to the class.

I think it would work well using it with the book, I learned some new things from seeing the 3D models and I found it more interesting to learn with. It was good that we could save the work and come back to it and see it on other devices.

I found it easy to use it was like a computer game, I think it would be good to use this in class at times instead of the book. It was good to be able to see how the organs connected in the body and see how they were broken apart. I also liked how I could email the model to other people.

Directive coding themes

Q. Did you find the project interesting? If so Why/Why not? Could you give me an example what you found the most/least interesting in the project?

I enjoyed using the Biodigital app, it has a lot of systems that help to learn about anatomy. I think some of the descriptions are a bit advanced for the level we need to know. Also, the quiz was very difficult even the multiple-choice questions.

Q. What did you find difficult/easy in using the technology and why did you find these difficult?

Yeah I think technology should be used more on this course, but sometimes people in the class might not be I.T savvy and its probably better if the teacher shows the models on the screen until everyone gets used to the app… …..

I was frustrated at the start because I couldn't log in and I had difficulty learning how to use the mouse and finding my way around the screen. Once I was shown how to login and separate the systems in the model it was better. I think this would be better if we used it from the start and didn't have as many tasks to do in one class.

I thought it was good but it would have been better if we used it from the start of the course because we didn't have much time to do the lessons at the end.

Q. Do think the exercises enable you to present, create work? If so how?

Yea it did, when we worked on our own models and could add in the labels and stuff that was creative and we could then use them to present at the end.

I think it's very creative way to learn the subject, there are a lot of features in the app than help to learn more detail and I liked how there is features that show health conditions and examples of dissections. The library feature was very good to see how the dissections work.

Q. Do you think how you learned using this technology was different? If so why/why not?

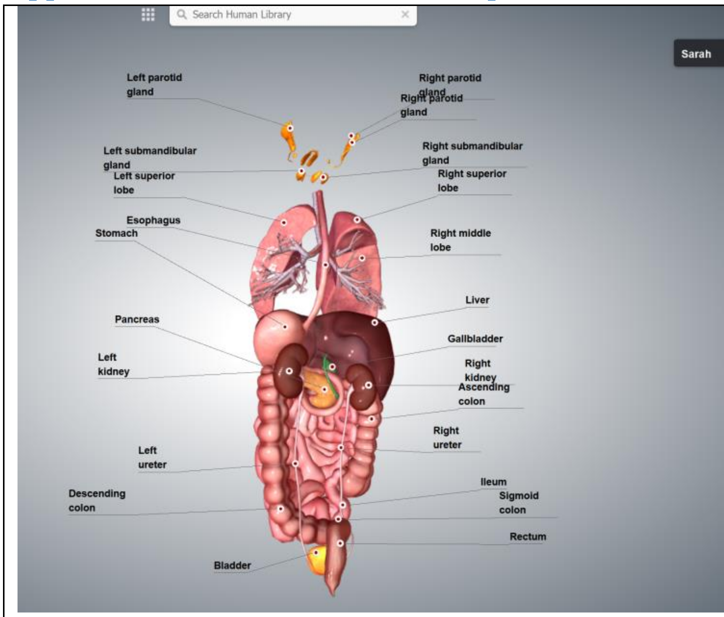
Yeah it was more visual, I could see the parts of the body more clearly, could see in greater detail and that helped me compared to looking at pictures in the book.

It was more interesting to be doing the discretions and exploring the different systems it helped build on the lessons we already had done in other classes.

Q. Would working with the technology in groups be a better approch to A&P Simulation? if so how?

I think working in groups would be better as those who know more I.T could help others who don't know as much... perhaps you could group people who know about I.T with those who know more about anatomy and physiology.

Appendix L Student Portfolio Samples



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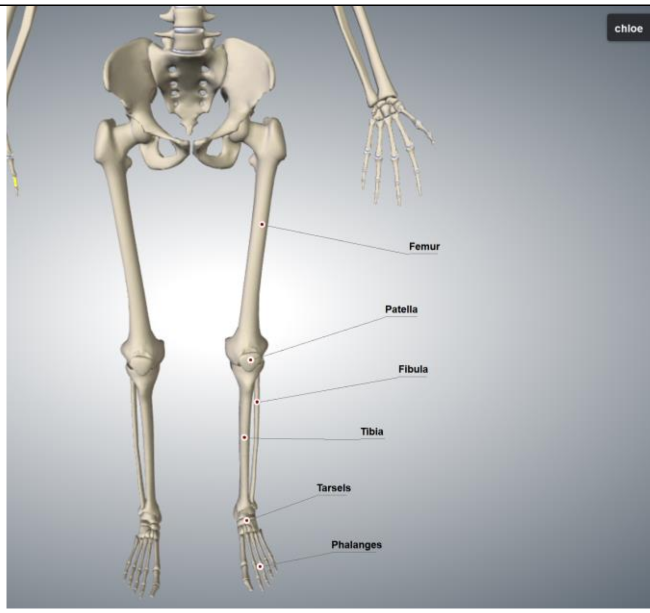

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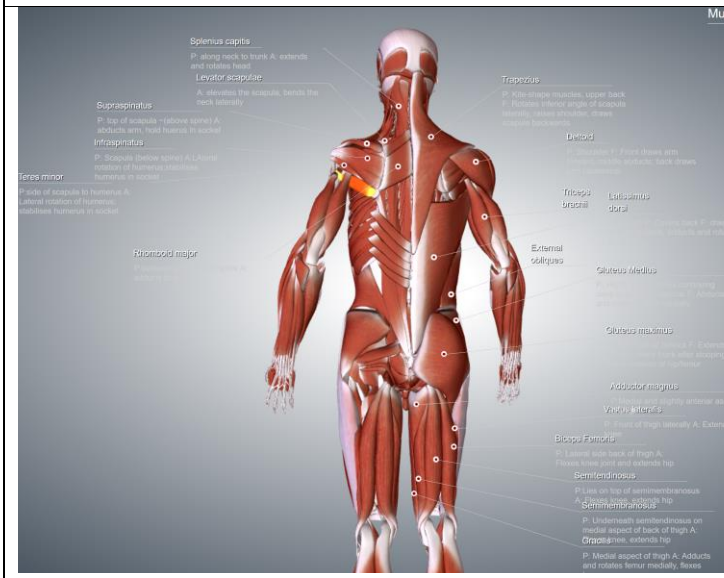

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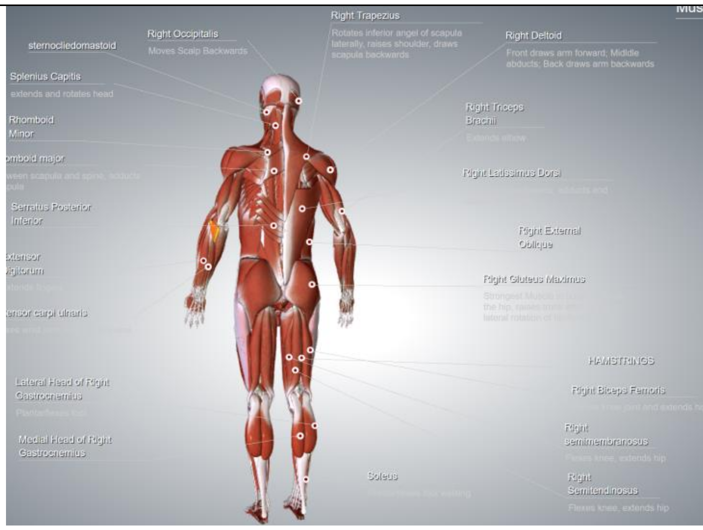

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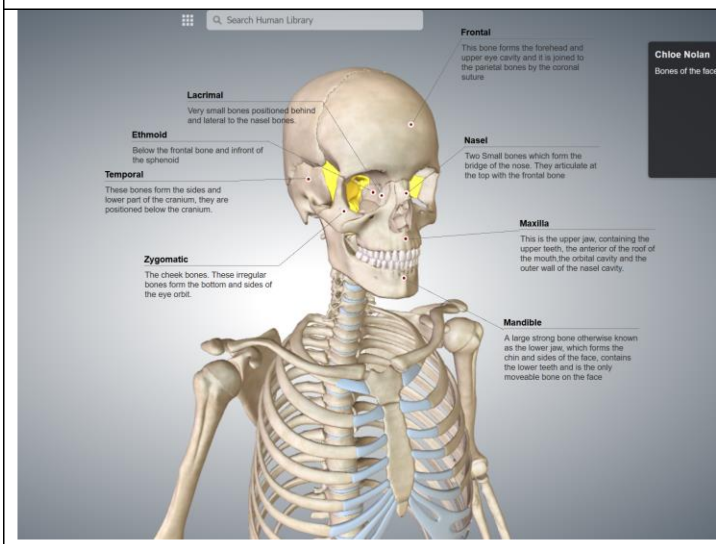

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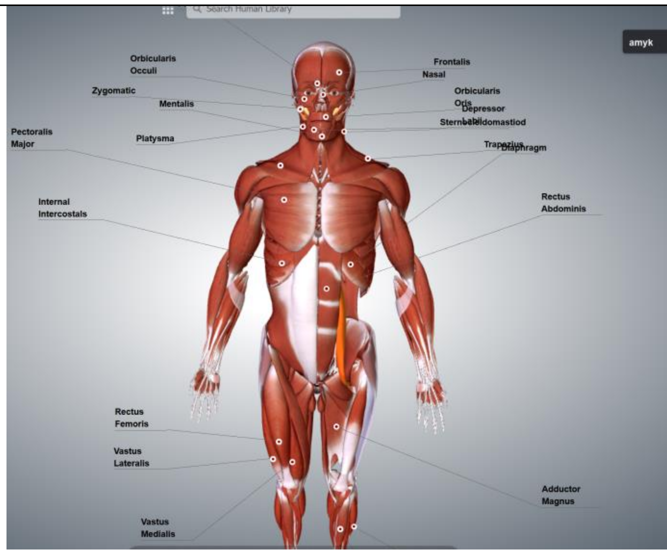

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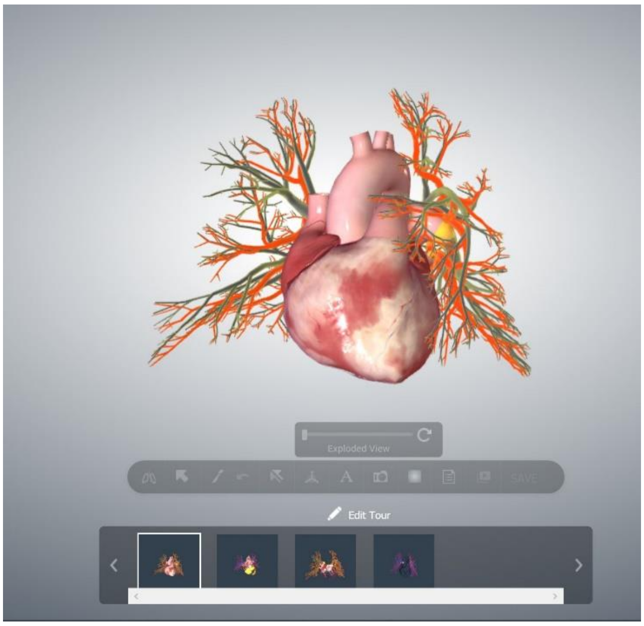

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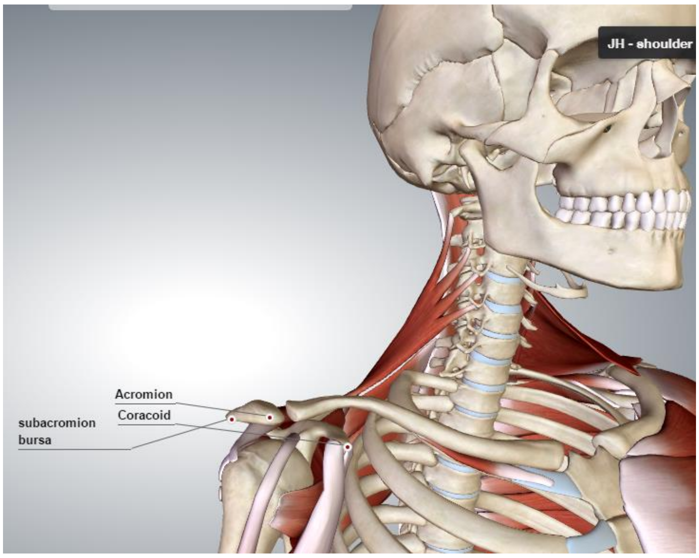

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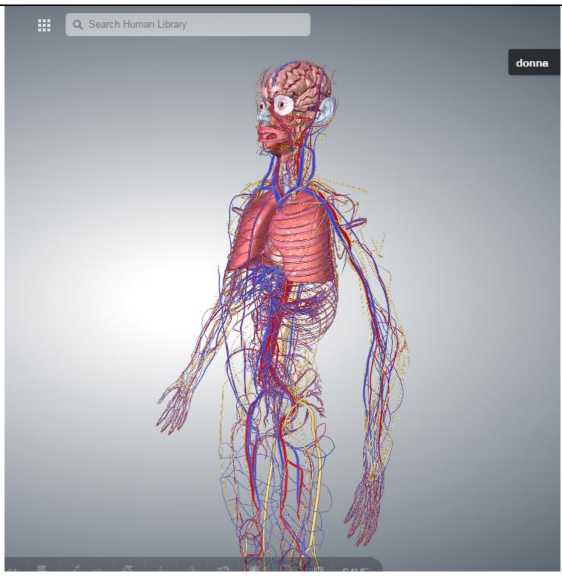

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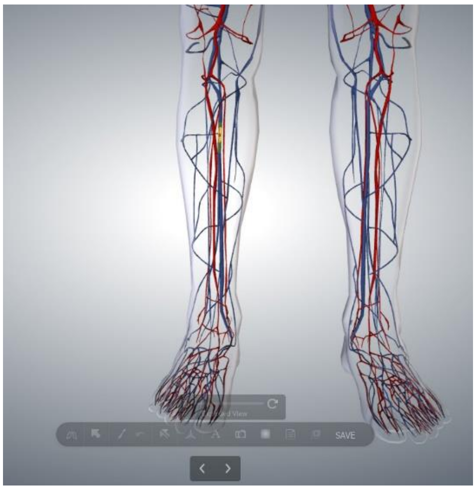

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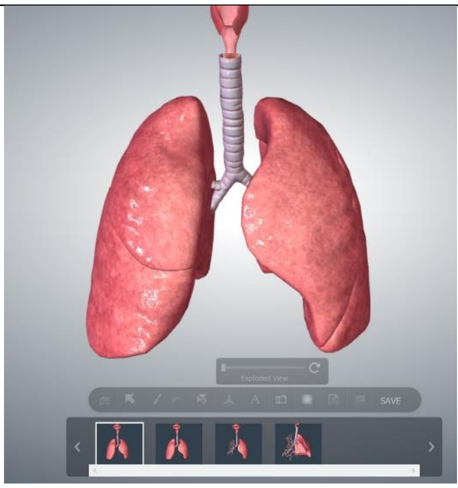

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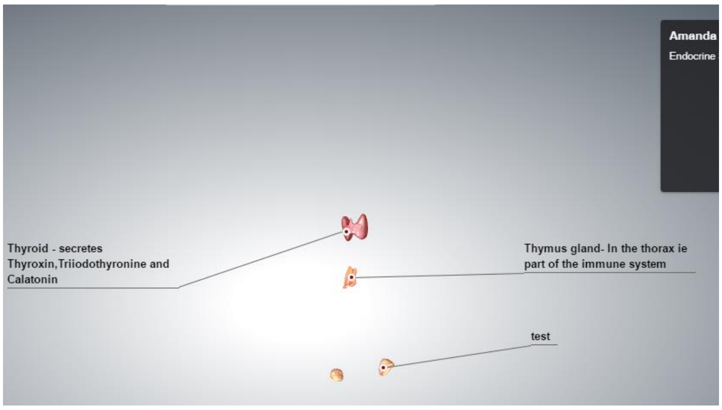


Available at: http://bit.ly/2oOsTmp

School of Computer Science and Statistics Research Ethical Application Form

Part A

Project Title: An Investigation into the use of technology in an active learning environment in the teaching of Anatomy and Physiology to Adult Learners.

Name of Lead Researcher (student in case of project work): Barry Ryan

Name of Supervisor: Dr Inmaculada Arnedillo-Sánchez

TCD E-mail: bryan3@tcd.ie Contact Tel No.: 0872422595

Course Name and Code (if applicable): MSc Technology and Learning

Estimated start date of survey/research: Jan 2017

I confirm that I will (where relevant):

- Familiarize myself with the Data Protection Act and the College Good Research Practice guidelines http://www.tcd.ie/info_compliance/dp/legislation.php;
- Tell participants that any recordings, e.g. audio/video/photographs, will not be identifiable unless prior written permission has been given. I will obtain permission for specific reuse (in papers, talks, etc.)
- Provide participants with an information sheet (or web-page for web-based experiments) that describes the main procedures (a copy of the information sheet must be included with this application)
- Obtain informed consent for participation (a copy of the informed consent form must be included with this application)
- Should the research be observational, ask participants for their consent to be observed
- Tell participants that their participation is voluntary
- Tell participants that they may withdraw at any time and for any reason without penalty
- Give participants the option of omitting questions they do not wish to answer if a questionnaire is used
- Tell participants that their data will be treated with full confidentiality and that, if published, it will not be identified as theirs
- On request, debrief participants at the end of their participation (i.e. give them a brief explanation of the study)
- Verify that participants are 18 years or older and competent to supply consent.
- If the study involves participants viewing video displays then I will verify that they understand that if they or anyone in their family has a history of epilepsy then the participant is proceeding at their own risk
- Declare any potential conflict of interest to participants.
- Inform participants that in the extremely unlikely event that illicit activity is reported to me during the study I will be obliged to report it to appropriate authorities.
- Act in accordance with the information provided (i.e. if I tell participants I will not do something, then I will not do it).

Signed: Barry Ryan ____________________ Date: 09/01/2017.................................

Lead Researcher/student in case of project work

Part B

Please answer the following questions.		***Yes/No***
Has this research application or any application of a similar nature connected to this research project been refused ethical approval by another review committee of the College (or at the		No
Will your project involve photographing participants or electronic audio or video recordings?		Yes
Will your project deliberately involve misleading participants in any way?		No
Does this study contain commercially sensitive material?		No
Is there a risk of participants experiencing either physical or psychological distress or discomfort? If yes, give details on a separate sheet and state what you will tell them to do if they should experience		No
Does your study involve any of the following?	Children (under 18 years of age)	No
	People with intellectual or communication difficulties	No
	Patients	No

School of Computer Science and Statistics Research Ethical Application Form

Details of the Research Project Proposal must be submitted as a separate document to include the following information:

1. Title of project
2. Purpose of project including academic rationale
3. Brief description of methods and measurements to be used
4. Participants - recruitment methods, number, age, gender, exclusion/inclusion criteria, including statistical justification for numbers of participants
5. Debriefing arrangements
6. A clear concise statement of the ethical considerations raised by the project and how you intend to deal with them
7. Cite any relevant legislation relevant to the project with the method of compliance e.g. Data Protection Act etc.

Part C

I confirm that the materials I have submitted provided a complete and accurate account of the research I propose to conduct in this context, including my assessment of the ethical ramifications.

Signed: ____________________ Date:..09/01/2017..................................

There is an obligation on the lead researcher to bring to the attention of the SCSS Research Ethics Committee any issues with ethical implications not clearly covered above.

Part D

If external or other TCD Ethics Committee approval has been received, please complete below.

External/TCD ethical approval has been received and no further ethical approval is required from the School's Research Ethical Committee. I have attached a copy of the external ethical approval for the School's Research Unit.

Signed Date: .

Lead Researcher/student in case of project work

Part E

If the research is proposed by an undergraduate or postgraduate student, please have the below section completed.

I confirm, as an academic supervisor of this proposed research that the documents at hand are complete (i.e. each item on the submission checklist is accounted for) and are in a form that is suitable for review by the SCSS Research Ethics Committ

Signed: Date: 09/01/2017

Supervisor

Completed application forms together with supporting documentation should be submitted electronically to research-ethics@scss.tcd.ie Please use TCD e-mail addresses only. When your application has been reviewed and approved by the Ethics committee hardcopies with original signatures should be submitted to the School of Computer Science & Statistics, Room F37, O'Reilly Institute, Trinity College, Dublin 2

TRINITY COLLEGE DUBLIN

INFORMATION SHEET FOR PROSPECTIVE PARTICIPANTS

Project: An Investigation into the use of technology in an active learning environment in the teaching of Anatomy and Physiology to Adult Learners.

BACKGROUND OF RESEARCH:

The background to this research relates to the difficulties adult learners face in learning Anatomy and Physiology, in particular the issues with information being abstract and the complexity of various systems within the human body**.**The purpose of the research is to investigate the effectiveness of teaching Anatomy and Physiology to adult learners using computer simulation. In particular what specific effects does computer simulation have on student engagement? How can computer simulation address the difficulties identified in learning abstract information? Are some of the questions to be addressed.

The work is being undertaken by the researcher towards the fulfilment of a requirement for the M.Sc. in Technology and Learning in Trinity College Dublin.

PROCEDURES OF THIS STUDY:

Participation in the research is completely optional and voluntary. You may withdraw at any time. If you choose to participate, the research will proceed as follows:

1. Students will be asked to complete a brief survey about current use of IT applications and asked to identify A&P topics that have been difficult to understand/learn.

2. A series of computer simulations will be run in class over a 5 week period where students will be shown how to use the Biodigital software and a number of exercises will be covered in class dealing with topics that have been identified. The researcher will be present in the room for these classes taking notes and populating a formative assessment rubric.

3. Students will then work on building a portfolio of graphics generated from screen captures and videos taken using the bio digital software.

4. Once complete students can volunteer to present their work to the class, students will then be asked if they would like to participate in a focus group discussion. No recordings will be replayed in any public forum or made available to any audience other than the researcher.

5. At the end of the final lesson students will be asked to complete an evaluation survey.

Voluntary nature

Participating in this project is voluntary. You may change your mind and stop at any time. You may also choose to not answer a question for any reason. If a student does not wish to participate in the learning activity they will be accommodated in the supervised study hall and be assigned revision work for the Anatomy and Physiology exam.

Benefits

The aim of this project is to identify the improvement of students understanding and depth of learning Anatomy and physiology through constructionist simulations in a collaborative learning environment.

Risks and Discomforts:

Answering questions about one's experiences may be uncomfortable. You can choose not to answer a question at any time. You may withdraw from the study at any time without penalty. You may withdraw your permission of participation at any time.

Confidentiality

I plan to publish the results of this study. My report will not include any information that would identify you or the college. To keep this information safe, I will store any audio file to an encrypted and password-protected USB device. This USB device will be stored in a secure safe for the duration of the learning experience. I will remove or change names in the interview transcripts.

I Barry Ryan am undertaking research in order to highlight the advantages of using technology in the teaching of anatomy and physiology to adult learners. I promise to ensure good ethical practice in conducting the research. I promise at all times to negotiate permission to conduct the research, respect confidentiality, and to ensure participants' rights to withdraw at any time from the research.

RESEARCHERS CONTACT DETAILS: bryan3@tcd.ie, phone: 0872422595

TRINITY COLLEGE DUBLIN
INFORMEDCONSENTFORM

Lead Researcher: Barry Ryan

Project: An Investigation into the use of technology in an active learning environment in the teaching of Anatomy and Physiology to Adult Learners.

BACKGROUND OF RESEARCH:

The background to this research relates to the difficulties adult learners face in learning anatomy and physiology, in particular the issues with information being abstract and the complexity of various systems within the human body**.**The purpose of the research is to investigate the effectiveness of teaching Anatomy and Physiology to adult learners using computer simulation. In particular what specific effects does computer simulation have on student engagement? How can computer simulation address the difficulties identified in learning abstract information? Are some of the questions to be addressed.

The work is being undertaken by the researcher towards the fulfilment of a requirement for the M.Sc. in Technology and Learning in Trinity College Dublin.

PROCEDURES OF THIS STUDY:

Participation in the research is completely optional and voluntary. You may withdraw at any time. If you choose to participate, the research will proceed as follows:

1. Students will be asked to complete a brief survey about current use of IT applications and asked to identify A&P topics that have been difficult to understand/learn.

2. A series of computer simulations will be run in class over a 5 week period where students will be shown how to use the Biodigital software and a number of exercises will be covered in class dealing with topics that have been identified. The researcher will be present in the room for these classes taking notes and populating a formative assessment rubric.

3. Students will then work on building a portfolio of graphics generated from screen captures and videos taken using the bio digital software.

4. Once complete students can volunteer to present their work to the class, students will then be asked if they would like to participate in a focus group discussion. No recordings will be replayed in any public forum or made available to any audience other than the researcher.

5. At the end of the final lesson students will be asked to complete an evaluation survey.

PUBLICATION:

The research will be published in the researcher's dissertation for the M.Sc. in Technology and Learning in Trinity College Dublin. Conclusions and findings may also be shared among FET management to inform policy decisions around the use of computer simulation in the teaching of A&P modules. All data will be aggregated anonymously and research reported on aggregate results.

Consent Form for students participating in the learning experience.

DECLARATION:

- I am 18 years or older and am competent to provide consent.
- I have read, or had read to me, a document providing information about this research and this consent form. I have had the opportunity to ask questions and all my questions have been answered to my

satisfaction and understand the description of the research that is being provided to me.

- I agree that my data is used for scientific purposes and I have no objection that my data is published in scientific publications in a way that does not reveal my identity.
- I understand that if I make illicit activities known, these will be reported to appropriate authorities.
- I understand that I may stop electronic recordings at any time, and that I may at any time, even subsequent to my participation have such recordings destroyed (except in situations such as above).
- I understand that, subject to the constraints above, no recordings will be replayed in any public forum or made available to any audience other than the current researchers/research team.
- I freely and voluntarily agree to be part of this research study, though without prejudice to my legal and ethical rights.
- I understand that I may refuse to answer any question and that I may withdraw at any time without penalty.
- I understand that my participation is fully anonymous and that no personal details about me will be recorded.
- I understand that if I or anyone in my family has a history of epilepsy then I am proceeding at my own risk.
- I have received a copy of this agreement.

Consent form for students participating in the learning experience.

PARTICIPANT'SNAME: ....

PARTICIPANT'S SIGNATURE: ....agree to take part in this research project.

Date...................................

Statement of investigator's responsibility: I have explained the nature and purpose of this research study, the procedures to be undertaken and any risks that may be involved. I have offered to answer any questions and fully answered such questions. I believe that the participant understands my explanation and has freely given informed consent.

Signature of Researcher.................

Date...................................

RESEARCHERS CONTACT DETAILS: bryan3@tcd.ie, phone: 0872422595

TRINITY COLLEGE DUBLIN

INFORMATIONSHEETFORPROSPECTIVETEACHERS

Project: An Investigation into the use of technology in an active learning environment in the teaching of Anatomy and Physiology to Adult Learners.

BACKGROUND OF RESEARCH:

The background to this research relates to the difficulties adult learners face in learning Anatomy and Physiology, in particular the issues with information being abstract and the complexity of various systems within the human body**.**The purpose of the research is to investigate the effectiveness of teaching Anatomy and Physiology to adult learners using computer simulation. In particular what specific effects does computer simulation have on student engagement? How can computer simulation address the difficulties identified in learning abstract information? Are some of the questions to be addressed.

The work is being undertaken by the researcher towards the fulfilment of a requirement for the M.Sc. in Technology and Learning in Trinity College Dublin.

PROCEDURES OF THIS STUDY:

Participation in the research is completely optional and voluntary. You may withdraw at any time. If you choose to participate, the research will proceed as follows:
Students will be asked to complete a brief survey about current use of IT applications and asked to identify A&P topics that have been difficult to understand/learn.

A series of computer simulations will be run in class over a 5 week period where students will be shown how to use the Biodigital software and a number of exercises will be covered in class dealing with topics that have been identified. The researcher will be present in the room for these classes taking notes and populating a formative assessment rubric.

Students will then work on building a portfolio of graphics generated from screen captures and videos taken using the bio digital software.

Once complete students can volunteer to present their work to the class, students will then be asked if they would like to participate in a focus group discussion. No recordings will be replayed in any public forum or made available to any audience other than the researcher.

At the end of the final lesson students will be asked to complete an evaluation survey.

Voluntary nature
Participating in this project is voluntary. You may change your mind and stop at any time. You may also choose to not answer a question for any reason. If a student does not wish to participate in the learning activity they will be accommodated in the supervised study hall and be assigned revision work for the Anatomy and Physiology exam.

Benefits
The aim of this project is to identify the improvement of students understanding and depth of learning Anatomy and physiology through constructionist simulations in a collaborative learning environment.

Risks and Discomforts:
Answering questions about one's experiences may be uncomfortable. You can choose not to answer a question at any time. You may withdraw from the study at any time without penalty. You may withdraw your permission of participation at any time.

Confidentiality
I plan to publish the results of this study. My report will not include any information that would identify you or the college. To keep this information safe, I will store any audio file to an encrypted and password-protected USB device. This USB device will be stored in a secure safe for the duration of the learning experience. I will remove or change names in the interview transcripts.

I Barry Ryan am undertaking research in order to highlight the advantages of using technology in the teaching of anatomy and physiology to adult learners. I promise to ensure good ethical practice in conducting the research. I promise at all times to negotiate permission to conduct the research, respect confidentiality, and to ensure participants' rights to withdraw at any time from the research.

RESEARCHERS CONTACT DETAILS: bryan3@tcd.ie, phone: 0872422595

TRINITY COLLEGE DUBLIN
TEACHERS INFORMEDCONSENTFORM

Lead Researcher: Barry Ryan

Project: An Investigation into the use of technology in an active learning environment in the teaching of Anatomy and Physiology to Adult Learners.

BACKGROUND OF RESEARCH:
The background to this research relates to the difficulties adult learners face in learning anatomy and physiology, in particular the issues with information being abstract and the complexity of various systems within the human body**.** The purpose of the research is to investigate the effectiveness of teaching Anatomy and Physiology to adult learners using computer simulation. In particular what specific effects does computer simulation have on student engagement? How can computer simulation address the difficulties identified in learning abstract information? Are some of the questions to be addressed.

The work is being undertaken by the researcher towards the fulfilment of a requirement for the M.Sc. in Technology and Learning in Trinity College Dublin.

PROCEDURES OF THIS STUDY:
Participation in the research is completely optional and voluntary. You may withdraw at any time. If you choose to participate, the research will proceed as follows:
Students will be asked to complete a brief survey about current use of IT applications and asked to identify A&P topics that have been difficult to understand/learn.

A series of computer simulations will be run in class over a 5 week period where students will be shown how to use the Biodigital software using various youtube tutorials and a number of practical exercises will be covered in class with the assistance of the teacher acting as a facilitator in the delivery of the e-lessons. The researcher will also be present in the room for these classes offering technical assistance as required and taking notes and populating a formative assessment rubric.

Students will then work on building a portfolio of graphics generated from screen captures and videos taken using the bio digital software.

Once complete students can volunteer to present their work to the class, students will then be asked if they would like to participate in a focus group discussion. No recordings will be replayed in any public forum or made available to any audience other than the researcher.

At the end of the final lesson will be asked to complete an evaluation survey. The teacher will also be asked to participate in a recorded interview at the end of the final lesson based on the themes of the focus group discussion.

PUBLICATION:
The research will be published in the researcher's dissertation for the M.Sc. in Technology and Learning in Trinity College Dublin. Conclusions and findings may also be shared among FET management to inform policy decisions around the use of computer simulation in the teaching of A&P modules. All data will be aggregated anonymously and research reported on aggregate results.

Consent Form for teachers participating in the learning experience.

DECLARATION:
I am 18 years or older and am competent to provide consent.
I have read, or had read to me, a document providing information about this research and this consent form. I have had the opportunity to ask questions and all my questions have been answered to my satisfaction and understand the description of the research that is being provided to me.
I agree that my data is used for scientific purposes and I have no objection that my data is published in scientific publications in a way that does not reveal my identity.
I understand that if I make illicit activities known, these will be reported to appropriate authorities.
I understand that I may stop electronic recordings at any time, and that I may at any time, even subsequent to my participation have such recordings destroyed (except in situations such as above).
I understand that, subject to the constraints above, no recordings will be replayed in any public forum or made available to any audience other than the current researchers/research team.
I freely and voluntarily agree to be part of this research study, though without prejudice to my legal and ethical rights.
I understand that I may refuse to answer any question and that I may withdraw at any time without penalty.
I understand that my participation is fully anonymous and that no personal details about me will be recorded.
I understand that if I or anyone in my family has a history of epilepsy then I am proceeding at my own risk.
I have received a copy of this agreement.

Consent form for students participating in the learning experience.

TEACHERS NAME: ....

TEACHERS SIGNATURE: ....agree to take part in this research project.

Date...................................

Statement of investigator's responsibility: I have explained the nature and purpose of this research study, the procedures to be undertaken and any risks that may be involved. I have offered to answer any questions and fully answered such questions. I believe that the teacher understands my explanation and has freely given informed consent.

Signature of Researcher.................

Date...................................

RESEARCHERS CONTACT DETAILS: bryan3@tcd.ie, phone: 0872422595

Letter to Principle and Board of Management

Dear, Deirdre

Permission to undertake research:

As part of my work in the Masters in Technology and Learning in Trinity College, I am conducting research into the use of Constructionist Simulations in a collaborative learning environment in the teaching of Anatomy and Physiology to Adult Learners. I would be grateful if you would give your permission and support for this project.

My data collection methods will include data logs on the student's activities using TEL software, access to anonymised exam results on the A&P ITEC module, questionnaires and a focus group interview with the students. The course tutor will facilitate the learning experience with my assistance and I will complete an observational report after each lesson. An audio recording device will be used to record interviews with the students. A series of screen shots will be taken of the students participating in the learning experience.

I guarantee that I will observe good ethical conduct throughout. I will secure permission from the students to involve them in the research. I will also secure permission from all colleagues who may become collaborators in the research. No research will commence until permission from both students and teaching staff is received. If a student does not wish to participate in the learning activity they will complete revision work for the Anatomy and Physiology exam.

I guarantee confidentiality of information and promise that the names of College, Staff or Students will not be made public.

I promise that I will make my research report available to you for scrutiny before it is published, if you wish, and I will make a copy of the report available for your files on its publication. I would be grateful if you would sign and return the slip below at your earliest convenience. I enclose two copies of this letter. Please retain one copy for your files

Yours sincerely,
Barry Ryan

I Barry Ryan am undertaking research in order to highlight the advantages of using technology in the teaching of anatomy and physiology to Adult learners. I promise to ensure good ethical practice in conducting the research. I promise at all times to negotiate permission to conduct the research, respect confidentiality, and to ensure participants' rights to withdraw at any time from the research.

Signature Barry Ryan

Name: Barry Ryan

To whom it may concern

I Deirdre HanamyPrincipal of Blackrock BFEI give permission for Barry Ryan to undertake her/his research in a classroom at BFEI.

Principal's signature:

Deirdre Hanamy

Consent Form for teachers participating in the learning experience.

DECLARATION:

- I am 18 years or older and am competent to provide consent.
- I have read, or had read to me, a document providing information about this research and this consent form.
- I have had the opportunity to ask questions and all my questions have been answered to my satisfaction and understand the description of the research that is being provided to me.
- I agree that my data is used for scientific purposes and I have no objection that my data is published in scientific publications in a way that does not reveal my identity.
- I understand that if I make illicit activities known, these will be reported to appropriate authorities.
- I understand that I may stop electronic recordings at any time, and that I may at any time, even subsequent to my participation have such recordings destroyed (except in situations such as above). I understand that, subject to the constraints above, no recordings will be replayed in any public forum or made available to any audience other than the current researchers/research team.
- I freely and voluntarily agree to be part of this research study, though without prejudice to my legal and ethical rights.
- I understand that I may refuse to answer any question and that I may withdraw at any time without penalty.
- I understand that my participation is fully anonymous and that no personal details about me will be recorded. I understand that if I or anyone in my family has a history of epilepsy then I am proceeding at my own risk. I have received a copy of this agreement.

Consent form for teachers participating in the learning experience.

TEACHERS NAME: JANICE HEALY

TEACHERS SIGNATURE: Janice Healy ...agree to take part in this research project.

Date 5-4-17

Statement of investigator's responsibility: I have explained the nature and purpose of this research study, the procedures to be undertaken and any risks that may be involved. I have offered to answer any questions and fully answered such questions. I believe that the teacher understands my explanation and has freely given informed consent.

Signature of Researcher.................

Date...................................

RESEARCHERS CONTACT DETAILS: bryan3@tcd.ie, phone: 0872422595

Consent Form for teachers participating in the learning experience.

DECLARATION:

- I am 18 years or older and am competent to provide consent.
- I have read, or had read to me, a document providing information about this research and this consent form.
- I have had the opportunity to ask questions and all my questions have been answered to my satisfaction and understand the description of the research that is being provided to me.
- I agree that my data is used for scientific purposes and I have no objection that my data is published in scientific publications in a way that does not reveal my identity.
- I understand that if I make illicit activities known, these will be reported to appropriate authorities.
- I understand that I may stop electronic recordings at any time, and that I may at any time, even subsequent to my participation have such recordings destroyed (except in situations such as above). I understand that, subject to the constraints above, no recordings will be replayed in any public forum or made available to any audience other than the current researchers/research team.
- I freely and voluntarily agree to be part of this research study, though without prejudice to my legal and ethical rights.
- I understand that I may refuse to answer any question and that I may withdraw at any time without penalty.
- I understand that my participation is fully anonymous and that no personal details about me will be recorded. I understand that if I or anyone in my family has a history of epilepsy then I am proceeding at my own risk. I have received a copy of this agreement.

Consent form for teachers participating in the learning experience.

TEACHERS NAME: SERENA DUFFY

TEACHERS SIGNATURE: Serena Duffy ...agree to take part in this research project.

Date 15/3/2017

Statement of investigator's responsibility: I have explained the nature and purpose of this research study, the procedures to be undertaken and any risks that may be involved. I have offered to answer any questions and fully answered such questions. I believe that the teacher understands my explanation and has freely given informed consent.

Signature of Researcher................

Date..................................

RESEARCHERS CONTACT DETAILS: bryan3@tcd.ie, phone: 0872422595

Principal and Board of Management Information Sheet

Research Participation
My name is Barry Ryan, I currently work for SOLAS in the corporate strategy and evaluation division.

Project: An Investigation into the use of technology in an active learning environment in the teaching of Anatomy and Physiology to Adult Learners.

BACKGROUND OF RESEARCH:

The background to this research relates to the difficulties adult learners face in learning Anatomy and Physiology, in particular the issues with information being abstract and the complexity of various systems within the human body**.**The purpose of the research is to investigate the effectiveness of teaching Anatomy and Physiology to adult learners using computer simulation. In particular what specific effects does computer simulation have on student engagement? How can computer simulation address the difficulties identified in learning abstract information? Are some of the questions to be addressed.

The work is being undertaken by the researcher towards the fulfilment of a requirement for the M.Sc. in Technology and Learning in Trinity College Dublin.

PROCEDURES OF THIS STUDY:
Participation in the research is completely optional and voluntary. You may withdraw at any time. If you choose to participate, the research will proceed as follows:
Students will be asked to complete a brief survey about current use of IT applications and asked to identify A&P topics that have been difficult to understand/learn.

A series of computer simulations will be run in class over a 5 week period where students will be shown how to use the Biodigital software and a number of exercises will be covered in class dealing with topics that have been identified. I will be present in the room for these classes taking notes and populating a formative assessment rubric, some screen shots of student’s work will be taken from the exercises prescribed in class.

Students will then work on building a portfolio of graphics generated from screen captures and videos taken using the bio digital software.

Once complete students can volunteer to present their work to the class, students will then be asked if they would like to participate in a focus group discussion. No recordings will be replayed in any public forum or made available to any audience other than the researcher.

At the end of the final lesson students will be asked to complete an evaluation survey.

All information that is collected by the researcher will be anonymised and stored in accordance with the Data Protection Act at Trinity College, Dublin. In the unlikely event that information about illegal activities should emerge during the study, I will follow the TCD data Protection policy and inform the relevant authorities. There may be lectures, Ph.D. theses, conference presentations and peer-reviewed journal articles written as a result of this project, however the students and school will not be identified.

Voluntary nature
Participating in this project is voluntary. A student may change their mind and stop at any time. A student may also choose to not answer a question for any reason. If a student does not wish to participate in the learning activity they will be accommodated with revision work for the Anatomy and Physiology exam.

Benefits
The aim of this project is to identify any improvements in students understanding and depth of learning Anatomy and physiology through constructionist simulations in a collaborative learning environment.

Risks and Discomforts:
Answering questions about one's experiences may be uncomfortable. A student can choose not to answer a question at any time. A student may withdraw from the study at any time without penalty. A student may withdraw their permission of participation at any time.

Confidentiality
I plan to publish the results of this study. My report will not include any information that would identify you or the school. To keep this information safe, I will move the audio file from the recorder to an encrypted and password-protected USB device. I will remove or change names in the interview transcripts. I cannot absolutely guarantee confidentiality because the students will share information in front of each other during the interview. I will address this by asking that students not repeat what others said.

I Barry Ryan am undertaking research in order to highlight the advantages of using technology in the teaching of anatomy and physiology to adult learners. I promise to ensure good ethical practice in conducting the research. I promise at all times to negotiate permission to conduct the research, respect confidentiality, and to ensure participants' rights to withdraw at any time from the research.

Principal and Board of Management Consent Form

Project: An Investigation into the use of technology in an active learning environment in the teaching of Anatomy and Physiology to Adult Learners.

The Board of Management has been provided with an information sheet which outlines the activities the students will take part in, how the data will be collected and stored and how it can contact the researcher.

The Board of Management understands that it may withdraw the college/training centre from the project at any time should it wish to do so for any reason and without penalty.

Signature of the chair of the Board of Management: .... Date: ....

Signature of the Principal: .... Date: ....

Name of College/Training Centre: ....

Signature of Project leader. Inmaculada Arnedillo Date: ....

RESEARCHERS: Barry Ryan, bryan3@tcd.ie, phone: 0872422595

Academic Supervisor: Inmaculada Arnedillo-Sánchez

Ethics Approval Timeline

Thursday, March 30, 2017 - 12:08
State change:
from *Commented by Reviewers; Pending REC Meeting*
to ***Approved***

Thursday, March 30, 2017 - 11:50
State change:
from *Assigned to Reviewers; Pending Comments*
to ***Commented by Reviewers; Pending REC Meeting***

Friday, March 24, 2017 - 15:09
State change:
from *Submitted to REC; Awaiting Reviewer Assignment*
to ***Assigned to Reviewers; Pending Comments***

Friday, March 24, 2017 - 15:09
State change:
from *Submitted to Supervisor; Pending Review*
to ***Submitted to REC; Awaiting Reviewer Assignment***

Friday, March 24, 2017 - 15:06
State change:
from *REC Amendments Required*
to ***Submitted to Supervisor; Pending Review***

Friday, March 24, 2017 - 10:22
State change:
from *Commented by Reviewers; Pending REC Meeting*
to ***REC Amendments Required***

Wednesday, March 22, 2017 - 15:14
State change:
from *Assigned to Reviewers; Pending Comments*
to ***Commented by Reviewers; Pending REC Meeting***

Friday, March 3, 2017 - 10:37
State change:
from *Submitted to REC; Awaiting Reviewer Assignment*
to ***Assigned to Reviewers; Pending Comments***

Friday, March 3, 2017 - 10:37

Appendix N NASA Task Load Index

NASA Task Load Index

Hart and Staveland's NASA Task Load Index (TLX) method assesses work load on five 7-point scales. Increments of high, medium and low estimates for each point result in 21 gradations on the scales.

	Task	Date

Mental Demand — How mentally demanding was the task?

Very Low — Very High

Physical Demand — How physically demanding was the task?

Very Low — Very High

Temporal Demand — How hurried or rushed was the pace of the task?

Very Low — Very High

Performance — How successful were you in accomplishing what you were asked to do?

Perfect — Failure

Effort — How hard did you have to work to accomplish your level of performance?

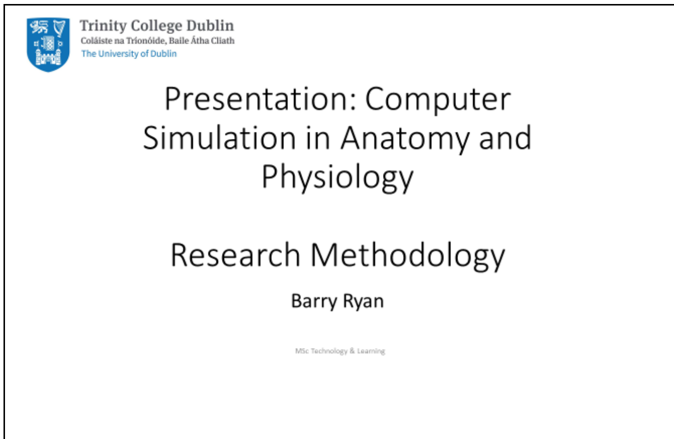
Very Low — Very High

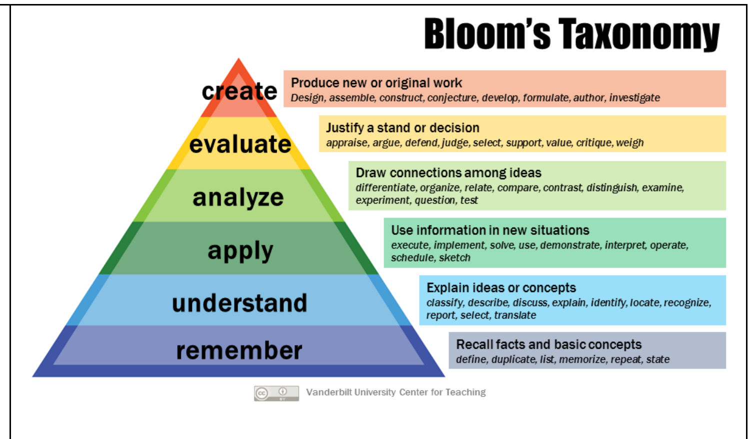
Frustration — How insecure, discouraged, irritated, stressed, and annoyed wereyou?

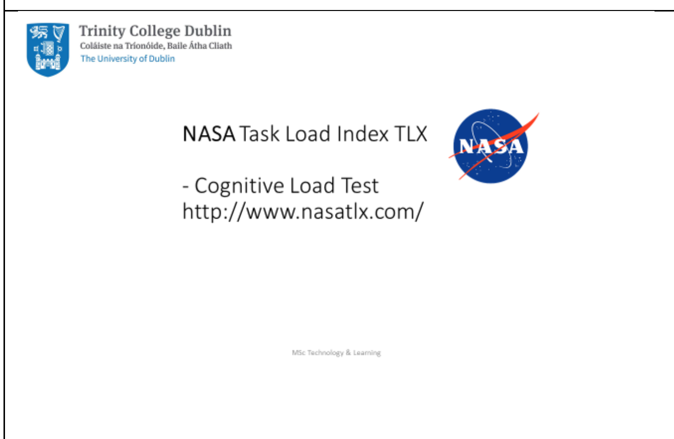
Very Low — Very High

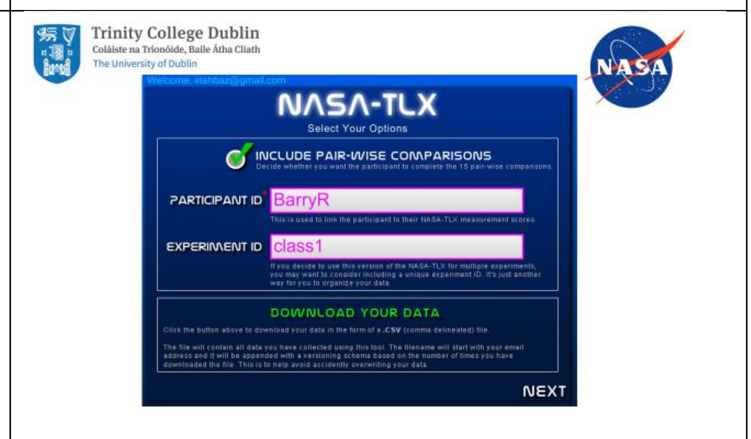
Figure K NASA task load index based on questionnaire (Hart 2006)

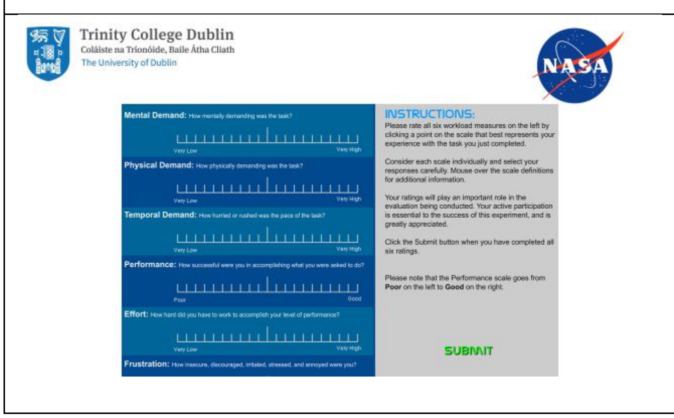
TLX Class presentation slides











TLX Results Table

experimentalID	participantID	tlx Score	scale mental	scale physical	scale temporal	scale perform	scale effort	scale frustration	workload mental	workload physical	workload temporal	workload perform	workload effort	workload frustration	workload Weighted mental	workload Weighted mphysical	workload Weighted temporal	workload Weighted perform	workload Weighted effort	workload Weighted frustration
Class1	NW	9.4	10	8	15	2	11	1	0.2	0.13	0.2	0.2	0.27	0	2	1.07	3	0.4	2.93	0
Class1	SM	47.6	43	50	55	39	49	35	0.2	0.2	0.2	0.07	0.27	0.07	8.6	10	11	2.6	13.07	2.33
Class1	DB	68.46	65	19	51	48	63	88	0.27	0	0.2	0.07	0.13	0.33	17.33	0	10.2	3.2	8.4	29.33
Class1	JennyS	43.73	43	41	62	41	33	35	0.27	0.07	0.2	0.2	0.2	0.07	11.47	2.73	12.4	8.2	6.6	2.33
class1	Chloen	58.13	64	29	59	35	64	54	0.33	0	0.27	0.13	0.2	0.07	21.33	0	15.73	4.67	12.8	3.6
class1	serenaduffy	48.8	74	18	54	21	59	25	0.27	0.07	0.27	0.27	0.13	0	19.73	1.2	14.4	5.6	7.87	0
class1	S.K	23.07	50	29	15	16	24	5	0.13	0.13	0.27	0.33	0.13	0	6.67	3.87	4	5.33	3.2	0
class1	ay	84.73	81	19	24	98	92	88	0.2	0	0.07	0.13	0.27	0.33	16.2	0	1.6	13.07	24.53	29.33
class1	rasila	59.07	58	28	39	76	64	19	0.27	0.07	0.13	0.2	0.33	0	15.47	1.87	5.2	15.2	21.33	0
class1	sharone	46	34	14	15	16	59	83	0.2	0	0.07	0.27	0.2	0.27	6.8	0	1	4.27	11.8	22.13
class1	Ethna	54.4	69	0	34	41	73	34	0.33	0	0.13	0.13	0.2	0.2	23	0	4.53	5.47	14.6	6.8
Class1	CLO	45.87	48	28	38	41	48	64	0.2	0	0.33	0.13	0.2	0.13	9.6	0	12.67	5.47	9.6	8.53
class1	Emma	60.33	65	38	58	45	63	64	0.27	0	0.2	0.13	0.2	0.2	17.33	0	11.6	6	12.6	12.8
class1	LK	58.4	51	53	48	77	76	37	0.2	0.2	0.2	0.2	0.13	0.07	10.2	10.6	9.6	15.4	10.13	2.47
CLASS1	GS	31.14	41	29	25	33	31	31	0.2	0.2	0.27	0.07	0.2	0.07	8.2	5.8	6.67	2.2	6.2	2.07
class1	Karen	41.74	46	37	46	11	49	36	0.2	0.07	0.27	0.13	0.33	0	9.2	2.47	12.27	1.47	16.33	0
class2	BM	27.94	22	20	24	34	59	25	0.27	0.13	0.27	0.27	0.07	0	5.87	2.67	6.4	9.07	3.93	0
class2	Amy	36.2	47	16	47	26	57	42	0.2	0.13	0.2	0.33	0.07	0.07	9.4	2.13	9.4	8.67	3.8	2.8
class2	CH	36.06	24	14	54	23	55	36	0.2	0.07	0.2	0.27	0.2	0.07	4.8	0.93	10.8	6.13	11	2.4
Class2	LiamH	42	62	12	36	32	52	30	0.2	0.07	0.33	0.2	0.2	0	12.4	0.8	12	6.4	10.4	0
class2	JennyK	33.2	40	13	42	11	52	29	0.2	0.07	0.13	0.27	0.27	0.07	8	0.87	5.6	2.93	13.87	1.93
class2	Connor	60.87	63	26	65	52	62	57	0.2	0	0.33	0.2	0.2	0.07	12.6	0	21.67	10.4	12.4	3.8
class2	Andrew	51.74	52	52	52	54	52	47	0.2	0	0.27	0.2	0.2	0.13	10.4	0	13.87	10.8	10.4	6.27
		46.5	50.1	25.8	41.7	37.9	54.2	42.0	0.2	0.1	0.2	0.2	0.2	0.1	11.6	2.0	9.4	6.7	10.8	6.0