CORA Cork Open Research Archive
Cartlann Taighde Oscailte Chorcaí

| | |
|---|---|
| Title | Enhanced e-learning and simulation for obstetrics education |
| Authors | Coffey, Donnchadh |
| Publication date | 2016 |
| Original Citation | Coffey, D. P. W. 2016. Enhanced e-learning and simulation for obstetrics education. PhD Thesis, University College Cork. |
| Type of publication | Doctoral thesis |
| Rights | © 2016, Donnchadh Padraig William Coffey. - http://creativecommons.org/licenses/by-nc-nd/3.0/ |
| Download date | 2026-10-06 18:04:20 |
| Item downloaded from | https://hdl.handle.net/10468/4513 |

UCC
University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

# ENHANCED E-LEARNING AND SIMULATION FOR OBSTETRIC EDUCATION

Donnchadh Padraig William Coffey, M.Sc., B.A.

A thesis submitted in fulfilment of the requirement for the degree of
Doctor of Philosophy

National University of Ireland, Cork

Department of Computer Science
August 2016

Thesis supervisors
Dr Sabin Tabirca, PhD.
Professor Richard Greene

# Acknowledgements

After a demanding and an intensive 3 years, the thesis is completed. It has been a period of intense learning for me, not only in the field of medicine and science, but also on a personal level. Writing this thesis has had a huge impact on me and I would like to acknowledge those people and entities of whom without their help and support I would not have successfully completed this thesis.

I would first like to thank my supervisors Dr. Sabin Tabirca and Prof. Richard Greene for aiding in the successful completion of the thesis work and subsequent thesis. You supported me greatly and were always willing to help me. I would particularly like to single out my supervisor Sabin Tabirca, I want to thank you for your excellent cooperation and for all of the opportunities I was given to conduct my research and further my thesis in UCC. I would also like to graciously thank Dr. Mairead O'Riordan for all her guidance through the interactions with Obstetric students and general help in conducting my obstetric research. I would also like to thank my fellow PhD colleagues for their help and support through module endeavors and general queries, thanking Tamara Vagg for her help and cups of coffee through statistical research.

In addition, I would like to thank UCC and its staff in both the Computer Science department for supplying the technologies and space needed to complete this thesis, and the Obstetrics and the Nursing and Midwifery department for assisting me in viewing and executing simulations within UCC. Most of all, I would like to thank my parents Billy and Alice for their huge help and support in helping me realise the potential of my work, I would not have done it without you. I would like to also thank my siblings Emma (and Jay), Stephen and Dearbhla for their added support through the years providing a much needed escape from the workload every odd weekend. I would also like to thank my girlfriend Shauna for keeping me sane for the past three years and supporting me through all the ups and downs. Thank you also to Shauna's family for providing me with much needed support and kindness.

Finally, to my friends and family. I am thankful to possess friends and family who can support me and also understand the time and effort it takes to undertake a thesis like this. I am thankful that throughout the course of this work my friends and family have gone above and beyond in their efforts to make sure I was supported and looked after to create a positive environment in order to complete my thesis.

# Table of Contents

**Acknowledgements** ..... **ii**
**List of Figures** ..... **vii**
**Declaration** ..... **x**
**Abstract** ..... **xi**
**List of Abbreviations** ..... **xii**
**Chapter 1. Introduction** ..... **1**
**Chapter 2. A Review of the Literature on Resources and Methods for learning.** **8**
2.1 Structure of Review ..... 8
2.1.1 Search Strategy ..... 8
2.1.2 Inclusion and Exclusion criteria ..... 10
2.2 E-learning in Medical Education and Learning Styles ..... 10
2.2.1 Search Strategy ..... 11
2.2.2 Review of the Literature ..... 13
Summary ..... 19
2.3 3D Modelling and Manipulation ..... 20
2.3.1 Search Strategy ..... 20
2.3.2 Review of the Literature ..... 22
Summary ..... 27
2.4 Video Production and Video Delivery ..... 27
2.4.1 Search Strategy ..... 28
2.4.2 Review of the Literature ..... 29
Summary ..... 35
2.5 Simulation Development and Utilization ..... 35
2.5.1 Search Strategy ..... 36
2.5.2 Review of the Literature ..... 37
Summary ..... 45
Conclusion to Literature Review ..... 46
**Chapter 3. E-learning in Medical Education & Learning styles** ..... **47**
3.1 Background: Online Learning and Learning Styles ..... 47
3.1.1 Importance of learning styles ..... 49
3.1.2 Similar work & resources ..... 52
3.2 Background of the Online Platform and Planning ..... 54
3.2.1 Why use an E-Learning/Learning Style Survey? ..... 55
3.2.2 Choosing the FSLSM and Subsequent Survey Index of Learning Styles. 57
3.2.3 Planning an E-learning System ..... 57
3.3 Development of the Online Survey Tools ..... 58
3.3.1 Background of survey creation ..... 59
3.3.2 Iterations and Deliberations of the Survey Construct ..... 59

3.3.3 Finished Survey and Process of System Delivery ..... 75
3.4 Results of the Learning Styles Survey ..... 77
3.5 User Interface Implementation and Discussion ..... 81
3.5.1 Continuation of Thesis Design and Implementation ..... 83
3.5.2 Tailoring Learning Style for UI Design and Resource Structure ..... 85
Summary ..... 87
**Chapter 4. 3D modelling and Manipulation ..... 88**
4.1 3D Modelling Background and Importance ..... 88
4.1.1 Importance of 3D in Medicine and Medical Education ..... 91
4.1.2 Similar Work and Examples ..... 93
4.2 3D Environment and Model Creation ..... 97
4.2.1 Baby model ..... 98
4.2.2 Amniotic Sac ..... 105
4.2.3 Placenta and Umbilical Cord ..... 107
4.2.4 Ventouse Cup ..... 109
4.2.5 Additional Models ..... 111
4.3 3D Animation and Output ..... 112
4.3.1 Cameras and Lighting ..... 112
4.3.2 Rigging models ..... 113
4.3.3 Animation and Key Framing ..... 115
4.4 Output ..... 118
4.5 Programming 3D Fixtures and Manipulation ..... 119
4.5.1 Fetal Head Application ..... 120
4.5.2 Placenta Position ..... 123
4.5.3 Fetal Heart Rate ..... 124
4.6 Trial Application Testing ..... 126
Summary ..... 126
**Chapter 5. Video Platform Creation and 3D Amalgam ..... 128**
5.1 Video Background ..... 128
5.2 Video on the Web ..... 129
5.3 Medical Educational Impact ..... 131
5.4 Capturing the Procedural Footage ..... 132
5.4.1 Procedural Capture Setup ..... 133
5.4.2 Normal Delivery Capture ..... 133
5.4.3 Ventouse Delivery ..... 134
5.4.4 Caesarean Section ..... 135
5.4.5 Placenta Examination and Removal ..... 135

5.5 Editing Videos for Web Integration ..... 135
5.5.1 Editing the Procedural Footage ..... 136
5.5.2 Editing the 3D Videos ..... 137
5.6 Online Video Application Development ..... 141
5.6.1 Interface Structure, Navigation and Design ..... 141
5.6.2 Generating the Resource Design ..... 143
5.6.3 Incorporating the video components and structuring the content ..... 144
5.7 Usability Testing ..... 154
5.7.1 Conducting the Usability Test ..... 154
5.7.2 Results of the usability test ..... 157
Summary ..... 160
**Chapter 6. Simulation Development and Utilisation ..... 161**
6.1 Simulation ..... 161
6.1.1 Educational Simulation ..... 162
6.1.2 Simulation in Medicine ..... 165
6.1.3 Learning Platform Concepts and Simulation Structure ..... 168
6.2 Physical Medical Simulator Examination ..... 169
6.2.1 Obstetric Orientated Simulation Examples and Inspection ..... 172
6.3 Sensor Technology Interaction and Integration ..... 174
6.3.1 Wiimote Use and Test Programming ..... 177
6.3.2 IMU Use and Mobile Device Testing ..... 180
6.3.3 Industry Sensor Sourcing, Employment and Management ..... 184
6.4 Finalised Sensor Approach and Framework ..... 191
6.4.1 Linking Sensor Tag with PC ..... 192
6.4.2 Connecting Sensor Tag with Unity 3D ..... 193
6.5 Final Simulation: Physical and Digital Amalgamation ..... 195
6.5.1 Design and framework ..... 195
6.5.2 Internal Content Construction and Scene Creation ..... 197
6.5.3 Physical Simulator and Sensor Setup ..... 203
6.5.4 Performance testing ..... 204
Summary ..... 206
**Chapter 7. Conclusion and Recommendations ..... 207**
Limitations ..... 210
Recommendations from this research ..... 210

**References** ..... **213**
**Appendices** ..... **226**

**Appendix A** National Perinatal Epidemiology Centre Ethical Approval……..**226**
**Appendix B** Letter to the Ward Managers, Ethical Approval……**228**
**Appendix C** Learning styles survey Leaflet…….....**230**
**Appendix D** Obstetric Learning Styles, FSLSM Questions……..**233**
**Appendix E** Sensor Acquisition Enquiry Email – sent to multiple companies….**242**

# List of Figures

Figure 1: E-learning MESH terms. .....11

Figure 2: Learning style MESH terms. .....11

Figure 3: Prisma flow diagram of the e-learning & learning styles key term searches for literature.....12

Figure 4: 3D MESH terms. .....20

Figure 5: Prisma flow diagram of the 3D & VR key term searches for literature. ....22

Figure 6: Video MESH terms. .....28

Figure 7: Prisma flow diagram of the Video key term search for literature. .....29

Figure 8: Simulation MESH terms.....36

Figure 9: Prisma flow diagram of the simulation key term search for literature. .....37

Figure 10: Connection layout of website/database configuration pipeline. .....61

Figure 11: Site layout and linear navigation progression.....64

Figure 12: Result page layout with textual and graphical representation. .....66

Figure 13: Linear navigation layout of restructured site. .....72

Figure 14: Learning style scale, fairly to highly. .....78

Figure 15: Age group learning styles. .....79

Figure 16: Highest education scale corresponding to learning style.....80

Figure 17: High IT competency levels in students.....81

Figure 18: Framework for resource creation and progression. .....85

Figure 19: Arch Visual VR medical environment. .....94

Figure 20: Left - Ghost productions example, Right – Nucleus medical media example. .....96

Figure 21: BabyCenter 3D animation of labour and delivery. .....97

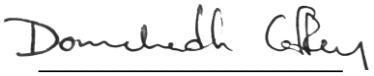
Figure 22: Front view and side view, 3D baby model head creation. .....101

Figure 23: Subdivision surface of the 3D baby head guided to reference image. ...102
Figure 24: Right: Low poly body, Left: High poly body with detailing and subdivision. ...103
Figure 25: Outline and low poly created 3D models of ears, hand and foot.....103
Figure 26: Unwrapped model, selected and seamed 3D baby model. .....104
Figure 27: Placenta model constructed and textured. .....107
Figure 28: Umbilical cord and placenta placed in amniotic sac. .....107
Figure 29: Amniotic sac, placenta, and umbilical cord rendered and unrendered 3D models. .....109
Figure 30: Ventouse vacuum cup unrendered model.....111
Figure 31: Armature half with labels and posed armature.....114
Figure 32: Normal delivery rendered image and ventouse delivery rendered image. .....118
Figure 33: Fetal head online application, right and wrong answers. .....121
Figure 34: Mobile interaction of the basic functionality of the fetal head Application. .....122
Figure 35: Placenta position mobile application still image. .....124
Figure 36: Fetal heart rate mobile application still image.....126
Figure 37: Normal delivery 3D animation still. .....139
Figure 38: Ventouse delivery 3D animation still. .....140
Figure 39: Video resource design blueprint. .....142
Figure 40: Video resource example with syncing 3D and procedural videos.....151
Figure 41: Video resource usability test structure. .....157
Figure 42: Post-test results separated by likert scale numbered questions. .....159

Figure 43: Wiimote connection, orientation configuration and operational processes .....179
Figure 44: Wiimote, 3D model connection and orientation manipulation.....180
Figure 45: Phone IMU connection, configuration and operation of orientation data .....181
Figure 46: Movement of mobile device (attached to fetal doll) in correspondence to the 3D fetal object. .....183
Figure 47: Comparative matrix of the IMU derivative options. .....186
Figure 48: CC260 Sensor Tag architecture. .....192
Figure 49: Final resource Internal and External structures. .....196
Figure 50: Application internal structure path. .....198
Figure 51: Mesh Collider in use with the Reverse Normal technique. .....200
Figure 52: IMP Marker position and removal, label injection on entering empty GameObject.....202
Figure 53: Final Physical simulator and sensor setup. .....204

# Declaration

This thesis is entirely my own work and it has not been submitted for a degree at this or at any other university.



Donnchadh Coffey

# Abstract

**Background**

In medicine, new media technologies have been used in recent years to simulate situations and techniques that may not be common enough for students to experience in reality or may not be visible to the naked eye. Especially in areas of medicine focusing on important surgeries or procedures, these simulated designs could train students and ultimately prevent possible risk or morbidity.

**Aims**

The aim of this thesis was to develop a multipurpose hybrid educational resource based on a physical/software driven simulator platform enabling the use of multimedia properties like 3D and video to enhance the educational training of obstetrics students through haptic interactions. All of this content was enabled by the learning preferences of the obstetric students involved.

**Method**

The learning resource was developed using a combination of student learning preference, online learning content, 3D, video, human patient simulations and sensor technology interaction. These mediums were all interconnected to create a multipurpose resource.

The learning preference was collected through a developed student online survey, the results consequently informed the creation of the other aspects of the finished resource. The interactive aspects were created through position and orientation sensors and the 3D/video influences which localised the position and orientation of an object like a fetal model relative to a human patient simulator. All of these methods combined with added assessment contributions for obstetric tutors, enabled the finalising of a prototype.

**Conclusion**

This form of learning resource has a vital role in the progressing higher level education in the digital age. This proposal is the development of a new type of joint simulator that allows students and practitioners physically involve themselves in a series of processes while assessing their own progression through real time digital feedback in the form of video narrative and analytics. Usability test was not conducted on the full resource (one on the video platform) due to time limitations.

# List of Abbreviations

| | |
|---|---|
| **2D** | Two dimensional |
| **3D** | Three dimensional |
| **AAeLS** | Automatic adaptive e-learning system |
| **AAMC** | Association of American medical colleges |
| **ADC** | Analogue to digital convertor |
| **ALT** | Alternative text |
| **API** | Application programming interface |
| **APK** | Android application package |
| **AR** | Augmented reality |
| **BLE** | Bluetooth Low Energy |
| **CAD** | Computer aided design |
| **CD** | Compact disc |
| **CDN** | Change detection notification |
| **CEVL** | Computer enhanced visual learning |
| **CGI** | Computer generated imagery |
| **CMS** | Content management system |
| **CPU** | Central processing unit |
| **CREC** | Clinical research ethics committee |
| **CRT** | Cathode ray tube |
| **CSS** | Cascading style sheet |
| **CSV** | Comma separated values |
| **CU** | Close up |
| **DLL** | Dynamic link library |
| **DOF** | Degrees of freedom |
| **DVD** | Digital video disc |
| **ECU** | Extreme close up |
| **EBL** | Evidence based learning |
| **EBM** | Evidence based Medicine |
| **ET** | Educational technology |
| **eLfH** | e-learning for healthcare |
| **FCP** | Final cut pro |
| **FFL** | Fixed focal length |

| | |
|---|---|
| **FHE** | Fetal head examination |
| **FHR** | Fetal heart rate |
| **FOV** | Field of view |
| **fps** | Frames per second |
| **FPS** | First person shooter |
| **FSLSM** | Felder – Silverman learning styles model |
| **GPIOs** | General-purpose inputs/outputs |
| **GPS** | Global positioning system |
| **GUI** | Graphical user interface |
| **HD** | High definition |
| **HR** | Heart rate |
| **HPS** | Human patient simulator |
| **HTML** | Hypertext mark-up language |
| **HUD** | Heads up display |
| **ILS** | Index of learning styles |
| **IMP** | Information marker path |
| **IP** | Internet protocol |
| **IR** | Infrared |
| **IT** | Information technology |
| **ISS** | On-site simulation |
| **IOS** | iPhone operating system |
| **OSS** | Off-site simulation |
| **LED** | Light-emitting diode |
| **MCQ** | Multiple choice questions |
| **MCU** | Micro Controllers |
| **MEMS** | Micro-electromechanical systems |
| **MIMU** | Miniature inertial measurement unit |
| **MOSES** | Multi- disciplinary Obstetric Simulated Emergency Scenarios |
| **MPU** | Micro-processing unit |
| **NEST** | Network enhanced surgical testing |
| **NVD** | Normal vaginal delivery |
| **OB/GYN** | Obstetrics and gynaecology |
| **OA** | Occiput anterior |
| **OP** | Occiput posterior |

| | |
|---|---|
| **OSCE** | Objective structured clinical environment |
| **P2P** | Peer to peer |
| **PBL** | Problem based learning |
| **PHP** | Hypertext pre-processor |
| **POI** | Point of interest |
| **PP** | Placenta position |
| **PROMPT** | Practical obstetric multi-professional training |
| **RF** | Radio frequency |
| **RFID** | Radio frequency identification |
| **SBE** | Simulation based education |
| **SBME** | Simulation based medical education |
| **SBT** | Simulation based training |
| **SDK** | Software development kit |
| **SLE** | Simulated learning environment |
| **SLP** | Simulated learning programs |
| **SoC** | System on chip |
| **SPM** | Simulated patient monitor |
| **SVG** | Scalable vector graphics |
| **SQL** | Structured query language |
| **TI** | Texas Instruments |
| **UDP** | User datagram protocol |
| **UE4** | Unreal engine 4 |
| **UI** | User interface |
| **URL** | Uniform resource locator |
| **UX** | User experience |
| **VARK** | Visual, Auditory, Read/Write, and Kinaesthetic |
| **VD** | Vaginal delivery |
| **VE** | Virtual environment |
| **VE** | Vacuum extraction |
| **VLE** | Virtual learning environment |
| **VRL** | Virtual reality Laparoscopy |
| **VR** | Virtual reality |
| **VRE** | Virtual reality environment |
| **VP** | Virtual Patient |

| | |
|---|---|
| **VPM** | Virtual pregnancy models |
| **W3C** | World wide web consortium |
| **WIMU** | Wireless inertial measurement unit |
| **WLAN** | Wireless local access network |

# Chapter 1. Introduction

Information Technology (IT) and multimedia have become popular areas regarding learning and education in the present day. The two mediums have brought about new and inventive ways of teaching and educating nations across the world with digital content and innovative technology. Online media is constantly being used every day from general queries to philosophical endeavours. The rise of online media has spawned numerous education sites and informative web directories. Sites like YouTube and Google, which are accessed every day by internet users, provide a variety of educational sources and teaching tools.

Other outlets like Blackboard and Moodle create a virtual classroom space, enabling students and teachers to submit work and provide feedback almost instantly. This idea of the virtual classroom has been adopted globally with students all around the world attending colleges through an online course. These educational platforms provide real-time classroom video conferencing, online continuous assessment and work boards (Blackboard) and other forms of collegian involvement through a digital lens. Another technology that has broken down the confines of traditional learning practices and environments is Mobile technology.

Mobile technology has also been quickly adopted as a means or source of information for any individual, virtually a multifaceted staple of our communication today. Mobile phone users and students alike can access learning applications with the freedom of travel and mobile involvement. Essentially these devices have created a form of pocket teaching, providing the users with an array of multidisciplinary applications and peer to peer involvement. Mobile technology has been used extensively in education providing online course platforms on easy to use scalable mobile applications. These technology mediums all lend themselves to inter-connection and complement each other for the target users. One of the more enthusing facets of technology in education is its use in conceiving and inciting creativity. There is an abundance of possible creative content available to retrieve and create whether it is textual, auditory, visual or involving some form of 2D or 3D. Technology can exist at every point of the educational process from the conception and the research all the way through to the presentation. In Ireland, the educational system (especially in higher education) has

been steadily looking towards adopting a more technology dependant and online cooperative teaching and learning approach.

There is a strong focus towards a future integration and a more cooperative relationship between education and technology in higher education.

In the Irish National Strategy for Higher Education to 2030, issued by the Department of Education and Skills (Hea.ie, 2016), a great deal of emphasis is placed on the full integration of technologically informed educational platforms. In the future, higher education will have a significant part in boosting innovation, academic excellence, all of which will have a positive effect socially and economically in the country. Accordingly, the strategy of the Irish Department of Education and Skills, is to support socio-economic change through innovative methods of teaching and learning, programme design, student assessment and quality assurance systems.

There is recognition in the strategy that prospective students of the future should have an excellent teaching and learning experience, delivered through relevant research and aided by high quality learning environments, including e-learning facilities. The National Strategy for Higher Education to 2030 (Hea.ie, 2016), also suggests that the focus of future investment should be in selected domains or disciplines in education, one of which is medicine. The medical field has already adopted a plethora of technologies ranging from online interaction to simulated virtual or robotically enhanced environments to support student learning in higher education. The increase in importance of the use of these technologies in medicine and the education of medical students, spawn from the need to minimise the risk of mortality or poor health in patients, to improve skills and techniques of the trainee medical students and to ultimately practice medicine efficiently with positive results. Medicine is a broad field encompassing all kinds of medical specialty.

Most if not all medical studies in universities engage through technology in the form of online-learning (Blackboard) or visual media (YouTube) but this only scratches the surface of the full potential of technology and the media within medical education. Although convenient and accessible, these online platforms lack the driving physical interaction most medical fields depend on especially if they are surgical or procedurally focused.

Some disciplines have adopted this haptic central educational focus by introducing virtual environments and virtual reality into their training. This focus on VR (virtual

reality) stems from the need to hone skills needed to accurately re-create the steps needed to perform a clinical intervention or surgery and to produce positive results.

The VR also creates a virtual window to view or visualise these procedures in 3D space creating high fidelity environments mimicking the aesthetic of any procedure. For example, a VR environment was created to visualise the procedural actions during a laparoscopic surgery, like most surgical orientated fields laparoscopy would focus on the detail and would benefit from an interactive visualisation of their practice. The introduction of VR creates this proficiency barrier enabling the student to learn by repeating the processes through VR and eliminating the risk of human error. Patient safety has promptly climbed to the top of the healthcare schema in recent years, and has been combined with quality assurance. There has been a high demand for courses in patient safety and transfer of safety lessons. This demand has created new responsibilities for medical educators and tutors. Simulations offer ethical benefits, improved accuracy and increased competency, and innovative approaches of teaching error supervision.

Therefore, the adoption of simulated learning in any medical capacity has the potential of beneficial outcomes however many disciplines in medicine have not fully immersed themselves into a more technologically inviting learning environment. One field in medicine that closely encompasses this need for immersive or interactive technology is obstetrics.

Obstetrics by definition is a medical study focused on pregnancy, childbirth, and the postpartum period. As a medical specialty, obstetrics is usually merged with gynaecology to form the OB/GYN (obstetrics and gynaecology) discipline. Students taking part in obstetric training engage with numerous online materials and are met with practical physical simulation examples during their study. These two mediums of online learning and simulation are usually dissected and used to management separate goals within a typical obstetric curricular structure. The online learning is usually localised to continuous assessments, exams, message boards and communication between tutors and students. The simulation practice is supervised and uses human patient simulators to re-enact or mimic a medical procedure or scenario. These simulators vary in type from robotic influence to manual assistance. Most colleges teaching obstetrics through simulation inform students through practical manual examples on a simulated patient or actor. The movements and instructions are guided by the tutor informing the students as the process or procedure is commenced.

This process could easily be assimilated into a digital landscape like other medical disciplines have adopted like previously mentioned in the field of laparoscopy.

Much like laparoscopy, obstetric procedures contain practices that would require visual aid. The obstetric procedure of a normal child birth contains multiple fetal positions and practical outcomes when aware of them. If a student was shown the process in 3D form these process would be more clear to the student as they would guide the baby out of the womb. Like the previously laparoscopic example, obstetrics focuses on the haptic involvement and physical process of childbirth, presented through manual simulation. An amalgam of these two aspects (3D VR environment, Haptic interface) could present a form of possible educational advancement.

A simulator that could offer the same amount of physical aid/visual representation with the introduction of narrated media and 3D visualisations would be of major benefit to the discipline of obstetrics. Visual aids involving 3D and live video (like YouTube) with narration are new forms of learning.

Teaching obstetrics procedures through 3D visuals enables the display of actions that would not ordinarily be visible in real life footage. This in conjunction with real life footage, learner interaction and narration creates a holistic learning experience for students and practitioners as the use of physical interaction is guided through instructive lessons and visual support. A multipurpose obstetric resource with media components along with the simulation aspects could provide the visual and haptic outlet needed with ethical benefits and increase competency. The creation of any innovative resource to support teaching and learning should not only consider new technologies and innovation but should also consider the learning preference of students and their behaviour towards the teaching material and methods. Student engagement with learning and the method of delivery of material is greatly influenced by their learning style and preferences (Hea.ie, 2016).

Therefore, knowledge of the students learning preferences would be an important starting point. So, the research question centred on whether there was an educational resource available for obstetrics or even medical education that combined 3D, video, and simulation, contained integrated assessment and was commensurate with student learning preferences.

To date, other applications have endeavoured to mimic or imitate aspects of this format, delivering some features of the above. However, no application was found that provided all of these aspects together in a synchronised platform.

The aim of this research thesis therefore was to develop a multipurpose educational resource based on a physical/software driven simulator platform enabling the use of Multimedia properties like 3D and video to enhance the educational training of obstetrics students and considering the students learning preferences. The objectives of this thesis follow a linear narrative through the thesis from the concept's infancy to its presentation. The literature also grasps these concepts through related research. The objectives were as follows:

- To develop software for this platform that contains user friendly content with accessible aids to positively influence the learning outcomes of the students.
- To create an interaction between the physical extension and the software orientated program to generate an immersive student experience.
- Integrate teaching and assessment alongside a Virtual Simulated Learning Environment.
- Assess student learning through practical and theoretical tests on the mobile application, while lecturers can review the students' progress remotely.

These objectives reference the obtaining of obstetric student learning preference, creating obstetric centric 3D and video based on these preferences, amalgamating human patient simulators with the created media content to create a multipurpose hybrid learning resource. As this thesis and its concepts connect two separate disciplines of computer science and obstetrics, a non-technical approach to the methodology descriptions was adopted to describe the intricate practices involved in the full completion of the thesis and its associated resource. The chapter structure of this thesis follows the linear narrative inspired by the conception of the final thesis resource.

In Chapter 2, a review of the literature is presented. The review focused on findings of research related to connections between e-learning, 3D, video, and simulation with medicine and obstetrics, defining their roles and possible beneficial factors. Research particularly related to medical education were extrapolated and reviewed.

Results showed that research literature existed pertaining to individual aspects of the core structure of the final resource but there was a gap in the literature when all of these technical and media driven factors were melded together alongside medical training and learning preference.

In Chapter 3, e-learning concepts are discussed alongside a more detailed description of its effect on education, medicine and more accurately medical education/obstetrics. Concerning the objectives, the e-learning chapter strove to retrieve learning style preferences and general user interface partialities from obstetrics students garnering a usable feedback in the development of the finished platform. The student input was garnered through a learning style survey. The results showed a general need for high visual and learn-by- doing content which in turn affected the structure of the research.

In Chapter 4, 3D and virtual reality is discussed through examples and similar work. The chapter describes the necessity for 3D integration for obstetric procedural visualisation while presenting an in-depth development cycle of the 3D models and environment for the final thesis resource. Applications were developed through 3D platforms that gave rise to deliverables created in the final resource. These applications were tested with students with interesting results and feedback paving the way to a construction end result.

In Chapter 5, the aspect of video and its integration in medicine/obstetrics is discussed particularly the potential video has in the design of a final platform including more interactive ways of manipulating video structures. In this chapter the creation of an application using the previously created 3D models and the obstetric procedural video is described. The purpose was to generate a synchronising application that has responsive web capabilities and an interface tailored to the learning preference of the students.

In Chapter 6, the simulation and all of its components generated in linearity within each chapter were amalgamated into one all-encompassing student preference centred learning resource. Firstly, simulation is discussed in relation to education and medicine, focusing on obstetrics. Then the chapter continues by outlining the connectivity created between the digital 3D and video aspects and the physical simulation using sensor technology. Although a usability test was conducted a full scientific test of the final software developed has not been completed. This test could be the basis of future work and further development in the area of medical educational enhancement. The intricacies of amalgamating of all the beneficial factors to create a multi-faceted hybrid resource to teach obstetric student procedural processes through

active learning are described. In the final chapter, the newly developed learning resource is discussed and compared with previous published research reviewed. This is followed by conclusion and recommendations for future work and the final thoughts on the topic.

# Chapter 2. A Review of the Literature on Resources and Methods for learning

The growth of technology in multi-medical fields has led to the propagation of research and reviews of literature including integrative reviews, systematic reviews, meta-analyses, and qualitative reviews. This chapter presents an integrative review of literature pertaining to the key elements of technology enhanced learning proposed for this study focused on obstetric education.

## 2.1 Structure of Review

The review is divided into six sections all related to research in the field of obstetrics. The first section provides an overview of the literature as a whole while also explaining the methods carried out for each search. The second through to the sixth section present research associated with technology or E-learning, video production and delivery, 3D modelling and manipulation, Simulation Development and Utilization and finally an amalgam of all previous sections to summarise the state of knowledge in relation to technology enhanced support for teaching and learning in obstetrics education.

### 2.1.1 Search Strategy

The search strategy differed for each section of the review but utilised the same parameters and was subject to inclusion / exclusion criteria and search process keys pertinent to each topic. The parameters for each section were tailored stipulating boundaries of each topic. The review topics were selected and key terms selected in the search options alongside a static variable: Obstetrics and its synonyms.

*The key terms below were combined with a combination of terms associated with "Obstetrics".*

*Key Terms:*

*(1). E-learning (2.) Learning styles (3). 3D (4). Video (5). Sensors (6). Simulation (7) Technology. Variants, synonyms and combinations of these main key terms were used in conjunction with the parameters.*

Two variants of the systematic search were conducted, one search was initialised using the Google Alerts application and the latter was formulated using a number of databases retrieved from the UCC library.

Other viable key terms were accessed alongside the research key terms in the search for new technologies in the field of Obstetrics (Coffey et al., 2014). This was in order to view related topics and structure a path for future developments of the thesis and widen the scope of the thesis. A search was conducted for applications or simulations that could potentially mirror or rival the elements of the research and thesis.

On a whole, the various terms amalgamated did not produce a research study or thesis that either emulated or matched the current thesis work.

Secondly a systematic search involving UCC library of databases was then applied using various combinations of text words and the key terms (in title or abstract) and subject headings relevant to the individual databases searched. Using the EBSCO platform, Web of Science and NCBI, the databases searched were: MEDLINE, CINAHL, Wilson Education Full Text and PubMed. Each database was chosen for its connection and bank of information pertaining to one or more of the key terms. MEDLINE and PubMed both retain information on any chosen medical field, in the confines of the review both databases are helpful in securing research studies relating to obstetrics. Additionally, CINAHL is connected to Nursing and Midwifery and helpful in the collection of material relating to childbirth in each field. Wilson Education Full Text database sheds a light on all things linked to education and teaching methods which aids in the acquisition of learning style research. All searches were limited to English language papers and papers published with between a certain bracket of years applicable to the topic. Results from both searches were combined for each topic and resulting citations were screened for full review.

### 2.1.2 Inclusion and Exclusion criteria

Inclusion and Exclusion criteria can create a refined search outcome within the review. The Inclusion criteria were research studies and peer review articles. The papers needed to be either explicitly focused on obstetrics or had relevant keywords associated with obstetrics and in medical and or midwifery. Excluded papers included those papers that centred on the topic but had no relevant relationship to a medical field or background. Papers that had no possible application to obstetrics were excluded. The criteria changed for each section adding exceptions on the grounds of a particular parameters or key terms specifications.

A full search strategy was developed to include key terms and their variations. The search strategy for each review was checked and matched on google for an accurate wording reference.

## 2.2 E-learning in Medical Education and Learning Styles

**Introduction**

Developing new modalities to achieve appropriate educational goals is within the scope of many medical faculties internationally. One of these novel approaches is E-Learning. E-Learning offers an additional tool for creating a virtual electronic network between individuals but not replacing human contact and clinical work. It enables the effective use of electronic learning materials as well as human interaction between trainees and trainers in Europe. E-Learning is an opportunity to form a bridge between basic and post-graduate medical training and continuing professional development in the medical community (Moule, 2006). In many EBCOG (European Board & College of Obstetrics and Gynaecology) member countries, E-Learning is already in active use. E-learning has become a blanket term that holds a multitude of miscellaneous traits regarding computer assisted learning (Moore *et al.,* 2011). Many of these aspects lead to various connected nodes including computer assisted educational management. The construction of this educational platform has revolutionized the way people learn, it also improved the way in which education is managed and taught. Online resources and online content on a whole are emerging as a beneficial hub of knowledge for colleges and areas of further education (Chen *et al.,* 2010).

### 2.2.1 Search Strategy

The search strategy for e-learning used the format or template set from the search strategy previously mentioned. The constant or static variable used was “Obstetric”, the variants of this variable would only differ in terms of plural and singular separations of the word (Obstetric, Obstetrics). This variable was applied to a multitude of different strings. The strings compared were variances of the words e-learning and learning styles, these variances compiled had structural and grammatical separations.

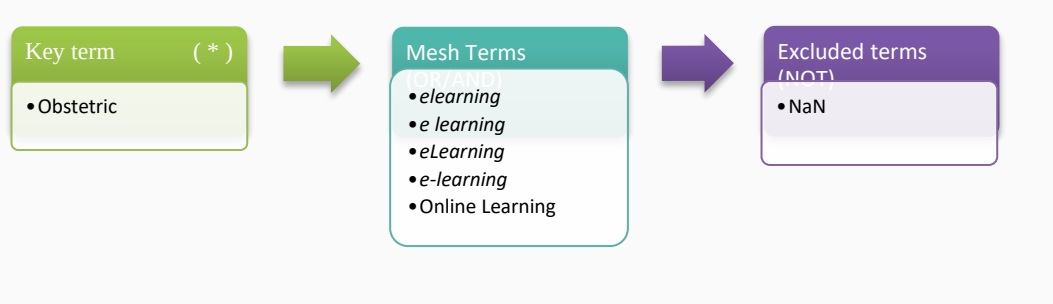



Figure 1: E-learning MESH terms.

The inclusion and exclusion criteria was tailored to fit this particular search, static criteria included English language papers, review or research studies, must have connection to Obstetrics and the key terms used in the parameters or have a strong connection to the key terms in a related medical field with application to Obstetrics. As part of the search process template all databases were used as previously mentioned. Results from the search presented fifty-three (n = 53) articles matching the criteria needed for the review. Out of this selection of results, only a select number presented the term Obstetrics or Obstetric in its subject matter, articles included in the review not listing this variable were not considered. In terms of the learning styles key term, the inclusion and exclusion criteria were virtually identical to that of the e-learning key term template parameters.

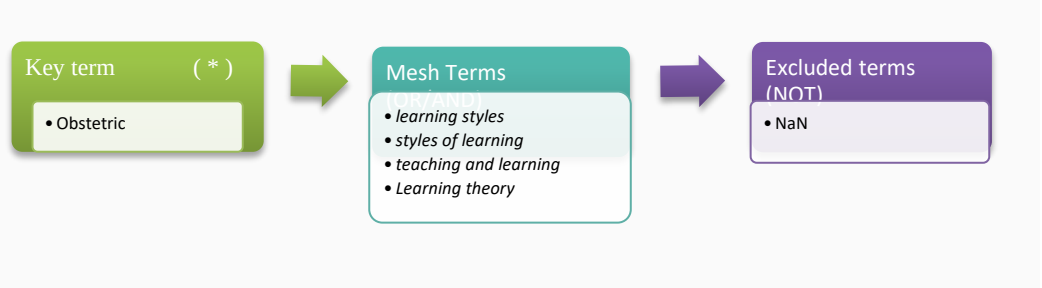



Figure 2: Learning style MESH terms.

The databases used were identical to the e-learning search with same cut off year. Results from the search that resembled a mixture of e-learning and learning styles in a meld of theory were considered as it supported the conjunction of the two staples. Results for this search were significantly lower, viewing a total of twenty-three (n = 23) articles which met the criteria. Some of these articles were informed on an e-learning strategy that had some form of application to Obstetrics so they were included.

The subsequent articles were listed on general learning theory and had no application to the field of obstetrics so they were excluded.

When screening the abstracts for learning styles literature, the articles present that connected to eLearning systems used the FSLSM (Felder-Silverman learning style model). In each article it was suggested that the FSLSM was a preferred learning styles model as it classifies learners in broader groups and has a more comprehensive explanatory description about learners' learning styles. In terms of the Google Alerts search, the results equated to news articles and editorials in relation to advancements in medical technologies, but no mention of e-learning progression in Obstetrics apart from five google scholar hits that matched articles retrieved using the database strategy (Graf *et al.*, 2007). Both searches were then combined resulting in 90 records for screening as set out in the prisma flow diagram in figure 3.

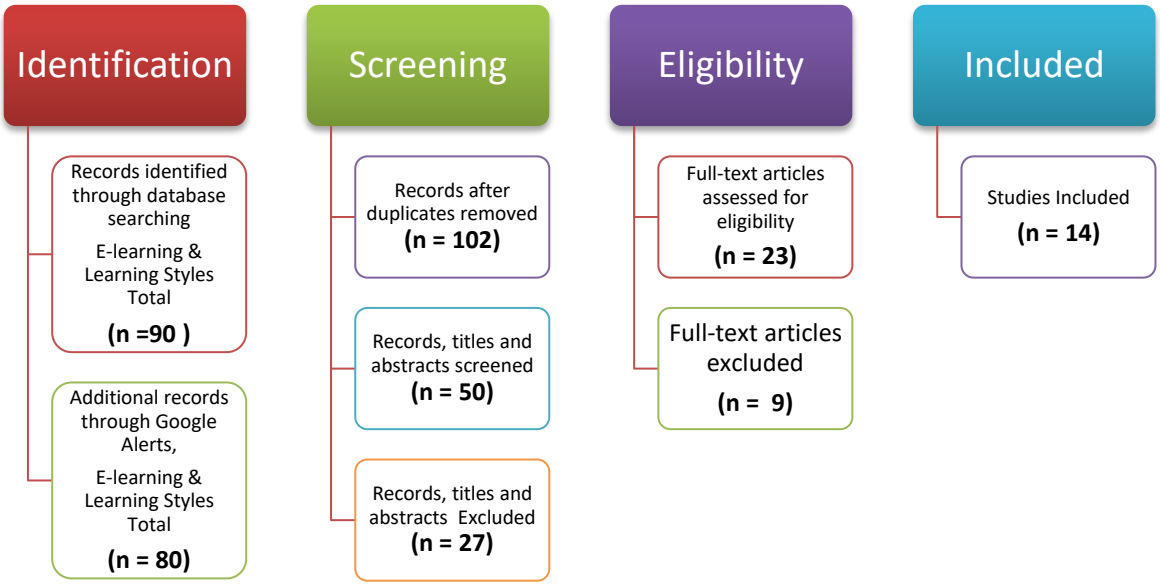



Figure 3: Prisma flow diagram of the e-learning & learning styles key term searches for literature.

### 2.2.2 Review of the Literature

After using parameters set in the search strategy, the results offered were limited contributions in terms of Obstetrics and e-learning interaction. A number of studies focused on the relationships between eLearning in medical education and student learning outcomes and learning styles.

For example, a qualitative research study was conducted by Valaitis *et al* (2005) to investigate health sciences students' views on their understandings in online problem based learning (PBL).

The researchers concentrated their investigation on the students' opinions about learning and group procedures in the online environment. These users were beginners to online learning but practiced a lot of PBL.

This meant they could mirror previous direct PBL practices. Three individual groups of learner types participated, comprising of undergraduate nurses, graduate nurses and midwifery students. The results of the study showed that it was possible to conduct PBL online. From the feedback the students thought that the online learning platform improved their adaptability and flexibility for learning, elevated their capacity to accurately understand material, and delivered access to a beneficial learning environment. The students involved, underwent an adjustment to the online environment, identified a great quantity of material, and had difficulties making group decisions online. In addition to using asynchronous communication, chats (synchronous communication) were valued by student as a support to group decision-making online. Students appreciated validation of their online contributions from their peers and wanted clear expectations of what constituted successful tutorial participation from their tutors. According to the researchers, although online PBL can work effectively, tutors and students needed to develop online literacy skills to smooth their transition to an online PBL environment (Valaitis et al., 2005).

In a study conducted with medical students in neuroanatomy, an online course was evaluated in relation to how successful it was at positively enhancing a deep learning method (encouraged learning by interest) to education and what factors would affect the approach or method. The study had a sample size of 205 pre-clinical medical students, their learning approaches were assessed through the Revised Study Process Questionnaire (R-SPQ-2F – developed by Biggs et al. 2001).

The course provided was a CAL (computer-aided learning) course in neuroanatomy and this was compared with their general studies. Attitudes of the students towards the CAL course were examined and the web page ratings were observed by independent raters in terms of learning method. The results of the study showed satisfaction with the course, evaluation of the quantity of information, simplicity of course and knowledge retention were all related to a deeper approach. The study suggests that to increase clinical relevance there was a need to escalate the interest and entertainment of the course, thus supporting deep learning and medical knowledge retention (Svirko & Mellanby 2008).

Bhatti et al., 2011, conducted a study to examine the value of educating medical students on a common surgical topic using a website and podcast in comparison to traditional lectures.

The student's standard knowledge was ascertained by a questionnaire given to two separate groups of third-year medical students starting their first clinical attachment. Group A (n= 73) was given a lecture and group B (n= 75) was asked to use a website comprising of text and pictures enhanced by a podcast. The students were then assessed using the same pre medical intervention questionnaire, and satisfaction was acquired from details given in a feedback form using a likert scale. From the results both groups showed the same amount of knowledge of the topic before the study and both groups demonstrated significant gains in knowledge after intervention ($P< 0.0001$). Group B (Web podcast) showed a significantly greater increase in knowledge ($P< 0.05$) than group A (lecture). Pre intervention subjective assessment of knowledge rated by the students showed no difference between the groups. Both groups of students were equally satisfied with the educational method. From the data and general consensus, the authors inferred that e-learning complemented by a multimedia format (podcast results) presented students with a greater bank of knowledge acquisition when compared to a traditional lecture. This was achieved without a reduction of fulfilment with teaching.

The authors suggested that by using amplified Web-based educational resources the demands on teaching time would be reduced with no decrease in quality for designated portions of the teaching curriculum (Bhatti et al., 2011).

A research study carried out in conjunction with the association of American Medical Colleges' Institute to successfully analyse the effectiveness of multimedia design principles on Medical Education Technology. The study involved a pre-test and post-

test, with a traditional learning group (n = 39) receiving traditionally designed slides and the modified-design group (n = 91) received the same lecture using slides modified in keeping with Mayer's principles of multimedia design. Both groups had similar levels of knowledge on the subject presented so no group gained an advantage. From the results both groups showed significant improvements in retention ($p < 0.0001$) between the pre- and post-tests. Repeated-measures ANOVA analysis showed statistically significant improvements in retention ($F = 10.2$, $p = 0.0016$) for those students instructed using principles of multimedia design compared with those instructed using the traditional design (Issa *et al.*, 2009).

A study was conducted in the UK West Midlands region to evaluate the educational effectiveness of a clinically integrated learning course for teaching basic evidence-based medicine (EBM) among postgraduate medical trainees compared to a traditional lecture-based course of equivalent content. The researchers (Hadley *et al.*, 2010), conducted a cluster randomized controlled trial to compare a clinically integrated e-learning EBM course (intervention) to a lecture-based course (control) among postgraduate trainees at foundation or internship level in seven teaching hospitals in the UK West Midlands region. Knowledge gained among participants was measured with a validated instrument using multiple choice questions. Change in knowledge was compared between groups. The results showed that there of 237 trainees, there was no difference in the amount of knowledge improvement between the EBM and control group. They suggested that an e-learning course in EBM was as effective in improving knowledge as a standard lecture-based course and that the benefits of an e-learning approach need to be considered when planning EBM curricula as it provides advocate of teaching materials and is a potential cost-effective alternative to standard lecture-based teaching. (Hadley et al., 2010). A related study associated with learning-style instructional strategies reported that for a traditional lecturer-based learning class, the learning style was unconnected, but for a web-based learning class, learning style was significantly important (Dunn *et al.*, 2011).

The teaching of Obstetrics through the use of an e-learning platform was the subject of research carried in the Medical University of Bialystok by Póljanowicz et al., (2012). Results were positive for the platform's usage with Obstetrics students. The study used carefully prepared teaching materials placed on virtual platform that in the authors mind increased the opportunity to prepare students for the credits and final examinations in the respective field of knowledge.

The organization of classes in both forms (e-learning and traditional) was highly appraised by students participating in the study. From this study it was clear that e-learning was a beneficial approach to obstetrics education providing a simple accessible means of viewing practical material without being physical present and allowing students to avail of material in their own time.

Multimedia design principles are easy to implement and result in improved short-term retention among medical students, but empirical research is still needed to determine how these principles affect transfer of learning.

Further research on applying the principles of multimedia design to medical education is needed to verify the impact it has on the long-term learning of medical students, as well as its impact on other forms of multimedia instructional programmes used in the education of medical students. In a research study deducing the effect of e-learning on knowledge retention and student's achievement in Obstetrical and Gynaecological nursing curriculum by Hassan, (2013), a percentage of students carried out the test using an e-learning course while the remainder of the students enrolled in traditional course. The controlled learning (traditional learning) students did not excel in comparison to the e-learning participants. In fact, findings were that the students with housed e-learning had better procurement and retention of knowledge. Most of these studies supported the use of e-learning as a progressive medium for advances in medical learning (Hassan, 2013).

A research study carried out by Adetunji *et al.,* (2014) aimed to provide basic information towards designing an e-learning system that adapts to learners' preference of learning Style automatically. It was established a literature review, that is if e-learning systems could adapt to learning characteristics of learners, it would increase learning performance and content knowledge acquisition from the learners. The research study reviewed trends in adaptive e-learning system development, proposed a model of an Automatic Adaptive E-learning System (AAeLS) based on learning-style concept/models. The research showed that the learning styles model used (i.e. the FSLSM) integrated well with the structure of the e-learning systems development. Results were varied and positive but needed further work on implementation and testing of the model (Adetunji *et al.,* 2014).

Another research study conducted by Camal Nat *et al.,* (2011) with a group of university multimedia students (n=46) focused on personalised e-learning.

The students were randomly divided into two groups and invited to use one of the two e-learning systems to study a chosen subject; a personalised e-learning systems were more effective than non-personalised e-learning systems. The FSLSM (Felder & Silverman Learning Style Model) was selected as the preferred model to profile students and create personalised e-learning environment. In both designs, individual student's learning styles were tested. The findings did not conclude that personalised e-learning systems are more efficient than non-personalised e-learning systems or vice versa. The researcher recommended further research due to the small sample used (Cemal Nat et al., 2011).

In 2014 a thesis was commenced by Obando *et al.*, which involved the construction of three individual interactive self-directed learning tools for third year medical students conducting the Obstetrics and Gynaecology cycle of their course. The learning tools offered modules with different descriptions of clinical case scenarios that included Amenorrhea, Vaginitis and Third Trimester Bleeding. These modules allowed students to see patient to physician relations and to identify symptoms and alternate diagnoses by using graphical representations of notes, images, text and animation. These formats granted the users/students to visualise these procedures and offer a greater scope for assessment for the lectures. The resource was created through Adobe flash and based its platform compatibility on browser plugins and user recognition of the flash player content. The resources graphical aspects range only to mouse click functions of interaction. Furthermore, the platform also required the user to download flash player to run the resource after downloading a zip packaged file containing the thesis file contents. Although the process of retrieving the resource did not complement the user interaction, the students' overall reaction was positive and their thoughts on the use of online modules were that they delivered a substitute to regulated teaching of subjects that is infrequent in a clinical setting. They added that the modules provided control of their own educational experience (Obando *et al.*, 2014).

Another study to discover the attitudes to e-learning amongst newly qualified doctors was carried out in 2014 by Goh & Clapham. This study used a blended learning approach which consisted of weekly sessions of lectures and flexible e-learning labs. A questionnaire survey was conducted among doctors in their first year of qualification.

The bulk of the students were required to complete additional e-learning outside of work and had no preference on where they worked on the e-learning material. Just over half (54%) of the respondents thought that e-learning had been useful for their education and training in their first year in medicine. The researchers concluded that recently qualified doctors appreciated e-learning as a beneficial addition to experiential and lecture based teaching.

They recommended that the medical educators should place equal emphasis on the delivery and administration of e-learning as well as on the course design(Goh & Clapham 2014).

A research study on providing online interactive scenarios to rural health care providers regarding HIV care for the pregnant female and neonates was conducted with the objective of increasing knowledge and preparedness on the part of the health care provider. The resource in question was the HIV Health Education, Assessment, and Research in Telehealth (HIV HEART). Instructional designers were contracted to make interactive case-based scenarios using adult learning theory, which could be accessed through a tailored learning organization portal. The results of the study showed positive feedback in terms of response from users and general consensus of the platform provided an understanding that online interactive learning tools provide a useful outlet for educational progression (Rhoads *et al.,* 2014).

A research study that investigated obstetric students' online learning technology needs at a medical school aimed to provide evidence-based guidance for technology selection and online learning design in medical education. The authors Goh et al., (2014), developed a 120-item survey in which the students took part. Overall 123 of 290 obstetric students at the medical school participated in the survey which was focused on perception of educational technology (ET) in general, online behaviours and its perception at the school. Students perceived multimedia tools, scheduling tools, communication tools, collaborative authoring tools, learning management systems and electronic health records as useful educational technologies for their learning. The authors suggested that learning technology environments had pedagogical potential, especially for clerkship curricula, by providing more flexible and ubiquitous learning experiences. According to Goh *et al.,* (2014), as clerkship learning is a switch from classroom learning to workplace learning, the smooth integration of online systems from hospitals and out-patient clinics into the medical curriculum was urgently needed. One negative perception centred on the constraints of using sensitive patient

information and the implications of using online material when working with people in hospitals (Goh *et al.,* 2014).

A study conducted in Australia surveyed e-learning system developers alongside learning style in 2014. The study suggested that learning styles were the most useful personalization sources among other factors such as background knowledge and user history. In addition, the study showed clear potential benefits for both fields of learning styles research and e-learning system development (Thalmann, 2014).

In contrast to the positive outcomes of the above research, a study carried out by the Faculty of Medicine at Dalhousie University found that e-learning modules did not improve the third year medical students' scores on a final test.

The study was designed to examine the influence of online learning modules, developed to standardize learning across education sites during the clinical clerkship, on the acquisition of knowledge by medical students during their obstetrics and gynaecology rotation. The study used a third year medical school class and divided it into two groups. Group 1 (n = 54) had their obstetrics and gynaecology rotation in the first term and Group 2 (n = 60) had theirs in the second. All students were given the opportunity to complete an online formative examination before their cumulative MCQ's (multiple choice questions). Group 2 students had sole access to six obstetrics and gynaecology e-learning modules, upon which the final test was constructed. 47 students in Group 1 and 45 students in Group 2 completed the final test, with an overall participation rate of 81%. However, the authors stated that having access to e-learning modules did not improve the third year medical students' scores on a final test, suggesting that e-learning material was no additional asset for the curriculum (Coolen *et al.,* 2015).

**Summary**

From research studies overall there is evidence from the published research that e-learning when used in medical / obstetric education has positive effects and is well received by students and educators alike. It is evident that there are positive outcomes from the use of online material in creating new educational material for Obstetrics and affiliated fields. However, studies provide evidence that the current online presence is in its infancy, and suggests a more robust library of content and with a greater range of visual representation. In addition, learning styles and e-learning are effectively closely associated, and affect the outcome of possible resource material.

## 2.3 3D Modelling and Manipulation

Physical anatomical model frameworks have been substituted for actual anatomy in medical teaching for many years. These models do not deteriorate over-time; they can be studied with ease and have also shown to be beneficial teaching utilities.

Simulated or Virtual models (3D), while being costly in time and money to produce, have developed on these qualities by being easy and economical to distribute and broadcast electronically. The virtual models also have the ability to grant students the ability to have replicated simulation experiences of surgical procedures without risk to patients. This is also enhanced by the introduction of haptic user interfaces that can provide students tactile responses.

The use of 3D modelling and animation also allows the visualization of subjects and scenes that could never be captured on film. 3D and Virtual reality grounded technology is a fresh but fast growing area in medicine, which will hopefully transform obstetrics in the conceivable future with backing and persistence. To investigate the evidence for use of 3D modelling in medical / obstetric education, a search of published literature was conducted.

### 2.3.1 Search Strategy

Similar to the previous search strategy, the search strategy for 3D modelling and manipulation used the format or template set from the search strategy previously mentioned. The constant or static variable used was “Obstetric”, the variants of this variable only differed in terms of plural and singular separations of the word (Obstetric, Obstetrics) and there were no changes in results when the variable was dissected in this fashion. This variable was applied to a multitude of different strings which were variances of the word three dimensional or 3D as presented below:

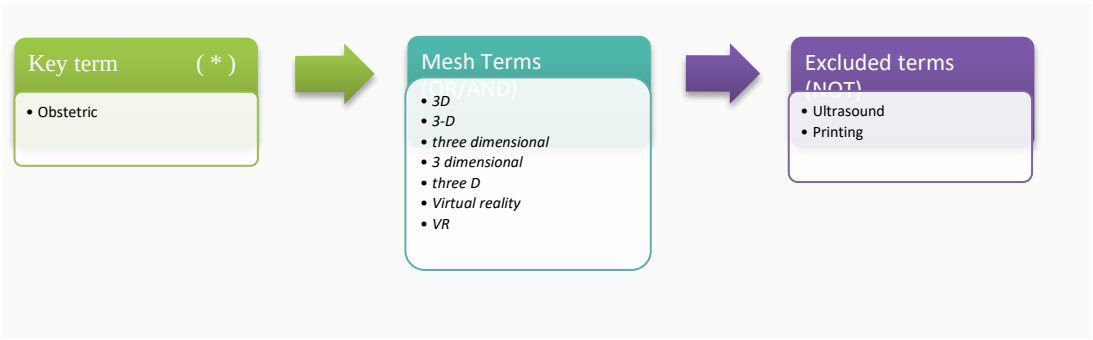



Figure 4: 3D MESH terms.

The inclusion and exclusion criteria was tailored to fit this particular search, static criteria were included English language papers, review or research studies, must have connection to Obstetrics as before and the key terms used in the parameters or have a strong connection to the key terms in a related medical field with application to Obstetrics.

As part of the search process template all databases were used as previously mentioned, with an emphasis on the EBSCO Library, Information Science & Technology (LISTA) database in terms of its repository of emerging technology based material. 3D representation became more popularised as 3D animation features became dominant in film in the early part of the 21st century. This influenced my decision on the bracket year, I wanted to have a cut-off point that deservedly viewed 3D advances in a new light, and the cut-off was the year 2000. Results from the search presented scarce findings in terms of 3D on its own.

Twenty -four papers matched the criteria needed for the review.

Included studies were those that included obstetrics or its synonyms in the subject matter and those that were peer reviewed. Out of this selection of results, few presented the term Obstetrics or Obstetric in its subject matter, Articles not listing this variable were not considered although those that were peer reviewed and possessed strong information on medical or nursing/midwifery 3D material were included as they had application to the obstetric 3D topic. The more recent Google Alerts search results displayed the abundance of 3D printing and ultrasound studies. Articles involving 3D printing and ultrasound on inspection however referred to the emerging technologies more than their influence on Obstetrics or Medicine. These topics were only included if they were proven to have some applicable reference to support the research. The majority of the listed articles under printing and ultrasound in connection to Obstetrics when screened had very little connection to the educational benefit of the 3D and the 3Ds type did not suit the CGI (Computer Generated Imagery) aspect represented in this thesis.

Two Additional parameters were added using the “NOT” parse in light of this to prevent the presence of these subjects. Articles listed in the Google alert search under the scholar banner provided similar articles but did not adhere to the search strategies parameters.

In terms of the Google Alerts search, apart from five Google scholar hits that matched articles retrieved using the database strategy the results equated to news articles and editorials in relation to advancements in medical technologies, but no mention of e-learning progression in Obstetrics. Google as a CDN (change detection notification) helps in the detection of the 3D video material online and creates an ease of access in a temporary repository format. Actions taken for identification of the literature, screening, eligibility, and inclusion can be seen in the prisma flow diagram in figure 5.

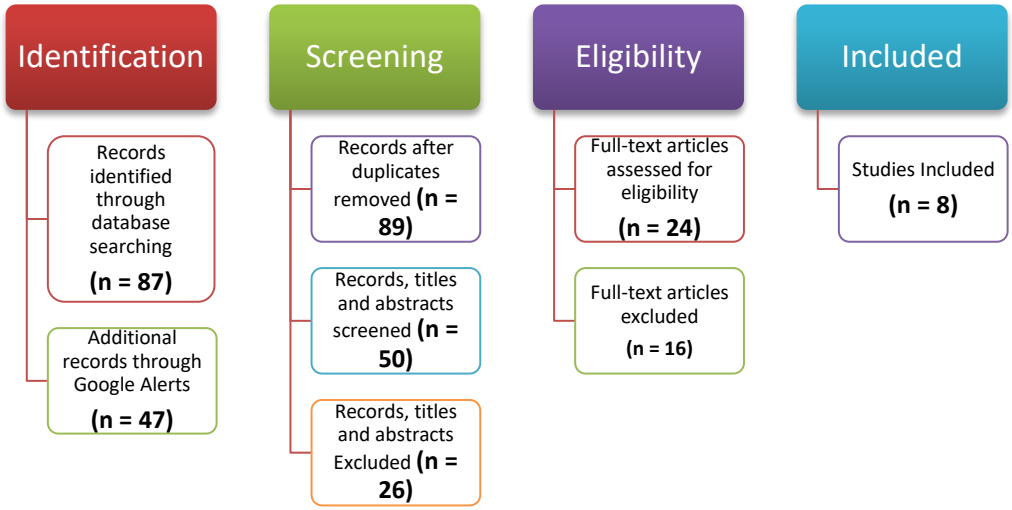



Figure 5: Prisma flow diagram of the 3D & VR key term searches for literature.

### 2.3.2 Review of the Literature

In relation to 3D modelling and obstetrics and or medical education, eight studies met the inclusion criteria. 3D simulation and visualisation is a new and exciting prospect for any field in science to convey processes that either cannot be physically seen by the naked eye (bacterial activity, cancer cell reproduction *etc.*) or involve extensive clinical trials and huge amounts of funding.

The move to three dimensional representations is relatively new, therefore few studies of the use of 3D have been undertaken in the area of obstetrics.

In 2002, Letterie having conducted a review of the conditions in science and education in which VR had been successfully applied and to analyse the role of VR for training in obstetrics and gynaecology and results revealed that simulated person-to-person interactions for application training in psychiatry and the social sciences in a variety of circumstances by using real-time simulations of personal interactions had proved successful.

He stated that these successful applications suggest that the technology might be helpful and should be evaluated as an educational process in obstetrics and gynaecology especially in training basic and advanced surgical skills for both medical students and residents. Letterie established that VR (Virtual reality - 3D taken into account) was untested but could be useful as process of training in obstetrics and gynaecology and a teaching essential in counselling and surgical skill attainment (Letterie, 2002).

In the UK, a study by Lapeer et al., 2004 used augmented reality to depict a ventouse delivery. The researchers used a series of media including ultrasound, 3D models of forceps and an array of software and tools to generate the augmented environment. The finished resource was capable of grabbing a 3D augmented fetal model with forceps and moving or pulling forward. According to the authors this showed progress, although they had difficulties with the alignment of the 3D fixtures and resulting in deforming of 3D models in processes. The study lacked procedural input or any form of test or task. The use of augmented reality might have removed the need for a physical simulated model but this also removed a haptic input which is essential in fetal delivery. The haptic involvement in this case was solely attributed to the forceps but did not go beyond this. However in saying this, the use of a motion tracked object according to the authors, was a step in the right direction in relation to an interactive resource for education (Lapeer et al., 2004).

In 2005, the Departments of Radiology and Obstetrics in Harvard, Massachusetts conducted a study on 'three and four Dimensional Ultrasound in Obstetrics and Gynaecology'. The American Institute of Ultrasound in Medicine convened a panel of physicians and scientists with interest and expertise in 3D ultrasound in obstetrics and gynaecology to discuss the current diagnostic benefits and technical limitations in obstetrics and gynaecology and consider the utility and role of this type of imaging in clinical practice now and in the future. Although 3D was used in correspondence with ultrasound, this study found that the use of 3D was viable enough to coincide with the accurate ultrasound findings in the field of Obstetrics and Gynaecology. Participants in this study stated that three-dimensional (3D) ultrasound had the potential to be a considerable advance in the armamentarium of medical sonography. The professionals considered 3D to have the potential to view equipment, and techniques available to a medical practitioner with the accuracy needed to assess problems and processes used.

Researchers suggested that if used in conjunction with 2D ultrasound, 3D ultrasound had added diagnostic and clinical value for select indications and circumstances in obstetric and gynaecologic ultrasound. The researchers recommended the use of 3D and 4D ultrasound to practicing professionals in the field of Obstetrics as it encourages the use of the two media as a viable alternative to 2D rendered imagery (Beryl et al., 2005).

Another interesting study involved the evaluation of a virtual reality workstation (Fetouch system). This station offered three-dimensional (3D) fetal visual and kinaesthetic interaction and researchers examined whether it would affect maternal stress. The methods involved the use of maternal fetal visual and kinaesthetic interaction acquired via haptic interfaces based on 3D reconstruction of sequential bi-dimensional ultrasound images of the fetus.

Maternal stress was measured before and after visual/kinaesthetic interaction with the fetus and data were analysed using paired t test and analysis of variance for repeated measures. A significant decrease was detected in anxiety (low state anxiety group, $p < .0034$; high state anxiety group, $P < .0108$) after maternal interaction with the VR workstation. Results demonstrated that physical interaction with the fetus through a 3D model reduced maternal stress (Severi et al., 2005).

A study by Aggarwal and Tully *et al.*, (2006) involved virtual reality (VR) simulation training and its ability to improve technical skills during laparoscopic salpingectomy for ectopic pregnancy was conducted in 2006. The goal of the study was to assess a virtual reality simulator and integrate into training modules for inexperienced gynaecological surgeons to perform laparoscopic salpingectomy for ectopic pregnancy. Thirty surgeons were selected and separated into groups according to of their level of proficiency in training. Each person used the VR simulator and was given skill tasks to conduct. The time taken and instrument use was taken into account when assessing the tasks. The results for tasks produced a median of 551.1 (experienced surgeons) versus 401.2 (intermediate) versus 249.2 (novice). Experienced users had no improvement in their progress on a second attempt but greater numbers of sessions were necessary for intermediate (seven) and novice (nine) surgeons to achieve similar levels of skill. In conclusion, the authors suggested that surgeons with the minimal amount of knowledge of the procedural tasks could improve their skills during short-phase training on a virtual reality simulation.

The authors agreed that the introduction of virtual reality at an early stage in the surgeons' learning curve could develop the surgeons' proficiency and ease towards the real tasks in future. The need for live patients for practical assessments although vital when performing medical procedures including deliveries in the field of Obstetrics, the process can be burdensome when trying to achieve ethical approval for every patient seen.

With the use of 3D simulation, this vital practical stage can be reduced significantly by having virtually represented scenarios with no need for ethical consent (Aggarwal and Tully *et al.,* 2006).

Another study carried out in 2011 examined the use of virtual reality in three dimensional forms in relation to Laparoscopy and its effectiveness on a trainee's proficiency. This paper introduced another form of 3D visualisation and interaction with a VRL (virtual reality laparoscopy) trainer. The goal of the study was to identify personal characteristics that may predict the proficiency level of first-time virtual reality laparoscopy (VRL) trainees. The study involved undergraduate medical students (n=279) without experience attending a VRL training.

The student's performance of a task was correlated with predictive factors providing potential competence in VRL. Ninety-five percent of those who had taken part had the confidence to score equal and above the required status set for each task presented on the VRL. The results established that the frequency of video gaming was associated with quality of first-time VRL performance. Many people in society today are classified as 'gamers' as they have access and have played games through portable devices and mobile phones. The increased proficiency of these students suggests that task, 3D/virtual reality and interaction orientated applications could be a proficient form of training in the future (Paschold *et al.,* 2011).

If 3D is used in any format it has the technical format to be applied to a virtual world. Virtual Patient (VP) scenarios are a great example of this. These provide the means of training without physical presence in the room.

A study conducted by Weideman et al., (2014) provided insight on a resource that solely relied on the VP scenarios with application to Midwifery and Obstetrics.

This study used 3D VPMs (Virtual Pregnancy Models), to present stages of pregnancy in anatomically correct presentations. Students (n = 93) were given the still 3D models to inspect while also quizzed on the subject matter related to that particular stage of pregnancy.

The questions were linked to one or more of the VPM's outcomes i.e. learner's ability to anticipate the health promotion necessary, the learner's ability to differentiate between key phases of fetal development based on gestational age, learner's ability to anticipate the pregnant woman's need for education on the discomforts of pregnancy and risk factors.

Feedback from students showed that 98% of the students believed the VPM enhanced their learning about the healthcare needs of the mother and developing fetus, 97% believed it had engaged them in their learning, and 95% of the students would choose to learn future content and/or concepts through a similar learning module. Although the findings were positive, the sources were limited as they were reliant on other media outlets including "YouTube" and the VP site. This caused issues for a small number of students when some material did not show or stopped functioning abruptly. The longevity of this framework was questionable as the application relied so heavily on outsourced material and had few local data sources. Nevertheless, the VPM from student feedback, effectively allowed students to acquire and apply obstetrical concepts through a virtual patient's experience without an increase in the utilization of clinical or faculty resources (Weideman et al., 2014).

One recent study examined the use of digital technology in the three-dimensional reconstruction of human placentas.

The study used slides of placenta obtained at term elective caesarean section that were sampled, scanned and the digitised into images reconstructed using user customised software. Three-dimensional reconstructions were successfully achieved in placentas from normal. This 3D graphical representation presented an easier way to identify marked morphological differences. When trainees and practitioners inspected the outputs, those taking part saw the benefit of reading these changes and saw potential application in other areas of obstetrics. The authors suggested that the emerging research tool had the ability to accurately examine placental histo-architecture at high resolution (3D) and to achieve clinically relevant understandings into placental pathology (McCarthy *et al.*, 2016). This research is an acknowledgement of accurate 3D representation as a constructive tool to visualise a solid form or process.

**Summary**

From the research studies presented, the findings of research on the use of 3D modelling and VR in obstetrics and midwifery demonstrate benefits particularly in interactive nature of this media. Overall consensus points to the benefits of 3D and virtual reality training/visualisation as an educational aid.

Most studies found benefits in aided visualisation, especially in medical procedures that cannot be seen by the naked eye or with invasive camera procedures. This process alleviates the need for patient interaction which may also prevent the likelihood of fatal error.

## 2.4 Video Production and Video Delivery

The use of video in medical education encourages teaching and learning in an array of different environments. Video Technology is a widely used medium for demonstrative, training and educational purposes. Video has been used in medicine since the 1950's providing a signal reference for CRT (cathode ray tube) technology. As video is a more viable and obtainable technology resource, it is used extensively in medicine.

Video is now easily compiled and distributed through the means of online support making it an accessible interactive type of learning for medical students. Medical education has adopted video technology as an essential learning resource next to online learning, online learning tools and video tutorials are more prevalent in the curriculum of major Universities. The need for visual demonstrations are essential in medicine, as operations and surgical skills must be taught but are constrained to practical classes.

Along with these constraints, consent for surgery review is undertaken; this can be time consuming giving students' insufficient time for reflective learning. Student learning research has shown that visualisation with well- designed visual tools can result in students learning in a shorter time and can foster long term learning (McClean, Johnson *et al.*, 2005). In obstetrics training, simulation techniques have been used extensively. However, sources of obstetric video material for students take the form of video lectures including 2D still image representation of deliveries and procedures. Online platforms such as "YouTube" offer some tasks involved but miss the narrative elements needed to educate an Obstetrics student.

Obstetric and Midwifery students are familiar with video use in terms of its use in assessing students on their ability to cope with an array of clinical procedures. These recordings are fed back to the students as a form of acknowledgement of their mistakes or improvements. Recent research into the use of video in obstetric education was reviewed to inform this study.

### 2.4.1 Search Strategy

Similar to previous search strategies, the strategy for video production and delivery used the format or template set from the search strategy previously mentioned. The constant or static variable used was “Obstetric”, the variants of this variable would only differ in terms of plural and singular separations of the word (Obstetric, Obstetrics). This variable was applied to a multitude of different strings using variances of the words Video and production as shown in figure 6.

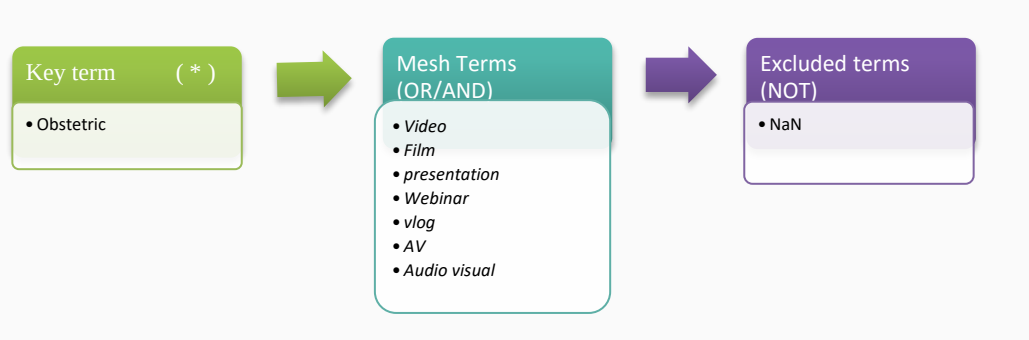



Figure 6: Video MESH terms.

*(((((obstetric) AND video) OR film) OR presentation) OR vlog) OR audio visual)*

The inclusion and exclusion criteria were again tailored to fit this particular search, with static criteria as before. Initial screening was conducted on 42 articles matching the criteria needed for the review. Finally, 10 papers met the inclusion criteria. Actions taken for identification of the literature, screening, eligibility, and inclusion can be seen in the prisma flow diagram in figure 7.

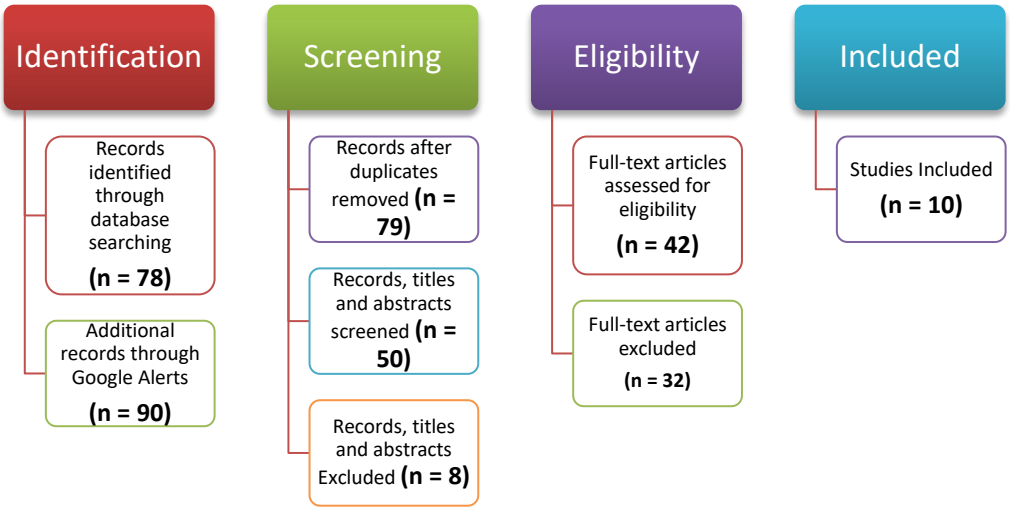



Figure 7: Prisma flow diagram of the Video key term search for literature.

### 2.4.2 Review of the Literature.

Video format has been extensively used in the field of obstetrics, the possibilities for amalgamation and integration into wider platforms makes it an asset in any medical field. The following research studies examined the typical uses of video in obstetrics education and its positive and or negative responses.

A study by Gambadauro et al., (2008) progressed the development and assessment of a network enhanced surgical training (NEST) unit, which was pitched as a cheap and effortlessly reproducible tele-mentoring practice. The instruments and methods involved two regular PCs, a desktop computer kitted with a digital video-capture system for the surgeon in an OR (operating room) and a laptop for a tutor/mentor outside the OR. Visual and audio interaction was achieved through freeware use between the two computers with no IT participation. Rigorous testing and analysis for half a year led to the effective development of NEST (network enhanced surgical training).

The system was tested against an abundance of gynaecologic and obstetrics interventions comprising of but not limited to abdominal, vaginal and laparoscopic surgery. The system also provided a visual contact to medical students and endoscopy representatives. From the results of the surgeons' and student's interaction with the system, the users noted it to be reliable in terms of instruction.

According to the researchers the increased proficiency of marking and surgical procedures resulting from the tele-mentoring monitoring system deserves attention and video has its place in assessment in the future of obstetrics and gynaecology. The students also remarked that their mentor, although using the second PC was easily accessible as they were next door if any complications arose (Gambadauro et al., 2008). The study helps create another possibility for the progression of the media of video and visualisation in the field of medicine and furthermore obstetrics. Live video, visual assessment is a step forward in the right direction in terms of educational material development and could be tackled in a multitude of ways, including raw data assessment in real time.

An ethnographical study was conducted to understand the experience of pregnant women viewing childbirth preparation videos in childbirth preparation courses. This study was interesting as the childbirth preparation courses have advanced into a significant factor in modern perinatal patient training with extensive multidisciplinary backing.

Although the fields of Obstetrics and Midwifery are used to this teaching/learning strategy, it is interesting to view the effect these scenario videos have on pregnant women and practitioners involved. The study aim was to examine the influence this education had on the pregnant woman's preparation for childbirth. Eleven pregnant women took part in the childbirth preparation course, under the supervision of researchers who observed the activity. During the course, quasi-controlled discussions were conducted with the women in order to record their experience of watching childbirth preparation videos. Discussion records, notes and logs were kept. Some of the women noted that viewing the video birth images in childbirth preparation evoked an emotional catalyst to prepare for them up-coming labour and birth. Others stated that the childbirth preparation videos had the capacity to impact significantly on their processing of information for purposes of childbirth preparation, but these women also noted a lack in this medium of full explanations and technical information. According to Gibeau, (2008), childbirth preparation videos hold the promise of providing a key teaching and learning experience within childbirth preparation classes. They also suggested exploring other means of media to interpret the processes with educational potential for obstetrics students as well as women involved (Gibeau, 2008).

Bahl et al., (2010) used video as a medium to address the non-technical skills of an operative vaginal delivery (forceps or ventouse). The skills of trainee obstetricians

were compared to midwifery experts using interviews and video recordings. The skills recorded on video were those cognitive and social skills required in an operational task and the interviews were carried out using routine clinical scenarios in a simulation setting. The study took part in two university hospitals in St. Michael's Hospital, Bristol and Ninewells Hospital, Dundee. Participants included ten (n = 10) obstetricians and eight (n = 8) midwives identified as experts in conducting or supporting operative vaginal deliveries. Data were collected using on skills using tick lists related to situational awareness, decision making, task management, team work and communication. The trainees where presented with the data and visual material and asked to give their reactions to the process. Participants stated that the process explicitly defined skills that could aid trainees' understanding of the non-technical skills to be considered when conducting an operative vaginal delivery. According to participants this could potentially reduce morbidity and improve the experience of delivery for the mother (Bahl et al., 2010).

This study differed from other similar studies as the control of what appeared on the video presented to those participating fell solely on the participants. According to the researchers, no post-production was needed and the video offered the trainees a much needed validation of their skills (Bahl et al., 2010). Thus the study offers an additional usage of the medium and further supports the claim that it provides aid in the education of obstetrical trainees and students.

A study by Chao et al., (2010) utilised an instructional DVD with videos on anatomy and repair of anal sphincter lacerations. The researchers then assessed its effectiveness on improvement of postgraduate trainees' understanding. Seventy-one obstetrics and gynaecology trainees took part in a pre-test to assess their baseline knowledge of the subjects. After one year of clinical experience, sixty -seven (94%) of trainees were randomly assigned into DVD (experiment) and non-DVD (control) groups with a post-test four weeks after. The increase in score from pre-test to post-test was significantly different between the 2 groups, independent of year ($p < 0.001$). DVD group scores improved significantly ($p = 0.01$, on two years) over non-DVD group scores in anatomy ($p = 0.005$) and repair methods ($p = 0.042$) (Chao et al., 2010).

The researchers recommended an educational video as an effective tool for improving understanding of third- and fourth-degree lacerations for physicians and students in training.

The DVD might have been a viable format to use for educational purposes in previous years, but as the medium is slowly becoming extinct due to online video content (i.e. Amazon Prime, Netflix, and YouTube). The clinical groups would benefit more from online video material. This is supported by its ease of access, lack of a need for physical representation (the CD or DVD as an object), or necessity for tailored hardware for single processes (DVD player or CD drives). All this is easily managed as DVD and CD files are easily extracted and their content transcribed into viable online video formats (.mp4, .m4a, .mov).

A similar study examining the capture of video scenarios was investigated in the Netherlands. The study focused on the attitudes of women and healthcare providers regarding the use of video capture in the delivery room for quality improvement, prior to its application. Focus group meetings were convened to acquire qualitative data on advantages and disadvantages of using video during birth. During 2011 researchers conducted four focus group discussions representing all possible members of the delivery team (e.g. Midwife, Qualified doctor, pregnant woman.). The questions centred on the aspects of beneficial outcomes of the use of video. Delivery room staff were worried about the use of videotape for professional evaluation, especially in relation to their colleagues or supervisors viewing and criticising their clinical practice. The researchers felt that video capture could be used as a data gathering technique in patient-oriented clinical research relating to quality of care issues in acute obstetrics. In their opinion, it represented an unbiased record of reality, is objective and independent of personal interpretations and may be an important tool for quality improvement during labour and delivery (van Lonkhuijzen et al., 2011). The introduction of this method however is hampered by fear of litigation and breach of privacy, but s considered useful and seems acceptable if specific conditions are met (van Lonkhuijzen et al., 2011).

Another study was conducted to test the feasibility and acceptability of using video web communication to teach and evaluate surgical skills in a deprived resource setting. The research by Autry *et al.,* (2013), was a case controlled study that used video/web communication for surgical skills teaching and evaluation.

Intern physicians (n = 18) commencing their rotations in Obstetrics and Gynaecology Department Makerere University Uganda, were randomized to the control (n = 7, traditional practice) or intervention (n = 8, three video teaching sessions with a US university Obstetrics faculty representative). Pre-intervention and post-intervention

videos were made of all interns tying knots using a small video camera and uploaded the files to a file hosting service that offers cloud storage. A faculty member then blind tested the videos and graded them. Both groups then completed a survey at the end of the study. Results showed that marks improved for 6 out of the 8 interns in the intervention group (75%) compared with 1 out of the 7 (14%) in the control group. Marks dropped in 5 out of the 7 (71%) in the control group but there was no decline in the intervention group. Both intervention and control groups relied on classmates and the Internet as bases for knot-tying information, although the control group was more unlikely to rehearse knot-tying than the intervention group. The trainees and the instructors felt that this method of training was entertaining and accommodating. The researchers noted that isolated teaching in deprived resource settings, where faculty time is limited and access to visiting faculty is an irregular occurrence can be assisted by these media enable learning devices. They stated that the process was feasible, effective and well regarded by both learner and teacher (Autry *et al.,* 2013).

Although an accepted and feasible method of teaching, it had some faults. When the reliance for information is dependent on an internet connection, latency and poor connection response can be an issue. An independent platform could offer a more secure system for the students without any possible issue when conducting tests. It is clear from the results that some student participants preferred the traditional lesson structure. To have a more unified acceptance of the new media teaching platform, a more diverse media approach may be necessary, incorporating text and audio for those learners who prefer textual and auditory examples.

Another study conducted by Nilsson et al., (2014) compared e-learning and video. The study was carried out at a secondary health care centre in Kenya. The objective was to compare two teaching methods; interactive hands-on training vs. non-interactive video training. The two methods (e-learning and traditional) were evaluated using structured observation of a scenario before and after training, video and with no video. Both successfully passed training with equally matched scores. The results were that training by mobile media was just as effective as conventional training.

The researchers concluded that mobile training was an achievable way to overcome the outreach gap in Sub-Saharan Africa's rural areas (Nilsson *et al.,* 2014). This study proves a great point in the accessibility of this educational material.

With mobile technology today, most users can connect to the web in any part of the world; this creates a new portal for those who have been deprived of this online content a new means of educational standing.

Obstetrics educators want practiced/skilled doctors and midwives to exit their courses with valuable knowledge and productive skills. For example, skilled performance of caesarean deliveries is essential in obstetrics and gynaecology residency. Technical training is essential in this case and hands on training requires visual aids and some form of physical representation. One study used a computer-enhanced visual learning module (CEVL) for this particular task. This platform was solely developed to teach obstetrics residents the skill of caesarean deliveries. The platform was distributed online as a module for students. It presented caesarean deliveries as a series of mechanisms using text, audio, and mainly video. The researchers tested the CEVL Caesarean platform on first year residents ($n = 12$) and then they were intra-operatively evaluated by trained raters who provided feedback about the students' surgical performance. Over four hundred caesarean deliveries were observed and analysed.

After using the platform the resident's performance significantly improved with each repeated operation ($p < 0.001$). Procedural performance, independent of resident, also improved significantly and also levelled off after a high number of attempts from each participant. This indicates that a user, in this case the obstetrics residents, were adapting to the measures set by the platform and understanding the processes well enough to effortlessly work at a levelled pace and have a levelled baseline knowledge of the task. The researchers concluded that the positive findings from their study provided evidence that the introduction of teaching using computer-based modules for caesarean sections in pre-clinical formats is a viable method to progress with (York *et al.*, 2014). The findings also demonstrated that the trainee surgeons needed no less than 30 practices before performing the procedures proficiently and competently. This is not a downside to the platform, as with anything that requires training, practice makes perfect and practice like this is perfect as it is self-contained on the web without physical human representation.

Research involving students in paediatric and obstetrical nursing courses monitored the student's satisfaction with receiving traditional classroom lecture format without recording versus video streaming of live and simultaneous online lecture, which was recorded for digital library subject to local viewing (Parilli et al., 2014). At the end of

the semester, students (n = 53) responses showed the strengths of both approaches and showed a great deal of potential of the integration of both styles in continuous educational conditions (Parilo et al., 2014).

Researchers Youssef et al., (2015) presented a five-minute video tutorial on the management of shoulder dystocia to students, using a simulator that included maternal pelvic and baby models. After this presentation the use of the video was evaluated main purposes - clarity, simplicity and usefulness by distributing an online questionnaire to the obstetric students. Out of 483 students more than 90% found the video tutorial to be clinically relevant and clear. The researchers found that the video tutorial was considered by health professionals and students as a useful complementary training tool. According to the researchers, video aided material is subjective to students that have a learning preference to this type of media outlets (Youssef et al., 2015).

**Summary**

From the research reviewed, the present utilisation of video in obstetrics education and in multi-disciplinary fields is evidenced. The research demonstrates an array of uses in the field of obstetrics today e.g. as a supportive measure for assessment and information, as a tool to present students with recordings of procedures in retrospective error reporting, as a supportive tool for information on procedural techniques and for assisting the capture and display of precise procedures in obstetrics.

## 2.5 Simulation Development and Utilization

Simulation and sensor manipulation are a relatively new area in the medical field in terms of Virtual Reality (VR). Simulations support a field of study by strengthening real life practices with directed scenarios that copy or imitate extensive features of everyday practices in a fully interactive and immersive method (Moulton et al., 2009). Safety is a main concern when practicing any medical procedure and simulation focuses on removing patient contact to minimize safety risks. This requires full incorporation of its applications into the daily constructs and practices of health care. The advantages and cost effectiveness of simulation are problematic to regulate, particularly for resources that are difficult to manufacture, especially those in which an extensive usage is required. The longevity of simulation in health care rests on the assurance and resourcefulness of the health care simulation field to see that improved

patient safety using this tool becomes a reality (Gaba, 2007). Simulation is arguably the most prominent innovation in medical education in the last decade. The spread of simulation orientated writings and research have all indicated the potential of simulation as a foundation of health vocational training and patient care. Most of these simulated aided advances come under the heading of Simulation Based Education (SBE). In relation to the subject matter and research of this thesis, the type of SBE comes under the banner of the medical field of Obstetrics. The form of SBE used in Obstetrics is be SBME (Simulation Based Medical Education). This type of education uses physical representations of humans to follow particular procedural scenarios for educational purposes. Obstetrical SBME training includes a range of pressure sensor child birth simulators and synthesised fetal heart rate monitors.

These simulators have been used for many years and have a proven track record of beneficial procedural training for students and practitioners (Lepage et al., 2016). The main focus of simulations in the literature reviewed, in contrast with the final outcome of this thesis, is their emphasis on robotics. They also focus on leading their simulations into a more realistic environment, whereas this thesis focuses on the skills retained from an interactive scenario and the assessment of this skill at a later time.

### 2.5.1 Search Strategy

The search strategy for this section used the format or template set from the search strategy previously mentioned. The word simulation was set against obstetric for the first set of databases; variants labelled were simulation, sim, clinical environments, delivery training, ventouse training, C-section training and caesarean section training as set out in figure 8.

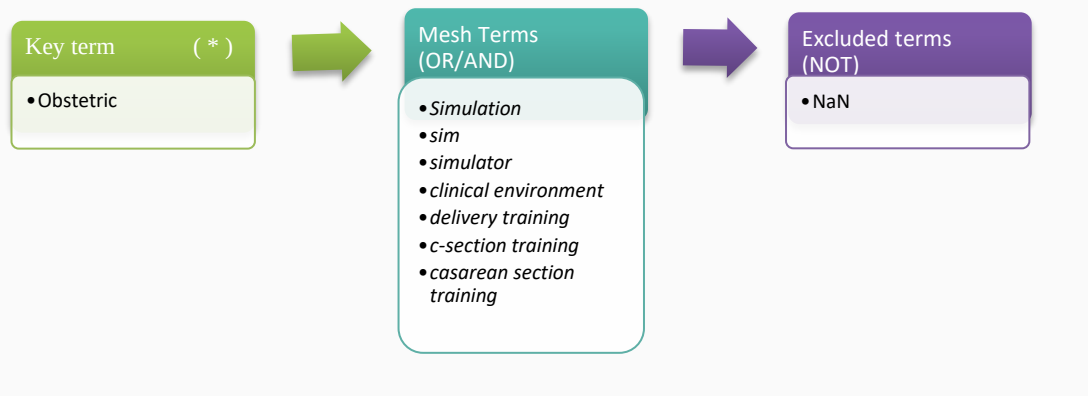



Figure 8: Simulation MESH terms.

The inclusion and exclusion criteria was tailored to fit this particular search with static criteria as with previous searchers. The results garnered from the simulation search were the highest out of all the key term searches, which didn't come as any surprise as the simulations are already used in force as an educational support in most areas of obstetric education. The search results were (n = 166) articles matching the criteria needed for review. Only those that met the search strategy criteria and those whose subject matter matched the key terms affiliation with the thesis's end goal were analysed before inclusion. All titles and abstracts were screened and following initial screening (n=50) papers were selected for full text review. Screening of full text resulted in 13 studies for inclusion.

Actions taken for identification of the literature, screening, eligibility, and inclusion can be seen in the prisma flow diagram in figure 9.

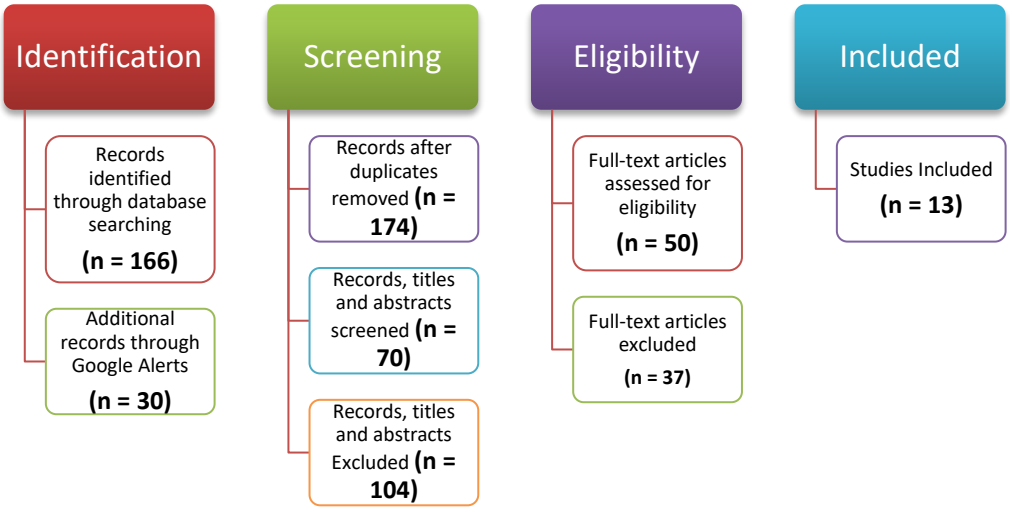



Figure 9: Prisma flow diagram of the simulation key term search for literature.

### 2.5.2 Review of the Literature

The bulk of the literature concentrated on the interactions of students and medical professionals with the simulations. Research into the benefits of this learning resource, attempted to show the usefulness of obstetrics simulator training for medical students by comparing confidence in normal obstetrics skills of students with and without training.

One study involved thirty-three obstetric students who performed their skills either on an obstetrics simulator (n = 17) or received no further formal instruction (n = 16). All students involved were asked to respond to surveys of their experience and confidence

in performing the procedures. Results showed that students who practiced deliveries on the simulator were more likely to believe that they could perform the majority of a vaginal delivery tasks independently or with minimum supervision than students who did not receive simulator experience. There was a significant difference in those who received the simulator training and those who received lecture only in their readiness to attempt a vaginal delivery independently or with minimal supervision ($p < .001$). The study provided evidence that students who practiced and trained in deliveries on a simulator reported higher levels of confidence in their skills (Jude *et al.*, 2006).

In the journal Academic Medicine (Journal of the Association of American Medical Colleges- AAMC) a paper by Amitai et al., (2006) on the subject of simulation in medicine argued for its ethical necessity. The authors highlighted the need for live patients in training and the fact that these training sessions hone skills needed in a professional environment. The authors suggested that health professionals were under 'ethical tension' in that they have an obligation to ensure safety to their patients and provide the utmost care and optimum treatment. They recommended simulation-based learning to help alleviate this 'ethical tension' by developing health professionals' knowledge, skills, while also protecting patients from needless risk. The authors added that simulation-based training using VR had been institutionalized in other high-hazard professions, such as aviation, nuclear power and the military, to maximize training safety and minimize risk (Amitai et al., 2006).

Later a study was conducted by the lead author of this paper, in relation medical professional and educator's views of simulation based medical education. The results were that medical professionals and educators recognised that Simulation Based Medical Education (SBME) complimented medical care by improving medical professionals' performance and developing patient safety.

A key message from this paper was the hypothesis that the numerous characteristics and components of SBME could also aid analytical assessment and inquiry method concerning clinical competency (Amitai *et al.*, 2007). It was clear that empirical research was necessary once utilising the SBME became common so that feedback concerning essential changes reached the objective of mastering medical professionals' performance.

Accordingly, SBME should be used to measure outcomes concerning educational techniques, the rate of mistakes, and whether the student's capacity to manage these mistakes significantly improved.

The authors suggested that the research should apply to long-term effects of the experience in changing professionals' opinions and performance. These researchers were concerned with the need to define a newly emerging profession SBME educator. The ability to conduct medical processes with trial and error provides the student and practitioner with room to develop learning practices without live subject liability (Amitai *et al.*, 2007).

Freeth et al., (2009) conducted a study that encapsulated this form of simulated scenario training in Obstetrics.

According to the researchers simulated scenarios may not always involve a physical simulator, but it is beneficial in the development of a proficient practitioner that in turn informs the way in which simulated education in terms of the physical models can be assessed.

The study in question retrieved participants' observations of MOSES (multidisciplinary obstetric simulated emergency scenarios) courses in terms of their learning practice and their transfer of learning to clinical practice. These courses were designed to improve non-technical skills amongst obstetrics student groups and educators to increase patient safety. Those who took part in the study (senior midwives and obstetricians) participated in interviews and video recorded informative examinations that were constructed from essential portions of the course. Team training was well received by the midwives and obstetricians taking part. Participants were able to check progress and judgement of fellow participants that would cultivate an admiration for the various roles in delivery. Proficient incubation of the skills and feedback from peers after each scenario was central to learning. Participants involved testified to having acquired new information and understandings regarding the function of communication and leadership in emergency situations. Witnessing their peers operating in the simulations improved participants' knowledge by emphasising alternate approaches.

The authors acknowledged that the students would benefit from a more tailored scenario with added media interventions (Freeth et al., 2009). This study provided an additional insight into the varied aspects of simulated training in Obstetrics, beyond the physical model representations. The idea of peer or educator feedback from observation have merit in its application to any future learning platforms in obstetrics. As the study of obstetric scenarios applied not only to obstetrics students but also to midwifery students, studies in the field of midwifery become applicable to obstetric

research and were generally adaptable to the educational progress of the obstetrical students' knowledge and skill set.

One study with to Midwifery students critically examined the evidence for simulation based learning in midwifery education. A systematic review incorporating critical evaluation approaches was conducted, which set well-defined aims and a clear search and analysis strategy for the results. Data from obstetrics, neonatology, technical and non-technical skills was included. Twenty-four papers were identified that met the inclusion criteria.

The benefits of SLP (simulated learning programs) over traditional structures was evident, as evidence of growth of non-technical skills confidence and competence was found and the authors were clear that there was sufficient evidence that simulated learning of midwifery skills was beneficial (Cooper et al., 2012). As this study was conducted nearly 5 years ago, the argument for increased methods of simulated learning have populated most disciplines medicine and healthcare in recent years, as new and emerging technologies create scope for new learning techniques. However, simulations are relatively localised in hospital. The question is would conducting these simulations outside of the normal constraints have an effect on the learning outcomes?

Another study that actively supports this claim involved identifying the affiliation between simulation training for vaginal delivery (VD) manoeuvres and consequent participation in live deliveries throughout the clinical rotation. The study also assessed medical students' performance and confidence in VD manoeuvres with and without simulation training like the previous study. The study randomized medical students (n = 33) either to have (n = 18, experimental group) or not have (n = 15, control group) simulator training. Both groups received traditional teaching. The researcher blind tested the randomized groups' competence of delivery manoeuvres and overall delivery performance on simulator scores. Scores were scaled from one to five, five being the highest while student confidence was assessed on likert scale surveys.

The results showed that the experimental group contributed in more deliveries than the control group (9.8 ± 3.7 against 6.2 ± 2.8). The experimental group registered increased confidence in the capacity to execute a vaginal delivery in comparison with the control group. The total delivery performance score was considerably greater in the experimental group. The authors were clear and accurate in suggesting that students who received simulation training participated more actively in the clinical environment (Dayal et al., 2009). From these results, it is apparent that student

simulation training is valuable in the process of learning obstetric skills in a minimal risk environment, demonstrate competency with manoeuvres, and convert this competence into improved clinical involvement and confidence.

A study by Rodríguez-Díez et al., (2013) centred on human patient simulators and assessing the obstetric residents and students training on a birth simulator.

This study had already included newly hired residents and those whom had performed on the SIMone birth simulator.

The method of data retrieval included analysis of four supervised sessions, two on instrumental extraction (ventouse and forceps) and two on labour observations conducted by twelve interns (n = 12).

Three evaluations were performed and findings were that there was substantial progress in marks between the first and third session for instrumental extraction (11 ±1.8 against 8 ±0.9; with a significance of $P<0.05$) and for labour monitoring (5.2 ± 1.4 against 6.6 ±1.3). Feedback from Interns was that the training improved their theoretical and practical knowledge respectively. The authors stated that training on birth simulators would allow an improvement of knowledge and skill of obstetric interns (Vieille et al., 2015).

One absent feature identified by both authors and students centred on the lack of formal debriefing instruction in devices. They recommended a media driven representation of the process to help instigate the teachings and make the training process easier. A simulator as advanced as the SIMone could possibly benefit from more creative media driven video tutorials and other haptic interactive mobile instructions. A similar study sought to define the level of confidence of students had concerning obstetric examination before and after training with the human patient simulators (like the SIMone). The study also sought to evaluate student's level of satisfaction with the use of simulation as a resource for gaining expertise. To answer these questions the study involved a training group of 10 students.

These students learned how to execute procedural manoeuvres on the simulator while an instructor supervised all physical exams respectively. The results showed that the students' confidence in performing the procedures increased significantly ($p\leq0.001$) after the evaluation (Rodríguez-Díez et al., 2013). This is a positive outcome further displaying the beneficial placement of simulators in obstetric education. Having students' knowledge of the processes increase by physical simulated actions cements the learn-by-doing approach actively enables the learning process.

In one particular study by Hughes *et al.,* (2014), midwifery educators evaluated the use of the simulated learning package: Practical Obstetric Multi-Professional Training (PROMPT) with final year direct entry midwifery students.

The researchers used questionnaires and focus group interviews to determine whether simulated learning, for emergency obstetric training enhanced self-efficacy and confidence levels in preparation for post-registration practice.

The main themes emerging from the study indicated that this style of learning increased midwifery students' feelings of self-efficacy; highlighted the importance of a safe learning environment; reduced their anxiety regarding their ability to make decisions in clinical practice and reinforced confidence in their level of knowledge (Hughes et al., 2014).

Research by Sabourin et al., (2014) compared clerkship medical students' confidence in performing a simulated normal vaginal delivery (NVD) after participating in a simulation training session using two different models. The medical students (n = 110) were randomized to participate in a simulated NVD session using either an obstetrics mannequin or a birthing pelvis model. A survey was used to measure the student's confidence and to assess the simulation before and immediately after the session. At the start of the clerkship, those involved had obstetrics exposure and confidence levels were matched. Just 13% of the students agreed they were prepared to attempt a NVD with minimal supervision. This considerably increased (40%) immediately following the simulation training session. In the end, 98% of the students reported that they were confident to attempt a NVD with minimal supervision or on their own. The authors suggested that simulated NVD training that employed any type of birthing simulation provided students with a positive experience and increased confidence instantaneously and recommended that it should be accessible to students early in their rotations (Sabourin et al., 2014).

The study results provide evidence of an effective connection between levels of competence and confidence, shows a relationship between continuous practice and proficient outcomes. Like the previous studies, the implementation of a simulated learning resource succeeded in its ability to enhance student learning by reproducing scenarios continuously with no human patient or complications associated. This enables the student to improve without affecting real life scenarios and in turn improve competency and confidence in practice.

The effectiveness of simulation-based training on learning and long-term retention of skills to perform general anaesthesia for an emergency caesarean delivery was evaluated by Ortner et al., (2014) with medical residents (n = 24).

Operation assessments which consisted of pre- and post-tests were conducted during the first and fifth weeks of teaching. A post retention test then followed eight months later. The resident's competency level and errors were evaluated in each testing session.

Six obstetric anaesthesia attending physicians, unaccustomed to the simulator formulated a mean performance total mark which was compared for each evaluation. In the pre-test, the residents' performance was significantly below the mean attending physician's' performance mark (pre-test: 135±22 against 159±11, p=0.013).

In the post-test, the residents' performance was similar to mean performance mark of the attending physician (post-test: 159±21) and this continued at the same level at eight months (post-retention test: 164±16). Findings therefore demonstrated that following a combination of lectures and simulation-enhanced teaching, the residents not only attained a competency level in a simulator comparable to that of obstetric anaesthesia attending physicians but also and retained this competency beyond eight months. The authors suggested that the errors identified in performance and the missed tasks could be used to improve residency training and continuing medical education (Ortner et al., 2014). This study supports the longevity of simulation based education and platforms as they foster a learn-by-doing training technique that can be retained for an extended period of time. This is in line with the goals of both educators and students who seek training techniques that ultimately secure life-long skills and procedures.

A study by Rose et al., (2014) examined the outcomes of educating both trainees and experienced physicians via simulation techniques about pre-natal analysis procedures. According to the authors the study supported the notion that pre-natal analysis procedures are essential for targeted fetal evaluation but on a much more limited scale. The study found that not all trainees would be able to become competent in these procedures without the aid of concurrent training which could be provided by simulation. Additionally, results showed the lack of available procedures for skill retention for experienced physicians caused possible loss of competence. The authors suggest simulation-based curricula has the potential to both educate trainees and to help maintain physician competence.

This study also supports the positive aspects of simulation training education, for example, the ability of trainees to reflect on the learning outcomes multiple times, which in turn supports retention of the information provided (Rose et al., 2014). One learning outcome that applies to all areas of academia is knowledge retention. Educational devices or techniques effect students in different ways.

Depending on the field of study a form of teaching technique could provide long term skill training due to its ability to aid retention.

In contrast, one study by Sørensen et al., (2015), investigated the effect of in-situ or on-site simulation (ISS) versus off-site simulation (OSS) on knowledge, patient safety attitude, stress, motivation, perceptions of simulation, team performance and organisational impact.

One hundred (n=100) participants took part comprising of ten teams made up of midwives, consultant doctors and students in obstetrics and anaesthesiology. Two inter-professional simulations (one focusing on clinical management of caesarean section emergency) were presented to the teams using the ISS against the OSS platform. Knowledge was assessed by a multiple choice question test and video evaluation of team task execution. The results found no variances concerning the two groups for the multiple choice test, or any subsequent test including the evaluation of the simulations. Video assessment of team performance also showed no differences between the ISS versus the OSS group. In this trial, that there were no significant differences found when comparing in-situ simulation against off-site simulation (Sørensen et al., 2015). However, the OSS platform was evaluated more favourably by the students. This implies that the training of simulated modules need not be constrained to a hospital environment. If, for example, a simulation was made portable or re-enacted in a different setting the effect on the students learning capabilities would not be affected according to the results of this study. This is a positive result in terms of mobile platform capability and in terms of intuitive ease of access learning.

A more recent study sought to evaluate the advantages of incorporating simulations in obstetric vaginal examination training. The randomized study involved medical students without prior obstetric experience, performing 10 to 30 vaginal examination training procedures using a simulator. Another group of students who had not performed any simulator training procedures acted as a control group. The medical students (n=66) completed six vaginal examinations on patients who were in labour. The students relayed the results of the examinations in five components (cervical

length, position, consistency, dilation, and fetal presentation). The study showed that students who had executed ten simulated procedures established significantly better accuracy in vaginal examination assessments in comparison with the control group ($P<0.001$).

No significant variance was examined between the results for students that had did 10 to 30 simulated procedures ($P=0.44$). According to the authors results show that the simulation training aided medical students in perfecting their vaginal examination skills before implementing these procedures on real patients and they believed that simulations should be included in the training curriculum for students who will examine pregnant patients (Arias et al., 2016).

The study also established that a simulator has the possibility of teaching a procedure, to medical professionals with no prior experience. This is paramount as working with live human patients leaves no room for error.

**Summary**

It is clear from the research that simulation is a key learning component in obstetric education, ranging from human patient mannequin simulators to simulated scenarios. Both of these are represented positively in the research presenting no downside to utilising these practices. Most studies reiterate the need for more obstetric student simulation interaction and at an early stage. The call for more elaborated constructs of procedural scenarios with the use of aided physical simulators are also made known in the research. Informing from the research its known that confidence and competence levels are seen as key factors of a successful procedural outcome. Success rate of obstetrics procedures is an important factor as it concerns the health and morbidity of the mother or child involved.

From the research there is a positive link from simulation training to high levels of confidence and competence, this would be in tuning with the students ability to learn from mistakes on a simulated model or environment without the possible fatal outcomes. Some studies add that simulations create an incubation stage to hone skills of a student to fully perfect a procedure. Simulation is not a new technology but has the potential to adapt and grew, to embrace other technologies to enable a greater form of procedural education.

## Conclusion to Literature Review

The review formulated a structure that required an unbiased approach to the search terms used, negative and positive results from studies were accepted and reviewed. Sceptical studies that were included, voiced an opposing opinion that structured a path in which the thesis could benefit and progress from. The overall positive response to future emerging technologies in obstetrics in the literature, further supported the claim that a merged-media simulated e-training resource could benefit students and positively affect the learning outcomes of the obstetric students. In terms of the literature as a collective, the term of e-learning has been referenced in all the key terms used, due to some studies using it as a blanket term to label all media used. The e-learning and e-training aspects seem to meld into a positive response from the studies used. Most aspects of the creative key term topics co-operate well together and seamlessly integrate. The creation of a multimedia simulation resource should in accordance with the research involved present a rich technology able to immerse obstetrics students into a series of instructional processes with the goal of student confidence in the process, effective knowledge retention and procedural competence.

# Chapter 3. E-learning in Medical Education & Learning styles

In this chapter the topics of E-learning and Learning styles are discussed along with their connection and effect on each other. The background of eLearning, importance of learning styles and related resources are also reviewed noting the significant correlation of the two subjects on the end goal of the resource. Along with the foundation of preliminary concepts, the integration of a learning styles questionnaire, the tallying of results and their ultimate use for future work were all examined correspondingly (Coffey *et al.,* 2014). The chapter ultimately produces a structure for the subsequent chapters following the topics conversed here. The level of technical detail presented in this chapter is by intention minimal to make it readable for both obstetrics and computer science representative readers.

## 3.1 Background: Online Learning and Learning Styles

E-learning can be referred to as learning conducted via electronic media, usually on the Internet and also referred to as electronic learning. E-learning characteristically utilises a computer to deliver a portion, or the entirety of a lesson be it in a school, office training or an entire remote learning course. Nearly two decades ago, in its first form, e-learning was poorly received. The general educational population assumed that introducing computers into the curriculum would eliminate the human element that a good number of learners require. However, this changed over time as technology progressed and developed, and we now accept smartphones and tablets in the classroom and office (Sun, Finger and Liu, 2014). The abundance of interactive designs increase the potential of the online material and makes it appealing for all learners. Studies have shown from the previous chapter that if appropriately applied, e-learning can be as efficient and successful as the more conventional approaches to education. The key benefits that e-learning proposes to Obstetric students and trainees are its flexibility, offering knowledge that can be organised around other responsibilities like tending to patients, college work and personal endeavours. Learners like these students can study wherever they have open access to an internet connection, which in terms of the current mobile culture and the mobile phones always on access to the web, would be everywhere they carry their phone.

The platform of e-learning centred education can be very convenient for these students, it enables them to carry out classroom focused tasks without having to travel in to the College or University. The platform informs the possibility of conducting this learning process in the comfort of their home or on duty in a hospital. E-learning and learning in general can be personalized to accommodate many learning styles which will inform the latter stages of this chapter and the general functionality and aesthetic of the finished thesis. Modules that encourage self-motivation grant learners the ability to complete work on course content and information in their own time. E-learning inspires learners to take charge of their own form of learning and it fosters a more deeply engaging learning environment that appeals to an array of sensory aspects of garnering a learners interest and concentration. Online learning offers all of these immersive qualities in a condensed and more resourceful form. The online platform also allows the chance to learn more skills and techniques about procedures.

Apart from student interaction, e-learning also allows practitioners, teachers and healthcare professionals learn skills to add to this content and helps cultivate an ever growing online library of informative data (Roszak, et al., 2015). Other advantages of e-learning include its capability to reach students in hard to reach areas, like remote countries where students are interested in the material but cannot travel to study. As previously mentioned e-learning content can be effortlessly revised and updated in a short period of time, in contrast to the effort involved in restructuring a traditional classroom or paper informed task. E-learning commonly tends to occur in real time synchronously (online learning taught by a teacher) or at the students leisure which is asynchronous (self-motivate online learning). The synchronous e-learning follows a computer-generated or virtual classroom when a group of students or learners are corresponding and virtually interacting in real time. Examples of these forms of synchronous e-learning can be found on online chat rooms, forums, and video conferencing applications like Skype.

Blackboard or Moodle or any other online learning tool that is in real time and that allow learners and instructors to request and respond to queries instantaneously, are referred to as synchronous platforms or applications. From this technology and instructor participation learners are capable of communicating with other learners and practitioners during an instructional class, instead of learning on their own. In contrast, asynchronous learning is instigated outside of real time task instruction.

Those who take to this form of online learning study at a time that is suitable to them, by means of online applications such as email, forums, audio and video content and e-training courses. Learners who are asynchronous normally finalise classroom tasks alone, utilising the internet as a base resource in juxtaposition to the online tasks laid out by online course coordinators. Learners are able to follow the module programs in their own time, which is an ideal choice for those students who favour researching topics alone or favour studying without instruction. Comparatively we also have a form of an incorporation of both the online learning and traditional learning experiences in blended learning form.

Blended learning combines online learning with the in person, face to face teachings of a traditional classroom. Most college modules incorporate this style of learning to an extent, moderately teaching students online, and additionally necessitating students to appear for training in a traditional environment. Blended learning is beneficial due to its ability to provide online support materials alongside more traditional training to students and trainees (Gill, 2011). All course component decisions rest with the course designer, this would normally be the teacher or instructor involved. The key decisions they would have to make would involve consideration of which components of the curriculum are best suited to traditional teaching, and which components are suitable for online teaching.

### 3.1.1 Importance of learning styles

Learning styles represent a variety of opposing and queried theoretical models or concepts that intend to clarify variances in a persons' learning attainment. These models suggest that every person can be categorised corresponding to their ‘learning style’. However, the different models exhibit opposing views on how the styles should be described and classified. A shared concept interconnected among all models is that people vary in how they learn. The idea of tailored learning styles grew to be a widely held concept in the nineteen seventies, and has significantly affected teaching and education, although it received criticism from some researchers in some academic circles (Pashler et al., 2009). Supporters of the general learning style theories propose that instructors evaluate the learning styles of their students and adjust their teaching approaches to match each student's learning style. However, there is sufficient proof that individuals convey partialities for how they favour the delivery of information and how they obtain the material.

It is important to recognise learning styles to guarantee that instructors or teachers are teaching according to the learner's style and not the teacher's style. A teacher who educates merely fitting his/her own style generates a more difficult learning environment for the learner or trainee.

Teachers should recognise concepts of learning styles to be capable of helping learners classifying their individual learning styles. This understanding should help learners to build self-confidence and to learn to control and direct their own learning. Teachers should know what their own personal learning styles are, since according to the models already mentioned, learning styles effect how we teach. Collectively it shows a necessity to recognise what those styles are and how they parallel the student's style. Understanding of learning styles could possibly help us become informed of relative styles and how to use these relative styles when in a teaching setting. Regardless of people having their own favoured learning styles, it is beneficial to acknowledge other styles and how to fortify the weaker styles. In accordance with this, employing numerous learning styles would support the fortifying of these learning experiences. The foundation of learning research must be the individual learner, which is in the case of this research has a focus on the Obstetric student. Although, the majority of current obstetric teaching endeavours are prepared traditionally in the classroom with a big group of obstetric students (Khan et al., 2006).

Therefore, while the teaching methodologies practiced in the classroom (known as macro level), learning should essentially focus on the individual student (known as micro level), an obstacle for a teacher or instructor is to attempt to aid this transition. Sadly there is an abundance of examples in which teachers fail to bring about this transition, amounting to confusion or alienation for some students as they transition from college to the workplace. This abrupt transition is well defined as some teachers are still not mindful of what essentially establishes learning for varied students in their courses. Regrettably, this is not taken into account by some disciplines of study, as some still disregard how individual students process material in tune with their learning style. The type of teaching is only successful when matched to a particular learning set. For example, in a VARK (visual, auditory, read/write, kinaesthetic, tactile – variances of the same model) system (which is adopted by most learning style models), teaching with visual aid and having a student with a visual learning style, would be successful (Marcy, 2001).

This could be applied to the other learner types. So if the teaching matches the student's learning partiality, be it perceptual, intuitive, allegorical, social or an amalgamation of a selection of learning styles, the teaching outcome is more likely to be successful. This could not be said for those students who are being taught outside of their normal learning preference. Furthermore, college or university educators and demonstrators who are dependent on the success of the learning outcome in their higher educational disciplines cannot manage to presume all students or trainees under their supervision will learn as a result of any approach the teacher favours.

The risk is too high with this teaching approach. The students learning acumen should be considered. Teachers ought to choose different approaches to teaching if they require students to adapt or to learn. Learning should be the objective, it requires new ways or techniques of encapsulating subject matter and these new methods need to be developed and applied for teaching approaches to be successful. The requirements of students in higher education differs and changes over time, which presents problems for conventional or traditional approaches, where the teacher repeats the subject matter year after year. How students learn should be offered precedence as the student's ability to immerse themselves into the subject matter. In truth, it is essential for teachers to possess an appreciative grasp of the learning style method in aiding or assisting individual and group learning. Teachers should take account of how these students learn. If repeated learning is not evidence of a learned subject, then further approaches are necessary. Many teachers maintain that students should validate their aptitude on methods highlighted in the course and have a grasp of the facts that defend the claims and structure of these methods (Myftiu, 2015). Authorities on learning theory maintain that the remaining concern in regards to learning theory is if learning occurs inherently to the student or is it achieved. In any case, the learning theory can potentially progress this mind set or establish a grounded understanding. E-learning or online learning is a useful medium for acquiring a student's learning style and is also a practical medium for displaying and altering material specific to the students' needs at any given time. Online learning presents itself as an adaptable medium for the learning theory models and will be discussed in detail, as it is integrated alongside a learning theory in this thesis.

### 3.1.2 Similar work & resources

Education has modified into a blanket of blended learning curriculum, with the majority of disciplines using online platforms for course/module content presentation, course work submission, and class discussions alongside traditional teaching material. Sites like Blackboard or Moodle (or variants), acquired by most colleges, offer students with the capability to involve themselves in the coursework with the ease of mobile use. These sites create an ease of access outlet for students providing a service that enables a faster assessment cycle, quicker approaches to content, and remote access. Obstetrics students, like students in other disciplines, are regularly in contact with online material, including email activity and the resource systems like Blackboard, so they're accustomed to the various mechanisms of online processes and web site interface deviations. Their content like other disciplines is secured on these sites with a classic navigational structure, simplistic interface (content over aesthetic) and list of downloadable material files. Most of the functionality of these sites does not stretch beyond the management of content and retrieval/distribution of the files without a focus on an interactive or immersive online experience. The files seen on these sites can range in format but can only be viewed once downloaded, eliminating the online element and making the media interaction local. Obstetric materials' online presence is not only limited to these practical websites. Some sites offer online courses in Obstetrics, giving users the opportunity to learn topics of great important with textual and visual (images) aid. One site that has garnered some popularity in the Obstetrics filed is the OBGYN-101 website. This website is dedicated to professional learning of women's issues. It contains an OBGYN Student package designed for third year medical students during Obstetrics and Gynaecology rotations. The online package contains multimedia training topics that are offered in a subscription to the site for twenty euros a month. The navigation through the online modules is based on any Multimedia site navigation, the videos/images/audio tracks are all laid out sequentially in folders. Each data format is of the highest quality making the lessons clear for those users presented with material. Text equivalents appear as hints within the options of the videos in the form of subtitle information.

The site is a great source of quick two- minute information sources but it is not visually appealing, and its navigation is clustered and archaic.

The majority of work handled by those involved in the site and its content was clearly visible including the editing of the obstetrics information videos and audio work.

The examples given were of good quality and information was not disrupted by media fault. The style of the information given to the users is much like any basic content management system (CMS) site formatted style; the sites style is traditional in its adoption of html table layout lacking in its use of CSS styling. The online application offered is a stand-alone package of multiple formats, so it has no affiliation with external video, image or audio sites for media storage or distribution. After my evaluation of this learning resource, it was considered effective for student use but it comes at a price, offers a clustered layout leading to poor navigation, although, this site has the potential to upgrade and present its site in a more appealing way (Obgyn-101.org, 2016).

Another site capitalising on the e-learning Obstetrics bubble is the StratOG website. This website offers learning resources for obstetrics and gynaecology but students have to register on a course and trainers have to request access to teaching resources. For twelve euros, students are able to access material on mechanisms of normal labour and delivery. Much like the OBGYN-101 site, StatOG offers a CMS based navigation cycling through multiple animated tabs, offering a tree-view structure for sub-headings. Text equivalents refer to alternative text provided for visually impaired users. This site provides alternative text (alt) for all of the images accompanying the information displayed. Scripting is present due to the tab based animations. The script used is JQuery, mostly used on tree-view controls. The use of this scripting makes it easier to join with many other types of style-sheets and scripting formats. Styling is CSS3 based using centred orientation, which is a typical site layout. The tabs have the same colour scheme with the subheading created with a darker toned theme. HTML standards refer to the standards set by the World Wide Web consortium (W3C), according to the Functional Accessibility Evaluator the sites standards are in compliance with those set. After my evaluation of this learning resource it was considered effective for student use but this application comes at a cost. There is a price for initial subscription and for examinations. It offers all the necessary information but it is not very accessible. Available multimedia learning resources were scarce especially in obstetrics.

Therefore, it was necessary to develop a multimedia learning resource to demonstrate the process of delivery to meet the learning needs of medical students and to meet the requirements for interactive, flexible and easily accessible learning resources for students at UCC (Stratog.rcog.org.uk, 2016).

An additional site that presents more on the creation of more interactive options for students and users on a site is the Obstetrics & Gynaecology e-learning module training site presented by Michigan State University. This site veers a step ahead of the typical site formula presented in the latter examples. There are similarities with the previous sites in the sites simplistic layout approach and the colour scheme of the site. The site initially presents the user with an informative video in the main index page. Under this video lies three neatly presented tabs of Obstetrics and Gynaecology topics, these topics include Vaginitis, Amenorrhea, Third trimester bleeding. This site is unique and differs from previous examples as it doesn't over load the site with an array of topics, but centres on a select few and dissects the information involved more accurately and at length. When one of these options is selected the site shows four corresponding panels relating to topic discussions with informative tabs on procedures, clinical cases with individualised windows on selection pertaining more information on each case example, a video panel showing the respective video for the topic chosen and the final panel presents a series of short questions in a stylised quiz. The interface structure on this page was sound, presenting four panels with no excess information, ease of navigation as it was localised to the single page, and no change in tab or window. The site's examples and interface design presents a positive outline for this thesis's possible interface layout, alongside learning style influence and user preference feedback (Learn.chm.msu.edu, 2016).

## 3.2 Background of the Online Platform and Planning

When creating an interactive learning resource there is an array of considerations taken into account as a learning resource needs user input and trial schematics in its framework, foundations and visual appearance. Before any schematics or frameworks are obtained, user feedback is drawn to surmise a general need for particular resource functions, navigation and appearance.

In the case of this thesis, the learning resources general functionality, navigation and appearance similarly relied heavily on the users personal requirements as a learner and operator of technology.

The fashion in which their individual preferences were collected involved the amalgamation of a survey involving the approximation of learning style and an e-learning (online) platform.

### 3.2.1 Why use an E-Learning/Learning Style Survey?

The reasoning behind using a combination of learning style survey and e-learning platform stems from the necessity to reach a wider group. An online platform gives participants ease of access and completion of material whether it be tests or surveys. Students in particular would find an online survey more efficient than your conventional hardcopy survey, as the majority course content and sources of classroom material can be found on the web with content management systems (CMS) like Blackboard or Moodle. An online survey can offer information on the given topic and be accessed at any time due to its static presentable nature. Finding the students learning style also offers further information about the user, creating a small bio on the preferences and likes of an individual student.

This furthers the development of applications as the information gathered presents an understanding at how the students collectively would want a tailored application to appear and function. In terms of this thesis, the target users were those operatives whose primary professional tasks involve the processes of childbirth (preparatory, during and after birth) procedures. The focus of the thesis centres on the education and training of Obstetric students, so the primary user would be an Obstetric student. Other users would preferably be students of a Midwifery background as they are taught delivery practices using a variety of educational materials and physical examples. Both disciplines would contribute their own take on teaching material (e-learning) and type of material retention (learning style) (Coffey et al., 2016).

In terms of presenting the finished online survey and e-learning additions, multiple iterations were cycled through until a user friendly and intuitive site was presented. These changes ranged from visual representation, questions asked, registration form data retrieved and content presented once completed. The focal part of a survey are the questions and how the questions are asked. The questions should reflect the expected outcome and in terms of the thesis this outcome should result in application preference and learning style data.

That being the case, questions were designed to encompass queries about IT (Information Technology) competence, user interface preference and learning style that culminate into a definitive desired outcome for an individual student and a rough outline for a student population. When fashioning the learning style questions, research was carried out to find a sufficient question format for collecting the learning style efficiently. There were numerous learning style indexes to choose from including and not limited to David Kolb's experimental learning style model, Felder-Silverman learning style model and VARK (Visual Auditory Kinaesthetic) learning style index. As the resulting application depends on a detailed output from the survey in terms of learning style, the learning style index applied garners some weight on the ultimate outcome.

Knowing this, each learner style model was researched in terms of its effectiveness in attaining the data and it application to the medical field of Obstetrics. Following the review of the literature both Kolbs and Felder-Silverman's models were used extensively in learning style research in Medicine and Obstetric studies, with VARK learning styles used for blanket terminology for the former indexes attributes. As both indexes have proven to be effective in their ability to accurately collect data, the employment of a particular calibrating method relied on other outstanding factors from each. Kolb's model cycles through learning styles, filters through all learning attributes and settles on a combination of two learning styles and suggests descriptive names for these joined styles.

For example, Active Experimentation, Reflective Observation is used in both Kolb's model and the FSLSM (Felder-Silverman learning style model) (Active/Reflective), but in Kolb's model, Active and Reflective can be merged to form a descriptive learning style term known as Assimilating learner which describes the user as a learner who learns by thinking and watching material. As an instrument the Felder-Soloman or ILS (Index of Learning Styles questionnaire) based on the FSLSM showed a more robust structure, offering added expressive attributes that have the ability to follow a structure that can definitively assign a learning style to a group of students. The attributes in the ILS structure are quite descriptive and when informing the students of their results, the output is in variant degrees of a learner type (for example one student could be 20% more of an active learner than others, and a similar student could be a mixture of two learning types by having a close score for both).

### 3.2.2 Choosing the FSLSM and Subsequent Survey Index of Learning Styles

Numerous learning style models have been proposed in literature including but not limited to Kolb (created in 1984), Honey-Mumford (created in1982), Fleming's VARK Model (created in 2001), and Felder-Silverman (created in 1988) models. The FSLSM (Felder-Silverman learning styles model) was chosen as the main focus model in this learning style data retrieval as it is well-known and often used model, particularly in technology enhanced learning resources. The FSLSM model also judges learning styles as inclined type's rather alternatively compulsory types (Oravcova *et al.,* 2009). The FSLSM model is user friendly and grants ease of use (Graf *et al.,* 2007), and blends key learning style models (Hong *et al.,* 2004).

Felder and Silverman (1988) express the learning style term as the qualities, assets and preferences in the way learners acquire and process information. So FSLSM, learners can be categorised by four components. Each learner is then categorised by a specific preference for each of these components, though these categories or characteristics are inclinations and not distinctive patterns of behaviours. The learners may show signs of either type on any given occasion. One of the categories in each component can be desired as strong, moderate, or fair by learners, and also a possible balance of the two categories. The model also classifies learners in broader groups and have a more detailed description about learners' leaning styles (Adetunji, 2014).

### 3.2.3 Planning an E-learning System

Planning an e-learning system requires negotiating the necessities needed, this would involve discovering the needs of the target user (obstetrics students) and centring blueprints formulated on the representation (Coffey et al., 2016). Beyond the use of learning styles information and the user interface centred questions, the end result should be grounded on an assumption of what will work with the background Obstetric theory and knowledge of the media to back it up. Assumptions create a starting point to adapt the platform from, receiving feedback on improvements on first glance. Before creating a learning resource or online student platform there are a milliard of important factors to consider. There needs to be a focus on the target audience, which in this case is the medical students participating in an obstetrics course (obstetrics students).

There needs to be a clear idea of what kind of learner these students are. Current knowledge and skills of these students needs to be assessed along with technological literacy. The module or platform then needs to be constructed in keeping with the learning style of the collective group. In addition, there is always a need to focus on the learners setting or environment and notice the implications of the end result for students potentially at a computer studying the created e-learning platform. There is an array of sources students choose to learn from, including textual (textbooks), online (websites), or face to face (conversations) communications with their peers.

There should be an active involvement of the student in the finished platform in terms of encouraged feedback to further improve or to complement the resource. Equally set, the resource should be independent and cover all that the student's requirements to reach its particular learning objectives.

Speaking of the learning objectives, these are necessary for the resources successful implication and need to be vividly outlined. Typical learning objectives key points rely on a clear understanding of what the student should be able to do by completing the tasks implemented by the resource. The student should be able to evaluate whether they achieved the learning objectives or not for themselves. The learning objectives should also centre on finding motivating methods to show material in the e-learning resource. There are numerous ways of presenting information in an interesting way. The key to presenting this information effectively is to actively involve the teaching or learning process without mollycoddling the student, keeping in mind the presence of the material is probably already in book or website format. The resource should extend outside displaying the material and exist as a dynamic learning tool.

## 3.3 Development of the Online Survey Tools

In the beginning, the survey and its counterparts were created as a foundation for potential iterations and periodicals of the finished questionnaire piece. The structure was guided under the prospective acquisition of obstetric students learning styles and especially those students hypothetically benefitting from the final thesis resource.

Although, online surveys including Survey Monkey or eSurvey are easy to use survey platforms that offer a great number a representable data and feedback in the form of informative figures and graphs with features and layouts that are usually crisp and well designed, these online surveys would not be effective in the processing needed for this particular study.

### 3.3.1 Background of survey creation

Initially the data and graphs presented were used to inform a number of key features of this thesis but ultimately in customising the data retrieved for later inspection. Potentially the end result or final piece should have a database that houses user (student) details and survey scores. These individual fields of user data in the allocated database should have the ability to be accessed at any point in the thesis. Like the survey applications offered online, data from this database could be graphically and figuratively presented but unlike the other survey applications this database data is in full control of the thesis offering endless custom manipulations and configurations in the timeframe of the thesis. This is certainly useful as when iterations progress, changes are inevitable, so change in a creation of your own resource is easier than change of a static online application. The initial surveys structure and aesthetic were informed by the typical layout of these online surveys in question.

The creation of a self-developed, tailored survey enables the thesis to source information beyond the capabilities of an online survey application. The finished created survey (unlike the online survey applications) would offer a registration for the students, gathering integral demographic (age, gender), education and background details together with the obvious calculation of learning style type. From initial iterations of the survey, the questions aesthetic and functionality were adapted from progressive feedback from obstetric tutor and supervisor input. The results gathered from the survey should inform the creation of subsequent material in its navigation, look, and functionality. When referring to the creation of the separate development stages, the terms backend and frontend development are referenced as means of programming progression. The frontend and backend differentiate between the division of control between the presentation layer (the frontend – the interface) and the data access layer (the backend – the coding background).

The front and backends may be distributed among one or more systems, which will be applied in each chapter of the thesis and stage of thesis development.

### 3.3.2 Iterations and Deliberations of the Survey Construct

#### *3.3.2.1 First Iteration*

As previously mentioned the survey was subjected to many iterations varying from content presented, user interface design and general functionality.

In preparation for the first construct of the survey system, key factors of initial setup had to be established. These factors enabled the foundation of the survey and structured the path from which the other key features could progress. One standing factor was the database which would house the details, information and results of the survey and potentially the details obtained from other aspects of the thesis at a later date. The database is a key feature of gathering, distribution and housing of vital information. Initially the database structure needed to be outlined to fully comprehend the details needed for final analysis. Originally in the first iteration, the database was constructed to gather information on the users' full name, course, studentID, survey password and the score of all the collected learning style in string (text) format.

Obviously this database was the first example of the structure used and was ultimately restructured due to adherence to either web compliance, supervisor suggestions or statistical compatibility.

The database was constructed using a combination of MySQL and phpAdmin, towards a dedicated server. A dedicated table was created under the name "ObstetricsSurvey", once this table was generated variables were assigned for future interaction. These variables matched the naming conventions of the information initially needed in the creation of the survey, "fullName", "course", "studentID", "surveyPwd", and "score". The reasoning behind the fusion of words and the particular placement of the capital letters in the variables mentioned spawns from correct coding practices, when working with any programming language, spaces and capital letter arrangement might interrupt the processing or build of a program developed. A great deal of programming languages are case sensitive and could react to incorrect parsing of the syntax involved and the variables established. In light of this, the practice of correct naming conventions paves a more secure and foresighted path to resource completion without any errors.

All variables created had type inputs, all variables had string values with the capacity for thirty characters, with the exception of the tables ID which was an integer.

This variable was static and had an auto increment feature, increasing the number of rows and incrementing the number as the table data were received. The table was created in the hope of applying it to the created survey and receiving the data needed for accurate learning style assessment.

From this database, a corresponding website needed to be created to house the login/registration content, questionnaire, result feed and information.

The database needed to rely data from the server at any point whether it was inserting or updating fields in the designated table or displaying values that were already inputted. The website needed to be a PHP website as PHP works better than most conventional html websites at interpreting database connections and establishing a form of e-commerce system with login protocols integrated. This website would need to be able to extract and manipulate sources of data from a database at any given time and present this to the user (an example of this layout can be seen in figure 10).

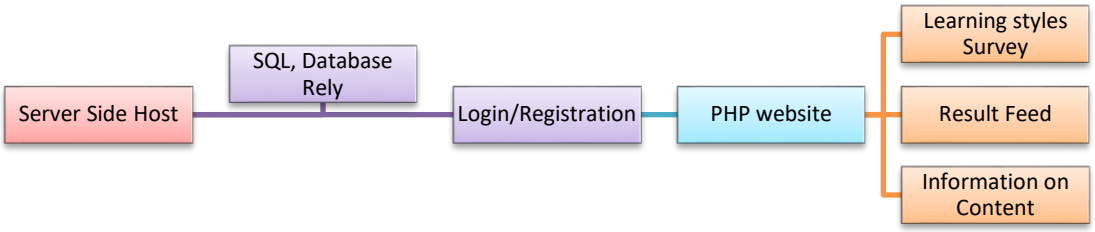



Figure 10: Connection layout of website/database configuration pipeline.

As it is the first point of interaction with the site for users/students, the registration/login content was created to begin with. Taking aside the aesthetic created using CSS3 (cascading style sheets), the first port of call for the development of the login/registration section was to create a form on a PHP document called index.php to house the inputs needed to correspond to the fields associated in the database. The registration and login placeholders needed to be separate and allocated separate forms, as the functionality of the two were very different. The registration form invoked the ability to insert new data from the registration form into the database, while the login form invoked the process of granting the user access to the rest of the website once a connection had been established between a current entry in the table. It is recommended for most instances of database interaction that this convention is applied to all form and database interactions to avoid confusion. This is to avoid confusion particularly when code is in need of an edit at a later date. Another fact to note is that the maximum length attribute in the forms fields are set to the same value as its corresponding database field.

This is to protect users from trying to enter a value greater than the database field will hold, making the length thirty as previously mentioned. This however is taken care of at the processing level when the form is submitted. From a security standpoint, validations parameters are added to each field to prevent submission of unnecessary or unrelated inputs to a particular field.

For both forms the POST method is used to send the input values received by the user to external files depending on the form used. Both forms have specific functionality and process aims. One other file is created that would be initialised in both registration and login external files and this is the connection file. The connection file is integral in the main process of database interaction, the connection file (connection.php) establishes the connection between the database and the index.php file on the server. The code written in this file retrieves the database and table needed while in turn landing on the external file allocated to either registration or logging in.

In the external file invoking the processes of the registration forms execution on submission, the connection file was initialised to establish a connection to cement a compatible process for further interaction. In this stage of programming a PHP session is used. A session creates a way to store information (in variables) to be used across multiple pages. So unlike a cookie (web sourced data), the information is not stored locally on the students/users computer or browser. The session makes it easier to make it known that a particular user has logged in, as the development stages progress. After using the session initialiser, this particular external file for registration processing creates variables using the POST form values and linked the newly created variables to the corresponding variables on the database. Inserting the values inputted into the database field relating to them. This is known as a SQL query, they can range from any form of SQL database interaction or manipulation and is also used in the login external file for processing. From the above code snippet presented from the registration database query, the variables created in PHP (indicated by the dollar symbol) are specified as the values for the database variables marked in the start of the query. The values within the PHP variables are as previously mentioned, the POST form values. This creates a link to the ObSurvey table, and inserts the values where allocated.

One key variable missing in this query was the score variable. The reasoning for this exclusion reverts to the goal utilisation of the score variable.

As the score variable refers to the final learning style score, the variable would be inactive until the questionnaire is active and completed by the user. This would in turn fill the score field in the database once a student completes the questionnaire section of the survey site. The final functionality of the external registration file is a process established from the external login files functionality.

This process involves selecting the variables of studentID and password where both variables match those inputted through the POST method. As the session process helps retain these values and variables, the information collected can be processed in an event. The event processed, refers to the relocation of the user to the survey with their variable information in tow.

This ultimately creates the ability for the system to assign a score to the student in the back end. The next important file essential to the surveys early range of capabilities is the login page. The login page relied on the structure of an already active and populated database. The first programming stage involved a session contribution, like the registration file before it; the session carried over the input values issued from the user and stored them for later calibration. This data carried through was then assigned variables to match those fields created in SQL. The same functionality as the final stage of the registration file was carried out, selecting the variables of studentID and password where both variables match those inputted through the POST method. The process itself involved an SQL query that cycled through the entries in the fields of studentID and password that matched those consisting of the two. Once finding the right match the user was relocated to the survey page. It should be mentioned that validation and error catching methods are presented in all files associated with the site at this stage in the development. In form validation (for incorrect use of symbols etc.) and in incorrect or inability to find a match where “else” iterations are present with echoed text to prompt the user of an inability to find the specific entry (“user name and password not found, please try be aware of capital letter usage”).

Once errors were detected the user was not relocated and was subjected to a text outlining a particular error and the ability to retry or attempt again. The main survey page at this point was blank, ready for an introduction of survey questions.

A test entry was created to populate the database and to access the site to view the internal processes of the survey once created.

In the first stages of style creation and layout alteration, at this point there was no advice given as to the structure of the layout or navigation of the site or the way in which the questions were presented. The sites initial look generated from a need to keep the content separate but easy to access, the colour scheme drew from colour palettes utilised in the obstetrics website used in the University (UCC).

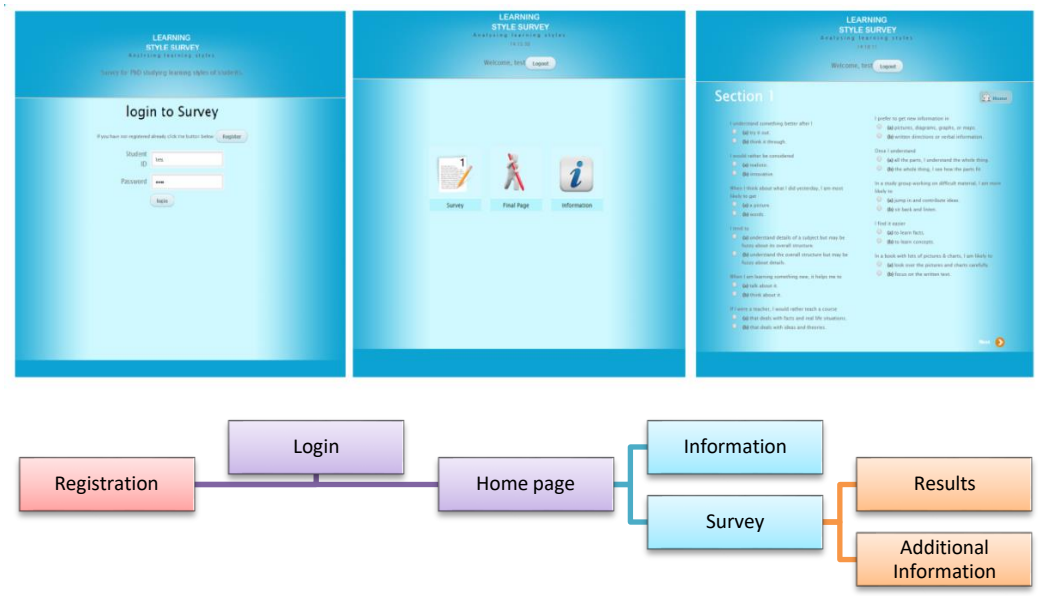



Figure 11: Site layout and linear navigation progression.

The navigation centred on the need for the student to be informed of the subject matter (learning styles) before and after completing the survey. This would catch students who would quickly approach the questions and then leave with results they wouldn't understand. The colour palette involved an array a various shades of blue constructed in a placeholder that enabled a tween (animated content movement) when moving from one section to another. Section placeholders were created in order to house the questions needed for the survey.

The questions were sourced from the Index of Learning Styles (ILS) created by Felder and Soloman. These questions were arranged to accurately read the students learning preference and provide a percentage or scaled reading of the prominent degree at which a certain set of learning styles is attributed to that student. As previously mentioned, the Felder-Soloman ILS was chosen over similar learning style models for its range of questions and more diverse range of learning style type. The ILS also creates a moderate to high scale to which the student averages on a particular learning type.

The ILS stored forty four questions which were added to the section placeholders on the site. These forty four questions were dissected into four groups that corresponded to the four scales of the ILS: Section 1: Actice or Reflective, Section 2: Sensing or Intuitive, Section 3: Verbal or Visual, Sequential or Global. The four sections contained eleven questions each. The tween animation was used to get from one section to another to create a notable transition to establish progression for the user.

The questions, as seen in the previous figure, were all structured within one form in the back end for all sections but were separated by placeholder sections aesthetically where each question had two possible answers “a” or “b”. Each question was attached with a variable and value for later result counts and deliberation after form submission. As this was the first iteration of the site, the collected data for the results page amounted to the ILS question count and the carried studentID from the login or registration session. The final task of the survey was to calculate the results collected and present the results in a textual and graphical format on a dedicated results page. The results page held the majority of the main goal functionality of the site, calculating the learning style score, presenting this data and ultimately distributing the data to the allocated table in the database. The first task associated with the events needed to complete this whole process, referred to the calculation of the answered survey questions.

The method used, required creating variables for each of the four established sections of the survey. The section variables (given associative naming conventions for each e.g. $section1) were all declared with a value of zero, meaning each variable in the beginning of the linear processing contained no values only the integer zero. An array was created to structure the POST inputs for those answers that sided with one particular learning style type, for example any answers that were affiliated with the Active type were set in an array and the same with the opposing Reflective type. An event was created to catch those POST inputs that sided with either learning type, once the input was assigned the value of the $section1 variable either incremented or decremented.

So the Active type answers were subjected to the decrementing of the $section1 variable and the Reflective type answers were incrementing the value.

This process was reiterated for each section, its related variable and its corresponding learning types. Each variable for every section in its completion of calculation would result in a score that would present a value ranging from minus eleven to eleven. Representing the scale in which a student could potentially find their preferred learning style. The data collected was then represented on the web page both textually and graphically using echoed text of the numbered values and four slider scales representing the degree of learning style the student falls under.

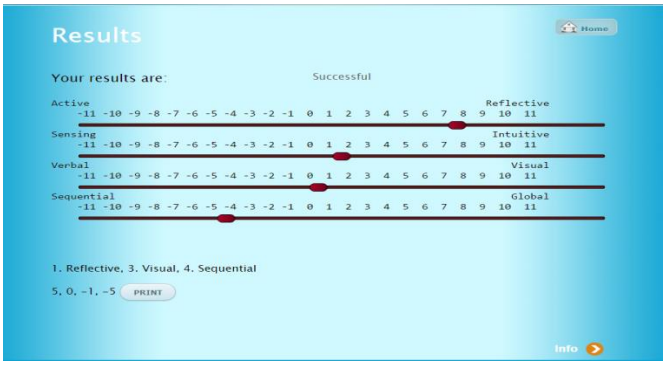



Figure 12: Result page layout with textual and graphical representation.

The four sliders were given min = -11 and max = 11 values of minus eleven to eleven to accommodate the scores created. To visualise the degree in which the pointer at each scale matches the exact score of the allocated section, the values of the individual scales were set to the section variables. This was set up to anticipate the scores of each section and represent the outputs with ease. The styles of the sliders were generated in CSS, the colour and look to sliders were created to contrast the colour scheme represented by the page. The reasons for this generated from the need to emphasise the results and make it clear that these results were the full focus of the page. The last stage attributed to this iteration was the relying process with the database. The information gathered from the results needed to be sent to the corresponding data entry in the database. Using the connection file, a connection to the database was established.

After making a connection to the table from the database, the POST input studentID was once again declared. All of the section variables were fashioned in a row and a new variable was declared storing all the section variables and their potential values within it. This new variable $insert would be a string of comma separated values (CSV) that would be placed into the database field score.

The SQL query used updated the database table where the studentID field matched the $studentID variable and set the related score field to equal the value of the $insert variable. All of these processes populated a table's row, giving details on the student and performance in the survey from the start of the web page to the finish. Once completed and data shown to be safely collected into the database, the beta survey site was presented to the supervisors involved in the thesis. Constructive suggestions were given; these suggestions specified key informative aspects of essential data retrieval and modified site aesthetic.

One key suggestion focused on the amount of information collected from the student. As the survey stood, little to no personal data was collected except for a full name.

The requirements following this particular suggestion inferred the creation of additional fields requiring more information on the students' personal details and background. These fields included: age, nationality, country of birth, gender, previous country of study, highest level of education attained and entry level. Those fields or variables first established in the database originally would be altered to suit the new creations.

Variables such as studentID were suggested to change, as students would more than likely insert their own student password in the survey alongside the studentID instead of a new survey password. This would bring about a security issue as the students' university logins should only be accessed by them. Another issue was the students' anonymity; the inclusion of a full name field reduces the students' ability to stay anonymous and prevents them from conducting the survey. The supervisor suggested the inclusion of line of text informing the student participating that the full name field was optional. The aesthetic suggestions ranged from the colour scheme to the arrangement of the questions. These suggestions included: more variety of colour (separate the colour scheme of the main page and the survey), include the university's logo and the logos of the associated disciplines and make the whole site mobile phone compatible – creating the sites survey interaction feasible for mobile gestures. Although the basic functionality was there, the site needed to be altered and reformed to adhere to some flaws in the interpretation of specific data retrieved. Only through foresight of potential analysis of this data were these specific errors recognised. Along with the suggestions gathered from supervisor input, these faults were corrected and resolved in the next iteration.

#### *3.3.2.2 Second Iteration*

The survey's results were passed through to the database without a hitch, populating the field with fake details from a test run and a comma separated list of the scores achieved for each section. From looking at the recommendations suggested by the thesis supervisor, the main bulk of survey alteration began with the database.

In order to fully adapt the survey to the needs of a comprehensive survey data result, the database variables needed to be modified and new instances created to match the recommendations suggested.

In adherence to the initial recommendations, the new variables were created with their corresponding field. These variables included: fullName (now an optional input), age, nationality, countryOfBirth, gender, previousStudy, highEducation, course, entry, username, password, ITCompetence, UI, time and score. As you might tell from the entries listed, there was an introduction of IT competence, user interface and time.

IT competence was planned to contain a computed score of eleven basic computational questions, offering a brief indication of the level of computer literacy an individual student has and more importantly a classrooms simple computer interactions. There were no min and max values for this variable as the score was only based on a Boolean logic system of yes and no answers summing to a total of eleven. Another addition that seemed to benefit the future analytics of the survey, was the time variable.

This variable was easily implemented. As the date and time function is inherent in most programming languages, the time was extracted and sent with the score and details once the result of the finished survey was distributed. Another addition was the creation of the UI or user interface variable. This field in the database was created to store multiple items of UI recommendations from the students. As the results of the learning style survey, should help structure the schematics, user interface and general learning aspects of the finished thesis resource, the UI field presents a more grounded view of what the students want to see aesthetically. The structure of these fields' various items will be discussed shortly. To prevent inconsistency, the test example entry was deleted and the database table left blank. After settling the database and its fields, the next stage in modifying the survey was to alter its webpages. The first file to adjust was the initial index page file, this page was the landing page all users would be subjected to when entering the provided URL (Uniform Resource Locator – web address).

The first changes were attributed to minor word replacement for both login and registry forms on the page. Username replaced studentID and additional values were added to the registration form to match the database units created. All options on the registration form were all variances of input methods, most of the input methods gathered were text from text fields. The deviation from this involved the gender, highest level of education, course and entry level input variables. The gender option was created as a choice of two radio buttons, this dynamic was already present in the creation of survey where the user was provided with two choices "a" or "b". The gender choices comprised of "male" or "female".

The other fields listed: highest level of education, course and entry level, were all given dropdown lists of set options to choose from. For highest level of education, the users were given a selection of educational attainment levels ranging from leaving cert equivalent to post doctorate. Course choices encompassed Medicine, Obstetrics, Nursing and Midwifery. The final addition entry level was an input that was supported by an event created in JavaScript (programming language). This event caused the entry level to appear only when the user selected either the options Obstetrics or Medicine. The choices consisting in this dropdown were: Two direct entry options (school leaver or other) and graduate entry.

The next stage of progression relied on the alteration of the backend system developed in the previous iteration. As the form had changed, the programming variables and the events assigned to them needed to follow suit. Both files that showed interface design and those external files working as a catalyst for processing additional information (like the external login and registration files) needed to be changed. The first port of call for the backend restructure after the reforming of the submission forms, was the external processing files associated with each. As with the preceding iteration, a connection was established with the database table that retained the fields and variables needed to form the necessary links. Sessions were created for each file to store the distributed POST values submitted by the forms. Taking one file at a time, changes to the external login processing page were minimal. The main change included changing the login identity from studentID to username. If this change was not made, an event would seek out an entry in the database that would relate to the studentID submitted and would cause an error due to no apparent field with the same naming convention appearing.

The registration form had to formulate additional entries into a new SQL query tied to the external registration file. This new query incorporated the variables from the previous iteration, alterations made to some variables and the addition of the new variable field e.g. gender, highest education, course and entry level. The query (like the previous query), selected the table needed and inserted the values from POST to the corresponding fields in the database.

The query involved two arrays that were linear in their processing, meaning that each item in the array was connected to item in the corresponding sequentially.

As you can see from the above query the fields are given shortened variable names to make the coding practice easier and more efficient when calling the variables later on.

These two external processes each presented the last form of communication from the index page to the surveys home page. In terms of aesthetic and style of the index page the colour scheme utilised four main light colours: light purple and white for background, green for forms, and red for validations. Tabs were created to store potential links to other aspects of the thesis and icons associated with the forms present. The forms were presented strongly on the front page without the need for navigation. The contrast of colour made the text and ultimately the questions asked resonate more than what the previous iteration presented. The logos affiliated with the various schools and departments (obstetrics and computer science) involved were presented alongside the UCC logo. The functionality in terms of frontend processing continued with the ability to hide forms using the icons provided, these icons enabled users to highlight forms that were use. Like the previous iteration, once the data retrieval or delivery from the forms to the database was successful, the user was sent or relocated to the survey page.

From the recommendations received, the layout of the survey and its navigation needed to change dramatically to suit the needs of a busy, active student. This layout needed to be accessed not only on a computer but have the capability to be accessed on a mobile device creating ease of access. Therefore, from developing off the home page or survey page, the backend development centred on the creation of a mobile compatible format. There were multiple approaches taken in optimising the website for mobile users, but only two options were chosen as a starting point for further progression.

The first option required distinct individual desktop and mobile sites including corresponding directories, i.e. the user would be redirected from one site to the other depending on what platform they viewed the site on. The second option referred to a single responsive site which works on all devices.

The first option offered the ability to redirect the mobile users to a completely different URL where a mobile only version of the site was hosted. In order to do this, it managed a redirection with a tailored URL with a .mobi extension or variations of these extensions for redirection like .htaccess files.

The use of JQuery Mobile was researched as a way to develop the mobile only site after the first process. This approach had the advantage of being a simpler way to develop a lightweight mobile only version of the site.

However, the negatives outweighed the positive as the sites scale would be inherently more than a lightweight version could handle. Additionally, it would be too difficult to maintain all of the content and changes occurring in the site on two separate websites (desktop and mobile). The second option, the responsive approach, seemed to resonate more with what the sites functionality was striving for. Under this option the site reconfigures depending on the widow size of the user's browser. The Bootstrap framework was set against the CSS programming edits for a responsive mobile interaction. Responsive sites like this second option rely on media queries to find out the window size which is appropriately supported in modern browsers but take issue with older browsers. In response to older browser operation, some websites have dropped support for older browsers including internet explorer 6 and earlier iterations entirely (Microsoft.com, 2016). A notable site which is known to have dropped support is Google, dropping support for some of its services to those using old browser repetitions (Support.google.com, 2016).

Despite this, a catch function was set up to detect older browsers. This function was programmed through JavaScript. The event would issue a popup window if the users were working on old browsers. The pop up would warn them about possible unsupported aspects of the site when using the old browsers, provide a URL to the main Microsoft site to update the browser and advise on the students return once they are ready. The second option for mobile delivery has its advantages. As a responsive site it maintains just that one site, and can work on all screen and window sizes. This is a very practical measure as it would anticipate the creation of new mobile device models with varying screen sizes.

The creation of this adaptable and consistent site format would be attributed to the style change of the site using CSS and events, listening for change in aspect of a browsers window size. The style change included incorporating a relative or absolute position for most placeholders of the sites home page.

These terms enable a content or placeholder to adapt to the change in size or aspect of a browser window. Relative positioning was attributed to the forms content including questions and submission, making their positive and scale relative to the margins set by the placeholders.

The header title was given an absolute position granting it the ability to be positioned anywhere on the screen according to the browser window.

As the float of the website header was created to centre the given title and position it on the top of the page, the title header appears like a heads up display (HUD) for those using a mobile device. The questions originally set in the placeholder and form had been changed to accommodate the mobile user, radio buttons were enlarged to adhere to the user hand gestures and finger motion selections.

After viewing the site in a mobile device setting using a test user account, only minor text alignment alterations were needed. The colour palette on the home survey page changed in response to the recommendations given, the palette was given a more simplistic set of colours not to draw focus away from the questions presented on the page. The colours included a navy border and header, and a white background displayed behind the form components and questions. The header of the page had variances of navy with segments of orange and grey colours with the title and UCC logo. Text was also displayed that requested the students participating to complete all the questions. An example of the new site linear navigation layout can be seen in figure 13.

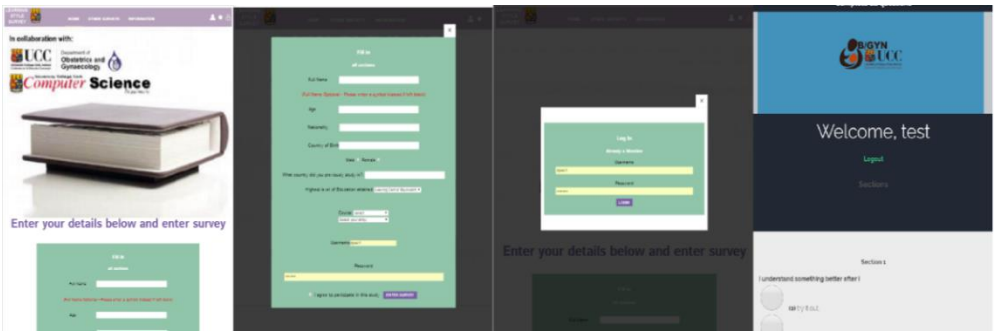



Figure 13: Linear navigation layout of restructured site.

As for the results page, the graphical representations were kept from the previous iteration but the colour was set to match the scheme present in the survey, matching a grey and blue hue. Once the frontend development framework was enabled, the next stage of backend development was in motion.

At the stage the information on the user was sent to the database and the subsequent fields were waiting for the input of user information from the survey. One key issue with the current setup of the site was its lack of questions relating to the corresponding fields IT Competence and UI.

Questions associated with these two variables were quickly interjected into the survey given an associative section (section 6 – part 1 and 2) to create order in the form.

When creating the questions for IT Competence, similar studies were researched to fully grasp the type of questions medical students would be asked on their technical computer skills.

One study carried out with final year medical students involved a long listed questionnaire. The sole purpose of the study was to create awareness of the students' computer literacy. The results of this study indicated that medical students had access to substantial information technology resources and demonstrated extensive knowledge towards computers and internet (Chudasama et al., 2009). The authors of this paper pointed out key facts about the new computer orientated generation and how most people including students have access to a computer and have the knowledge to be sufficiently competent in its use. From this paper it was possible to gather some key questions asked by the authors and create a sample of eleven questions similar in tone. These questions needed to be relevant to the processing of the site but also foresee the potential processes of the finished thesis. The questions created, mapped out essential navigational, processing and interaction techniques involving basic student internet and computer contact.

The result of these questions would give an accurate reading of the participant's level of computer competency and ultimately benefit the outcome of the thesis. Some of the questions used were: Can you find and start a program on a computer? Can you navigate through areas of a computer program or website? How confident are you with using a computer? And how would you rate your computer skill level? Some of these questions were treated to a Likert scale motif, letting the user choose between variants of confidence in their ability to process a task.

The end result of the IT competence section should set the bar for the UI components and design of the finished thesis, giving notice to the capability of these students to perform basic to intermediate computational tasks. If the scores for this variable are high, the UI would not need to be downgraded to adhere to inexperienced PC users. The variable and field named UI needed to be given questions to populate its database plot.

These questions were created to support the layout and design of the finished UI of the thesis and any additional thesis devices. The questions were also generated to support the learning style outcomes in how the finished thesis is displayed.

The UI questions, learning style outcome and additional user interface and learning theory will help establish a functionally grounded platform in the end of the thesis.

These UI questions centred on just the aesthetic of the UI and component orientation. Questions altered around, colour scheme, component panel placement, robust or minimalistic layout and whether or not theme and colour have an effect on your work. These questions supply the draft or schematics of what the finished UI layout and theme should be, in addition give an idea of whether or not these changes in layout effect the students. In the backend of the site, these new variables or instances needed to be referenced and their corresponding components needed to carry some weight on their submission to the results page.

Like the learning style questions before them, these new variables needed to be assigned values that would be POSTed on submission of the form they are kept in. As the sites questions including, learning styles index, IT Competence and UI recommendations were built-in, all questions were structured linearly removing the tween that preceded it. The students from this point onward simply needed to scroll down through the questions without the need to press a button every time there was a change of section. This process was also altered again to adhere to the PC format, listing tabs for easy access to particular sections at the top and after each section of the web page. All of the inputs collected were redirected to the results page where the student's inputs (POSTs) were redistributed into their individual sections for calculation.

Processes involving the first four sections were left uninterrupted, as their processes were solid in the last iteration of the site. The next changes involved the IT Competence relayed responses from the form submission. Like the first four sections, these POSTs for the IT competence levels were graded on a scale of a minus value to a positive value, in this case it was minus five to five. Questions that were asked that involved three options affected a created variable $section5's value that incremented or decremented depending on the question answered. For example, if the user was answering the question: how would you rate your computer skill level?

And the options were, High, Medium, and Low. The "High" option would increment the value of the variable by one, the "Medium" option would not affect the value and the "Low" option would decrement the value.

A function was created to analyse the given $section5 variable score. The function gave a string value to each bracket value for example: less than -5 (Not IT Competent), less than 0 (Below Average), 0 (Average), Greater than 0 (Above Average), and 5 (Highly IT Competent).

The UI POSTs were sectioned into four separate variables collecting the string input from the user. These variables were $CE (colour and thematic importance), $tone (light or dark tones), $layoutPos (UI component orientations), $layoutType (UI type, robust or simplistic). All these UI associated variables were all stored in one variable named $UI. Two separate SQL queries were created for the new UI and IT competence answers after the connection to the database table was established. The landing page of the results shows the same graphical sliders as the previous iteration with the same functionality, IT competence is given underneath. One variable that is also carried over from the survey page is time.

This variable is significant for both the user and those involved in analysing the results. The time variable gives the conductor a timeframe in which students completed the survey. The specific alterations in timeframe between students could show a period of the day in which the student might be more productive. This would be significant if the majority of the students performed the study at the same time. An additional contribution of the time variable would be its ability to log the students attempt at the survey. If the students were to redo the survey as part of a longevity study, the students' scores could be compared from one particular time to another.

### 3.3.3 Finished Survey and Process of System Delivery

Slight changes were additionally added to the survey site after the second iteration was finished processing and had a successful trial test of site navigation, survey completion, answer calculation, result display and database rely. These changes referred to the naming conventions of each section. The separate sections had individual corresponding learning style type attributed to them. Originally these types were displayed at the top of each section, but after some consideration they were removed. This was due to the possible tailoring of the results by students.

If the students were to know the learning types associated with each section, they would try and judge themselves on whether the questions they answered would suit a more "Active" or "Reflective" response.

The results of the trial testing runs were all logged on the database table, these entries were deleted before the issuing the site out to the students. An admin page was developed subsequently to view the incoming results of possible participants. This admin page ran on the same thematic skins as the layout of the final survey.

A login page was created separately for this page with a corresponding database table ("adminDB"). No registration page was created for this page, as those accessing it were those involved in the creation of the study, so the database entries needed to be added manually. Three entries were added, these entries contained two pieces of information, username and password. The admin login page used the same process the survey login page but the SQL query connection was to a separate table on the same database. The admin page itself contained a nested table with the data from the database table in it. The table acting as a graphical viewpoint for the supervisors to witness and assess the database populating in real time. Some fields were not added to this table, the reasoning behind this was to only display the relevant fields of interest. Fields like full name, and password were not left visible. Once completing the outlined recommendations for the survey completion and testing the result, the next step involved the participation of the obstetric students.

To contact or to have students participate in the survey required consent from the Obstetrics Department and an approved ethics approval form.

The first port of call was to address the Obstetrics and Gynaecology department of UCC and request permission to contact their students in relation to the learning styles survey.

The permission claim to contact students was granted on the completion of the ethics approval process. In terms of acquiring the ethics approval form, the Clinical Research Ethics Committee of the Cork Teaching Hospitals (CREC) had to be approached. They deal with ethical approval for clinical research involving human participants, which could infer their identifiable data. The approval claim can come under many headings which could involve surgery observation or patient clinical record access. This particular claim came under the heading of Interaction with / observation of individuals in a healthcare contact or setting (Ucc.ie, 2016).

A form was issued by the CREC to enable the access to the students, this form highlighted some possible restructures of the site to adhere to the parameters laid out by the ethics committee. The form was filled with detailed information describing the reasons for the acquisition of student information and what the intension was for the results of this data.

This informed another restructure of the survey site, creating a disclaimer for the information page. The disclaimer informed the students about the reasons behind the acquisition of their details and the way the information was going to be processed.

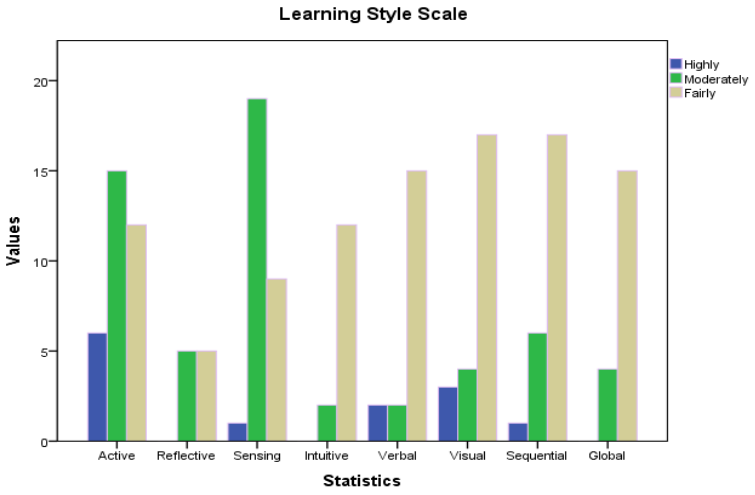
Additional information was also given about the potential reverberations of the results to help in the creation of a new resource for the students to utilise.

This was inserted to also create some incentive for the students to complete the survey. Once the ethics form was approved and the obstetrics department authorised student contact, the students were sent an email with details on the survey, the thesis wider study, potential benefit of the learning style result and feedback from the site. The email also contained a URL to the site.

## 3.4 Results of the Learning Styles Survey

As previously mentioned, the study was conducted with obstetric students from University College Cork. Fifty students were contacted after receiving the necessary permissions. These students were selected in order to fit a confidence level of 95% and a low margin of error from a possible population size of 63. Out of a possible fifty students, 86% choose to participate (n = 43). The results were analysed utilizing descriptive statistics and with beneficial replication from participants the findings were clear and diverse within a specialized group. Each of the learning style attributes results were categorized under three separate groups in order of attribute leniency on a scale of fair to vigorous.

Participants whose score was highly positive or negative had an active inclination toward that particular attribute (for example, Active is on the negative scale and Reflective on the positive) and as the score neared the 0 mark the applicants score was not as definitive. Generally, after the accumulation of data, the undergraduate student results seemed to veer towards the highly fair outcome on both visual/verbal and sequential/global. The results showed consistent data on both active/reflective and sensing/intuitive, but not on visual/verbal and global/sequential where no definitive allocation of learning style type was found due to the high number of participants deviating away from moderate to high distributions.




Learning Style Scale

| | Act | Refl | Sens | Int | Verb | Vis | Seq | Glob |
|---|---|---|---|---|---|---|---|---|
| Highly | 6 | 0 | 1 | 0 | 2 | 3 | 1 | 0 |
| Moderately | 15 | 5 | 19 | 2 | 2 | 4 | 6 | 4 |
| Fairly | 12 | 5 | 9 | 12 | 15 | 17 | 17 | 15 |

Figure 14: Learning style scale, fairly to highly.

As seen in the graphs above, the results showed that students were more Active, Sensing, Visual and Sequential learners with the latter two deviating from a definitive answer. The majority of students (n = 27) were categorised as moderate to highly active with a low number of reflective learners (n = 10).

Similarly, with sensing and intuitive, the students learning style leaned towards a moderate to high sensing style (n = 20) with a low intuitive participation (n = 14). In the case of both verbal/visual and sequential/global learning styles the students were indecisive and the results for both being on the fairly spectrum of the scale. Tests to see if the data accumulated was normally distributed were conducted to validate the previous scale results. Histograms and boxplots were used to determine the normality of each individual style pair (aka Active/Reflective). All histograms had a bell shaped curve which is a good indicator of normal distribution in the data, the boxplots all had no deviation from the expected normal except for verbal/visual.

As the normality could not be proven in verbal/visual from the latter tests, a Shapiro-Wilk normality test was conducted to prove normality. The results showed *p* values for each learning style pair, Active/Reflective (P = .000), Sensing/Intuitive (P =.023), Verbal/Visual (P =.131) Sequential/Global (P =.006). If a *p* value is less than .05 then the data is normality distributed and statistically significant. From the results it's clear that verbal/visual data is not normally distributed as the *p* value is not less than 0.05 (Coffey *et al.,* 2016). Other variables were used to deduce the correlations between the learning styles variations. These variables were age, highest level of academic achievement (highestEdu, as listed on the database) and IT competence. To begin with, the age variable was used to show correlations between each learning style.

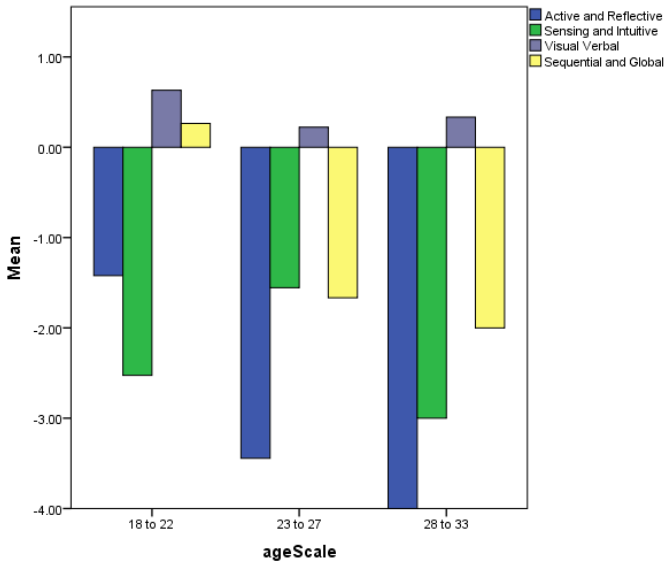



Figure 15: Age group learning styles.

The student's ages were categorically placed into three key age groups which were 18 to 22, 23 to 27 and 28 to 33 after recoding the age variable to an ageScale variable. From the chart above (Fig2) it shows the age groups and corresponding learning styles, the results showed all ages had a high rate of active learners with the 28 to 33 age group having the most definitive active counts. The strongest and most definitive learning style in the 18 to 22 age group was Sensing and the strongest from 23 to 33 was Active. The only learning style on the positive scale for all groups was visual learning with the exception of global learners in the 18 to 22 age group. When testing the correlations between the learning styles and the age scale, correlation was significant on the 0.05 scale in terms of age and sequential/global learners.

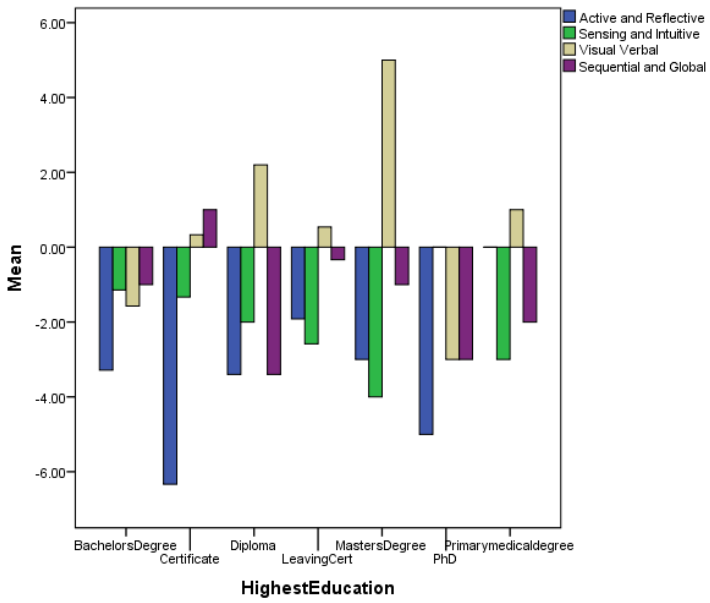



Figure 16: Highest education scale corresponding to learning style.

The student's academic achievements were categorically placed into the main educational degree groups which were leaving certificate, other certificate, diploma, bachelors, masters, PhD and primary medical degree. From the chart above it shows the educational groups and corresponding learning styles, the results showed all groups had most learning style rates generating towards the negative scale having more Active, Sensing and Global learners. The exception was the visual learning style as it is predominant in all groups except for the bachelor's degree. The majority of the students taking part had the leaving certificate as their highest educational achievement (as they were in there fourth year of a medical degree).

IT competence was tested using the technical questions gathered as previously mentioned as an instructional base of understanding and computational knowledge. The questions formed understandings of basic computational processes and online capabilities. There were eleven questions in total, all of which had equal footing on technical information and perception. All students who took part had high scores with 15 students achieving full marks, 19 students achieving 10 out of a possible 11, 7 students achieving 9 out of a possible 11 and 2 students achieving 8 out of a possible 11.

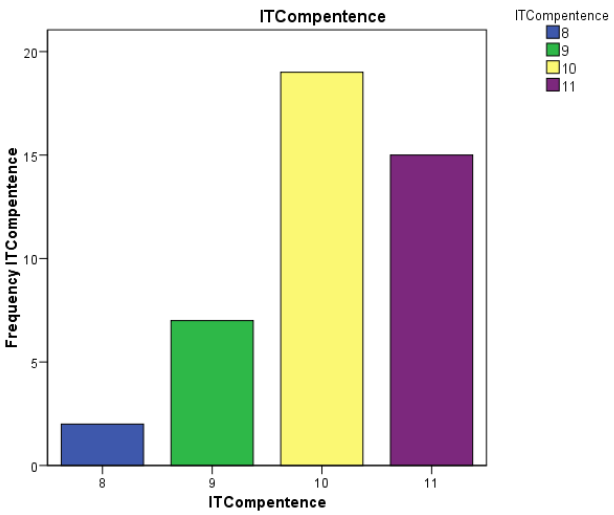



Figure 17: High IT competency levels in students.

User Interface (UI) aesthetic questions were proposed to the students, these four UI questions covered UI importance, UI colour tone, UI component position and amount of displayable UI. The results showed that students found colour of a UI to be very important, the tone to be light, the component to be aligned to the top of the interface window and the amount of components on the UI to be minimal. From the results it's clear to see a high rate of definitive learning styles in the Obstetric student group, this changes when students are divided in age and educational background. As a whole the students were generally Active, Sensing, Visual and Sequential learners meaning the students learn by doing (active), prefer to take information that is concrete and practical (sensing), prefer presentations of material (visual) and organise information in a linear manner (sequential). The deviations from this are in the results for age where the 18 to 22 group were predominantly global learners.

This would suggest that these students prefer a wider approach to organisation, the older age group seems to be in higher education longer (according to the higher education scale) and prefers the more linear approach.

## 3.5 User Interface Implementation and Discussion

User Interface (UI) Design focuses on expecting the user's potential processes and guaranteeing that the interface has features that are easy to access, recognise, and operate to fully aid in development. UI unifies models from interaction design, visual design, and information architecture.

Specifying interface users has been linked with the performance interface elements, which requires constancy and predictability in style choices and possible layouts.

This would aid in task completion, efficiency, and satisfaction in user experience (Lauesen, 2005). Interface elements and components comprise of but are not limited to: input controls which would include buttons, text fields, checkboxes, radio buttons, dropdown lists, list boxes, toggles, date fields. Navigational components which would comprise of breadcrumbs, sliders, search fields, slider, tags, and icons. Informational components which could encompass progress bars, notifications, message boxes, and windows. There can be periods where multiple elements could be suitable for presenting content. Occasionally elements that aid in conserving freedom of space can draw mental fatigue from the user. They can do this by constraining the user to perform a great deal of mental processing when it comes to dynamic elements with too many features. The best methods for designing an interface derive from recognising the users, including identifying their aims, abilities, preferences, and trends. Once an understanding is created the best interfaces seem almost invisible to the user. A good interface can avoid unnecessary elements and can be clear in the language it uses on labels and in messaging and also creating consistency in common UI elements.

By using these common elements in the UI, users feel more relaxed in the environment to perform efficiently (Galitz, 2002). It is also important to create patterns in language, layout and design throughout the site to help facilitate efficiency. As soon as a user learns how to perform a task, they should be able to transfer that skill to other parts of the resource. There should be a purpose to the layout, considering the spatial interactions concerning items on the page and structure the page founded on function significance.

Particular thoughtful placement of items can assist in attracting interest to the most significant sections of information and can aid scanning and readability. Deliberate use of certain colours and textures can also be an aid by drawing attention toward or away from elements. Like any document, the webpage uses typography to show an order in sections, in a website it’s used to create hierarchy and clarity so the user is aware of what page they are on and what is the main focus of the page (Galitz, 2002). This hierarchy can be seen from using different sizes, fonts, and arrangement of the text to help the user understand the importance of each text example, the size can also increase legibility and readability. The page should constantly notify the users of their setting, actions, and changes in status, or faults that may have occurred.

### 3.5.1 Continuation of Thesis Design and Implementation

The culmination of the survey and results were considered to be used for the optimisation and development of the finished students' resource User Interface. The broader mounted thesis was linked to these UI expansion processes and received the attributes at which the final UI and teaching apparatus was presented to staff and students (discussed in greater detail in a later chapter, Chapter 6). From analysis of the results, the teaching method best suited to the application was an active hands-on approach with haptic sensing structures, lots of visual and verbal cues and linear organisational assessment. The students felt strongly about a more active learning method and this was supported by the high number of students grouped as active and sensing learners.

Active learners tend to learn by doing and sensing learners learn from experience and generate knowledge from hard facts. The students were indecisive over two brackets of learning types visual/verbal and sequential/global. This would suggest an affiliation with both types, having a learning style affected by each type at an equal level. The visual and verbal results indicate that the two media stimuli have the same positive affect on the students and would benefit from a combination of the two (video). The sequential and global learning types grasp the concept of a learning timeline. Sequential learners for example would learn step by step and could easily explain how they got to a conclusion.

While Global learners would see the bigger picture and take large leaps through content but would not be able to explain how they got to a conclusion.

A resource that offered two approaches for the student that mimicked these timelines would be ideal. This could be managed through step by step introductory sections and robust testing sections that cover all topics at once. The student participants seem to relate to some aspects of each learning type in these two brackets in variant degrees. This is apparent in the results, as the majority of students veered to a more visual and sequential learning style. From the results, the lowest score achieved was eight out of a possible eleven (72%). This was achieved by two participants from a group of forty three (4.6%). This result showed a high tech knowledge from the entire obstetric group that participated. It also demonstrated that the students were more than capable in utilising new technologies and advances in their area.

As the finished resource structure relied heavily on technical computational factors and the student's competency at using it, the prospects of a positive and compliant resource response were positive.

In terms of the UI results, the feedback showed a clearer look at a basic structure to a resources UI layout. The students wanted the components positioned on the top of the page. This was reminiscent of a webpage layout, although the students were open to graphical representation in conveying navigational options. The students preferred a lighter toned interface and found that colour was very important in the visualisation of the resource. Some resources have dark colours applied to the layout to draw focus to the main components of the site. The introduction of a lighter tone could imply a view of equal weight importance, having everything on the screen appear as important as the other. The students also preferred a more simplistic approach to UI components and general layout structure. This meant not overloading the interface with components and elements on first glance. This need for a more simplistic layout could be a result of a mobile technology influence with mobile companies such as Apple creating their products with a clinical simplistic UI and framework design that a number of similar companies have proceeded to do in recent years. The associative iconography implemented by these devices has made it easier to condense information into small icons representative of a known process (e.g. house icon – brings you to the main page or "home" screen). The known identification of these subtle deviations from classic program interfaces has enabled stylistic ways in minimising the bulk of screen space in a programs environment. UI's can be tailor-made to teaching methods and vice versa, the objective is to produce and familiarise with students and formulate original productive ways of enlightening learning.

With the addition of the e-learning practice basics reviewed, the learning styles acquired, IT competence assessed and also the consideration of the UI design fundamentals and student UI input, the design and process schematics for the finished obstetric system were in place.

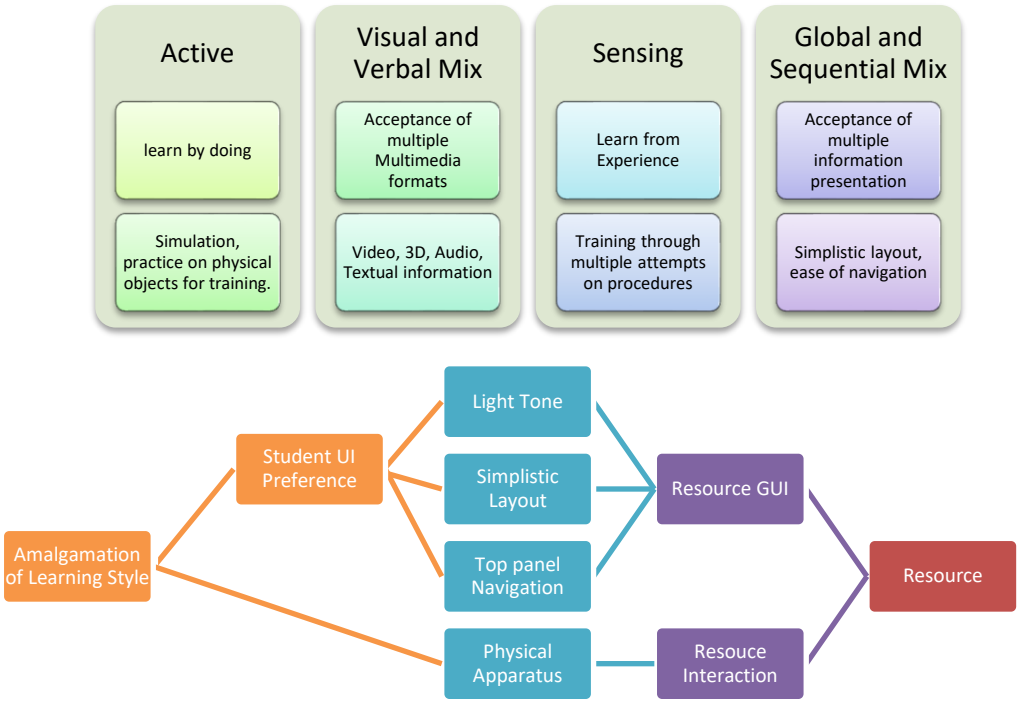



Figure 18: Framework for resource creation and progression.

From the results, it was clear that as illustrated in the above framework and learning style influence, the resource needed to involve a “learn by experience” and “learn by doing” approach incorporating multimedia and assessment through linearity and whole concept. As the material for Obstetric procedural practice like child birth/types of delivery focuses on physical involvement and visual cues, the integration of a physical simulation with a high visual (video/3D) component combination would be beneficial for student involvement and essential training. The 3D aspect helps make the visual aids clear and grant physical interaction.

### 3.5.2 Tailoring Learning Style for UI Design and Resource Structure

As learning styles are a significant contributing feature in terms of student development, they can represent some of the characteristics of the learning preferences within a user interface environment and help students in different parts of a learning cycle. The majority of these learning style elements apply to the layout, sequencing and structure as well as the navigation of a user interface.

The two major considerations in tailoring a user interface to accommodate the chosen learning styles were, the formatting of information (media involved) and the structure in which this information was processed (media enabled environment).

The UI (user interfaces) was matched to the students' preferences, guided on the majority vote on the strength of the scaled learning type. The difference in presentation of the different types of formats was apparent, so design mediums had to be structured as the user interface mimicked a learning style majority. In terms of the formatted information, it needed to mirror the learning style response from the students. The students responded well to visual aids and bit-sized added informational tabs. The Obstetric discipline offers some visual content of an observational nature but is lacking in visual representation of the internal processes which are key components of the learning criteria.

2D representation offers some forms of visual aid but does not provide the full range of rotational or orientation data to comprehensively track the processes involved in obstetric procedures (i.e. Normal Delivery). 3D representation grants this ability with an added ability of potential user interaction in real time. Orientation is graphical represented with 9 degrees of freedom in a changeable virtual environment. 2D information or normal captured footage can add additional feeds of information supplementing the key 3D procedural aspects. A focus on adding or meshing these visual components together creates a highly informative virtual learning experience which derives from the preferences of the obstetric students.

The visual aids compared together can cooperate in an educational narrative for students learning a particular topic within their course cycle. In terms of the structure of the information being processed, student input is key. From the results of the learning style preferences, a keen interest in 'learn by doing' is fully supported by the majority of obstetric students. As the structure stood, the 3D/video narrative had been established as foundation of the learning resource as part of the learning process for these students, but the interaction was lacking, providing only some video or canvas orientated input via mouse or keyboard. With the focus on 'learn by doing', interaction needed to be a key element in the structure when tailoring the learning styles for the potential learning system.

Simulations like HPS (human patient simulators) and their use in obstetrics have already been widely used but only lent themselves to physical operation providing only minor sensory inputs (pressure etc.), this creates a great opportunity to meld the physical aspects of the HPS and the VLE (virtual learning environment) to create an enhanced learning experience that incorporates every aspect of learning preference sited from the students.

## Summary

This chapter discussed the positive aspects of e-learning in education and in its general use. Learning style importance and its application in terms of relevant introduction to user interface and resource development was assessed pointing to an overlap in e-learning education. The process of the learning style survey development and its iterations was described in detail with the prospect of returning valuable data for evaluation. The results of this survey were inevitably measured alongside graphical representations of the data.

This data encompassing Learning styles, IT competence and UI results was discussed and showed clear learning style types for the collective student group in at least two learning types, and represented a clear look at a potential resource layout structure. The students' confidence in computational tasks was high which supported the progression of the finished resources computational heavy interactions. The application of this data accumulation in finally discussed in detail with a view to aiding the further progression of the finished thesis. Overall, education offers itself to a selection of new creative and resourceful ways of training and teaching. This group of obstetric students were positive in their acceptance of these new methods and had a clear openness to an educational resource progression.

# Chapter 4. 3D modelling and Manipulation

In this chapter, 3D modelling, its background, influence in medicine and its inspiration to the creation final resource of this thesis will be discussed. 3D modelling and its manipulation is a main component to the key functionality of this thesis and one of the core educational draws of the resource. The creation of the Obstetrical 3D objects will be described, through conception to completion. These 3D objects created refer to the baby models, amniotic sacs, placenta, and even procedural devices like the Ventouse vacuum cup. These objects have a large role in their integration to many different aspects of a wide ranging resource. The 3D objects lend themselves to web integration, animation, game development and visualisation (Coffey *et al.,* 2015). These aspects will be utilised fully to extract the best means of 3D visualisation. The significance of this chapter is it's interjection of 3D and VR (virtual reality) in describing unseen procedures through vivid and detailed 3 dimensional structures to educate students. The 3D interjection follows the student's learning preference for visuals that describe the obstetric content, show the content in various forms and engage the student with interactive content derivative immersive media.

## 4.1 3D Modelling Background and Importance

3D modelling is the method of refining a mathematical interpretation of any three-dimensional object using dedicated computationally specific software (Remondino et al.,2013). The end result of this being a 3D model. This model can be presented as a two-dimensional (2D) image via a method identified as 3D rendering. The model can also be physically manufactured using 3D printing devices which has been very popular in recent years in the development of medical apparatus and surgical implants (Liu et al., 2016). The modelling process involves the provisioning and formulation of geometric data for 3D computer graphics, which is comparable to the art of sculpting but instead using the graphical user interface provided by a 3D graphics software. 3D models present an image of a physical object using an assembly of vertices or nodes in three dimensional space. These nodes are linked by an array of geometric units like dots, lines or curved planes (3D surfaces) to name but a few.

Knowing that the 3D models are grouped data, they offer numerous means of manipulation, be it manually or algorithmically (computational intervention - automatically).

3D models are widely used anywhere in 3D graphics and CAD (computer aided design). Actually, their use predates the widespread use of 3D graphics on personal computers. Many computer games used pre-rendered images of 3D models as sprites before computers could render them in real-time.

Three-dimensional objects are capable of delivering data in shape, colour, texture, size, orientation, behavioural and position configurations. A 3D environment allows users to modify their viewpoint to expand observation and insight into the detected data. 3D grants users with an abundance of interactivity, not only in navigation of the environment but also interaction with the content with the environment like selecting, moving, and rotating them. Interaction proficiencies with 3D content in a 3D setting could be augmented and supplemented with additional 2D interface features recognisable to users familiar to PC or MAC program interfaces. 3D interfaces should be constructed with specific reflection on their usability. 3D virtual environments have been employed to visualise data in some research and application systems (as presented in the literature, Chapter 2). 3D interfaces can be effectively managed for the demonstration of spatial data in such scientific fields as medicine, chemistry, physics, and astronomy. Currently, 3D models are employed as broad examples in a multitude of academic and non-academic fields.

The medical field uses intricate models of organs, skeletal structures or static representations of processes. Apart from 3D software manipulation these models could also be produced using several 2D sliced images generated from scanning procedures like an MRI or CT scan, the impact or importance of these 3D models in medicine will be scrutinised closer in the next section. Other fields including film use the 3D models to represent narrative characters or objects for animation and an integration of CGI (Computer Generated Imagery) for blockbusters movie effects. Another field that utilises the 3D models and 3D software extensions extensively is the video game industry which manages the models and groups them as assets for the processed video game output. As it can be clearly seen from the above examples, 3D models adapt themselves into a wide variety of fields integrating into a host of multimedia platforms for recreational and educational benefits.

The 3D multimedia presented to date has enabled the development of new and inventive ways of creating more realistic and immersive depictions.

Even with the evolution of the television set, 3D has amalgamated the viewing experience with a new viewpoint into 3D programming and 3D interface viewing.

General widespread utilisation of interactive 3D multimedia technologies, including virtual reality (VR) and augmented reality (AR), has seen a rise in the need for 3D modelling outputs and application. As previously mentioned, the general populous are thoroughly equipped for the change from 2D to 3D interfaces due to the overwhelming popularity of 3D computer games, on-line communities and 3D movies. Establishing these platforms or entities using CGI and 3D examples has improved users understanding of 3D techniques and together elevated their readiness for more creative 3D engagement. It has become commonplace for students growing up in this generation to expect similar experiences in other areas warranting the need for more 3D multimedia technologies in education and training.

The application of 3D technologies into these capacities provides innovative and enriched user experiences. Interest has peeked in the endless possibilities obtainable through interactive 3D creations available online. This remote online access to the 3D material enables users to experience remote simulated environments in the same way a user experiences native 3D applications. Additionally, these online simulated environments can occasionally be shared with social media like Facebook or Twitter, which supports escalation in the environments appeal. A decade ago, it was difficult to comprehend significance of 3D visualisation.

VR or Virtual reality has been closely related to 3D as it is a computer technology that replicates an environment, real or imagined, and simulates a user's physical presence and environment to allow for user interaction (Mioduser *et al.*, 2000). The Virtual environment created usually relies on some sensory input like touch or sight. Haptic driven virtual environments are the focus on the end result simulation. The use of 3D in this thesis is to ultimately create a virtual reality environment that communicates with a simulated environment. This absence of understanding caused confusion in terms of visual interpretations of spatial data, design, and 3D modelling. 3D is an essential component of translation position and location anchoring to a wide range of coordinates to map from. While 3D and visualisation proceed to grow and transform, they are already altering means of software interaction. 3D visualization and Virtual Reality (VR) offers a promising range with a great probability of improving and altering users' learning experience.

VR or 3D orientated settings can offer an interactive and appealing educational perspective, supporting first-hand learning that provides an intermediate to learn by doing, through first-person experience (Hai-Jew, 2010).

3D and VR can grant the users an array of previously unobtainable interactive source material for example the recreation of prehistoric artefacts, restoration of derelict castles or even 3D rendered images of mars from collected imagery: that are all interactive. The practice of both 3D visualization and Virtual Reality progressively extends from teaching minor errands to procuring intricate expertise, for example theoretical rational, creation and management of complicated information spaces. This alteration in the use of this technology has led to recent challenges to teachers and developers alike. Subsequently it becomes imperative to comprehend what aspects or features should it have in order for it to coincide with recognized educational aims.

### 4.1.1 Importance of 3D in Medicine and Medical Education

Educational systems today are growing into denser and more demanding environments for practitioners and educators in which to engage students with the subject matter. To produce a more assertive approach, it is an imperative to be distinctive and innovative. Visualisation in medicine is a distinct area of scientific visualisation that had launched itself as a research area in the late eighties, early nineties. The geneses of scientific visualisation spans extensively through the years, presenting carefully crafted graphics constructed by scientists like Da Vinci's or Andreas Vesalius who provided extensive graphical anatomical representations (Russell, 2013). Nowadays, scientific visualisation is solely grounded on computer graphics that deliver graphical portrayals to collect and relay the required 3D geometry and algorithms to render these representations. Further impact derives from image processing, which essentially outlined the field of medical image analysis. Medical image analysis was initially used in the processing of 2D images but it is now a 3D component usually attributed to medical visualisation. Scientific visualisation concerns dataset analysis or visualisation resulting from dimensions or simulations of occurrences in reality. Significant aims and research settings of scientific visualisation comprise of the exploration of data to test a theory based on simulations/ their visualisation and the demonstration of their results.

Numerous applicable instances in medical visualisation directly refer to these conventional visualisation aims.

Patient disease investigations should be examined through this combination of clinical investigations and computer aided medical imaging.

Furthermore, if a practitioner is incapable of sufficiently assessing a patient on preliminary records and examples, image data might be attained excepting specific hypotheses. Computational backing specifically image analysis and visualisation should enhance a physician's diagnosis. If a practitioner has performed a diagnosis identifying the gravity of a disease, clear visualisations are created to represent this diagnosis. Such visualisations may comprise of quantities and comments to augment their clarification. The definitive aim of these visualisations and the attached information is to defend decisions made before treatment. The addressed aim is also pertinent to medical visualisations, these visualisations are generated to be deliberated among practitioners to use them for educational purposes. For medical visualisation systems, a detailed understanding of diagnostic processes, decisions, and information requirements is crucial to delivering computer support. It is also vital to deliberate over structural and procedural restrictions. An added concern is that interaction approaches comprise of vital components in blueprinting a satisfactory medical visualisation system. In keeping with the forward thinking aspects of these technologies, the medical field has recently opened its arms to their use. There are a milliard of changes emerging in medicine today, advances in technology (whether it is hardware or software) types of procedure or even change in routine. These changes can have a substantial impression on the structure of medical professionals' education. Roughly every eight years the medical field has changed and opened its eyes to numerous technological advances with educational benefits, emerging with new ways of conducting procedures (Zhang *et al.,* 2013).

Current advances in educational technology offer a growing number of innovative learning tools. 3D simulation or Virtual Reality representations come under this bracket and are relatively new introductions in the medical learning curriculum. These 3D orientated elements have promising scope with great prospects of enhancing the training of medical professionals. These forms of training can provide a lavish, immersive, engaging educational framework that in turn supports experiential hands on learning. As 3D interactive gaming is popular and used by all walks of life, virtual reality could raise the interest and motivate participants and effectively support skill attainment.

3D is a developing form of information visualization that can represent scenarios unseen by the naked eye in an interactive experience.

Current virtual teaching applications for medicine fluctuate greatly in terms of their technological media driven complexity and the kinds of expertise attained, fluctuating for instance from surgical applications in laparoscopy to collaborative simulations involving emergency scenarios or the human body. This paper's key objective is to deliberate the foundation and focal aids for the use of 3D visualization in medical/ obstetric education and training.

### 4.1.2 Similar Work and Examples

3D visualizations using VR have the scale for user engagement and practicality and can create vital objectives for certain methods in the medical field. The interactivity of the shown 3D models can lead to constancy in simulation of physical procedures including using a virtual surgical instrument and witnessing bleeding or other scenarios that invoke a sense of caution. The obtainability of VR depictions of a subject's structural parts is attractive to physicians for the purposes of education, training and procedure planning/simulation. VR systems can be used also by patients for specific kinds of medical therapy, such as the treatment of phobias or rehabilitation. Teaching and education is one of the more favourable practices for virtual reality technologies. Computer optimized 3D diagrams offering diverse features of anatomy and physiology as combined teaching plans are transforming the teaching of medical students and other fields of study. VR systems propose a chance to train professional surgical skills in a vast way tuning skill sets and offering repeated opportunities. Although preoperative planning systems, which demand a high level of involvement and scrutiny, medical training and education depend on more dedicated visuals and accurate involvement into the virtual space than on the detailed complexity of the models involving patient. The prompt implementation of marginally invasive surgical procedures is one of the major motivating positions in the expansion of surgical teachers.

The restrictions retained on visual control, counting the limited feedback and unfamiliar haptic references make training essential. In many instances preoperative preparation is restricted if its application in the operating room is not assured.

These plans were originally created mentally by the surgeon during the mediation, computer assistance and virtual reality technology can significantly add to the detailed implementation of preoperative plans (Heinrichs et al., 2008).

VR methods have also been used by patients where generated VR depictions of everyday scenarios for example staying in a closed space like an elevator were used to enhance the therapy of claustrophobia (fear of closed or small spaces). This use of the technology is an innovative approach to its use that can be applied to other phobias and other fields of science (Botella *et al.,* 2000). Medical VR systems are predominantly targeted at clinicians; one medical VR system developed involved an interactive VR visualization of cardiac magnetic resonance data that allows surgeons and the cardiologists to examine a heart as if it were in their hands using tracking devices and a visual aid. The VR system was meant to present the clinicians with a clearer understanding of the patient's cardiac morphology. This VR involvement was created to help in the planning of cardiac operations. (Sørensen *et al.,* 2001).

Medicine is a main field of application for virtual reality (VR), along with games and scientific imagining. The medical application of VR was motivated originally through the necessity for medical practitioners to picture intricate medical material, predominantly during surgery, medical procedures, planning, education and training. These applications have logically expanded to embrace telemedicine and cooperation, linking material amongst medical practitioners at a national level and abroad. Medical environments in VR have become progressively familiar, with many applications being generated for students and researchers to investigate representative environments for training and simulation. One of these established VR environments is Arch Virtual, which utilises a variety of interactions and content. Each bit of equipment is modelled in detail based on reference photos. By removing any sense of self motion, users are able to direct the VR application securely in the environment. The users have the ability to walk and talk in the environment, gesture or motion to objects with a laser, and interact with other users in the environment (Arch Virtual, 2016).

Figure 19: Arch Visual VR medical environment.

This type of immersive experience has huge potential for procedural integration but as it stands the Arch Virtual only houses an introduction to a procedural room without fully interactive surgery scenarios. An aspect of interactive procedural scenarios would increase the learning benefits of this resource. As previously mentioned, 3D in medicine makes it possible to easily describe surgical procedures and have coincide with medical procedural videos. Animation of this medium could also benefit the medical field and has been used to a great extent in the surgical fields. 3D medical animation videos can also help patients gain a better understanding of their treatment options. Ghost Productions are a company that produce 3D medical videos for an array medical areas including Obstetrics. The production company prides themselves on accurate representations of anatomy and surgical processes. Soft tissue representations are the speciality of the company, so still examples are general issued for anatomical representation. In terms of Obstetric examples, the company offers internal processes of gestation but provide no examples of the birthing process. The company can be attributed to multiple surgery techniques concerning surgical implants and possible introductions of prototype medical devices created.

The 3D examples can be bought but at a high price and other only visual interaction like image or video (Ghost Productions, 2016). A similar company offering 3D representation is Nucleus Medical Media. This company creates visual stunning representations of medical devices, animations of biological processes, 2D animated motion graphic presentations and patient education. There are many differences between Ghost productions and Nucleus Medical Media, these are apparent in its interaction and user contribution.

The company offer users the ability to offer a storyboard to convey the progression of the animation or presentation, where a rough draft of the presentation is relayed to the user and after deliberations between parties the result is completed.

The output of the 3D created by Nucleus can be created for mobile devices making the 3D objects subject to orientation manipulation, for example rotation and position. These objects are also presented alongside texts and visual information. In terms of Obstetrics field representation the 3D outputs portray a baby delivery process. The 3D processes displayed are very clean and precise. However even if the 3D represents a great representations of child birth, the material concerning Obstetrics is again limited to just the video representations and images.

Although Nucleus has a collection of great outputs, the interactive ability is not stretched enough to enable VR interaction, wireless device input and interaction, or haptic variability (Nucleusmedicalmedia.com, 2016).

Figure 20: Left - Ghost productions example, Right – Nucleus medical media example.

These examples tend to cater for practitioner, tutor and student use. Another example is removed from this demographic and offers 3D educational examples to pregnant women themselves. The company in question is BabyCenter. They provide an online service with multiple pregnancy orientated applications to better organise week by week processing, including due date calendars, ovulation calculator, gestation and others. This research focuses on the key appeal of the company's educational endeavours; the 3D examples. One key 3D feature offered by the company is the labour and birth instructional 3D animation. This animation presents great 3D visuals with an informative narrative that paces with the processes conveyed in the short 3D piece. The labour and birth process is described in great detail as the video tracks the audio narrative.

Just like the previous examples the 3D example offered is in a video format and the only interactive aspect is the configuring of the video player.

Although the former examples proceeding this 3D resource and at the start of this section showed possible outlets and capabilities for 3D integration and manipulation, there still needs to be a further exploration of the 3D integration and interaction in Obstetrics.

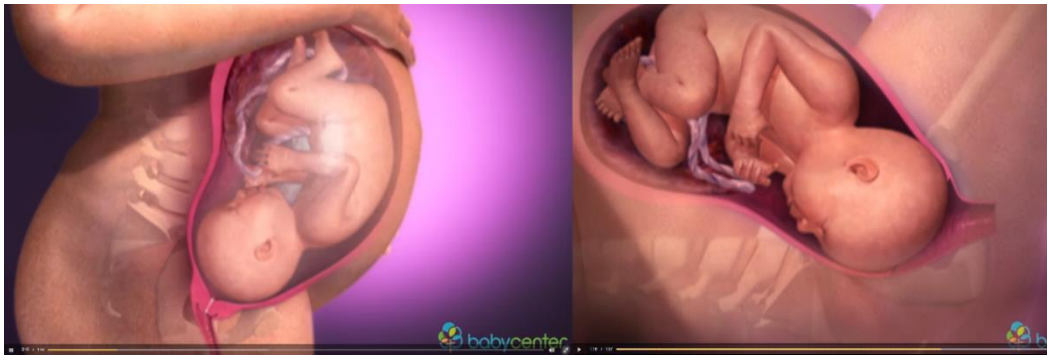



Figure 21: BabyCenter 3D animation of labour and delivery.

A resource that could bring together all of the above elements, integrating the beneficial factors of each to provide an educational and practical experience would be a beneficial output for the field of Obstetrics. The procedural processes involved in Obstetrics would lend themselves to these 3D and immersive elements as most practices involved are internal.

### 4.2 3D Environment and Model Creation

In this section the 3D models created for the final resource will be detailed and the processes conducted to complete these models will also be described. Some models created required a longer editing process due to the detailed depiction of some objects and their structural complexity. A number of 3D development and editing software could have been chosen, although the majority of the software available has a price tag attached. The software that was chosen (Blender), offered all the components and functions presented by similar software but for free. Other aspects of the software enabled high production value for the 3D objects created including integrated physics for fluid simulation, rigging, skinning and animation. When creating the 3D objects multiple modes can be accessed to enable separate functions of the manipulation process. For example “Object mode” enables a user to manipulate an object as a whole, modifier and physics additions are added in this mode.

Another mode essential to the creation and manipulation of 3D objects in Blender is the “Edit mode”; this mode enables a user to deform and construct 3D objects, handling the many vertices that would make up a particular 3D object’s form or structure.

Another mode generally used in the creation of a 3D model in Blender is the “Sculpt mode”, this mode enables a user to inflate, deform, flatten, carve or sculpt a model like as if it were clay.

The sculpt mode helps for detailed definition of certain features of a specific 3D model. The creation and texturing of the needed 3D objects (baby model, amniotic sac, placenta, umbilical cord, and Ventouse vacuum cup) use these modes to a great extent for full model realisation. Each model creation and full realisation will be discussed and described in detail. Most of the 3D objects created had a long creation process full of detailed accuracy tweaking for realistic depictions. The longest modelling process was the baby model as it was trying to resemble a humanoid, which involved careful detailing and sculpting. The other 3D models did not take as much time, as these models did not require as much detail. These models were based on static, inanimate objects or objects that have little function. For example the ventouse vacuum is an inanimate object but it was animated for the purpose of showing off the process of a ventouse extraction procedure in a 3D re-enactment. Other 3D objects that were present that interacted with the created models were imported from a previous masters' study and did not present any form of animation. The animations created from the output of the created models conveyed two essential obstetrical educational delivery procedures. The reason for the lack of additional procedures was due to the time consuming process of model creation, animation and rendering. The two 3D simulated delivery procedures offered a preview into what the resource could possible offer.

### 4.2.1 Baby model

The baby model was created in sections and then ultimately grouped together as a finished 3D object. To fully realise a static 3D baby model, the model needed to be formed (using meshes), manipulated, sculpted and textured. Multiple processes were used to generate the 3D object, including image reference tracking. Blender offered all the functions needed to enable full creation and manipulation of the model and its attributes.

The two sections developed in linearity were the baby's head then the rest of the body. The areas of great detail including the facial features, feet and hands hand to be tweaked beyond the initial creation of the model.

This involved the use of detailed scrutiny and precise sculpting on particular sections of the eyes, ears, fingers and toes etc.

#### *4.2.1.1 Model Creation*

To initiate the creation of the baby model in Blender, the 3D environment needed to be empty of any other meshes or 3D objects. The first model was the baby's head, to recreate the structure of a baby's head two reference images were needed to initially map the focal points of the head. The idea of having two reference images for a model establishes two points of reference when manipulation the 3D mesh mould to the head shape. The images chosen for reference were photographs of a real baby doll. The photographs taken were of the front and side profile of the doll showing two visual perspectives of the doll for displaying the main modelling steps and to get started with creating an accurate model. In Blender, the model needed to be aligned with the 3D environmental grid and centred in the virtual space given. To enable this, the 3D cursor location values were set to zero, fixating the objects generated into the focal point of the 3D environment. Two separate windows were created to distinguish two different viewpoints for model creation, Front and Side views. Then the reference images were added to the screen as background images for each viewpoint, creating a centred aspect on which to trace the added meshes. The front view and side view viewpoints will show any mesh or model creation in their aspect view and help create depth for certain character features. To begin the creation of the head, a mesh plane (flat 3D object, resembling a floor) was added, rotated ninety degrees around the x-axis and then aligned with the front of the face in the front viewpoint.

A mirror modifier was then added to mirror the mesh plane along its local x-axis across the object's centre. The mirror modifier was added to make it easier to model a full head, as a human head could be split in two and mirrored across to make a full head. This process helps create a full baby's head while only creating half a head. This modifier ensures that whatever is manipulated on one side of the face reoccurs on the other side. All of this mesh creation process had been created in object mode of the Blender program.

This next process of vertices manipulation and extrusion was created in Edit mode of the program. A plane was created over one eye then a loop cut was added at each side of the plane. The loop cut splits a loop of faces by inserting a new edge loop intersecting the chosen edge of the plane.

After adding four loop cuts in their proper places the top and bottom three corner loops are selected and merged at the centre. The bottom cuts were extruded downwards and lined up to match the reference image in the background.

These loop cuts and extrusions were created all around the face to create focal points of depth in the face and map out the facial layout from the Front reference image. This operation of loop cutting and extrusion was conducted until the entire face in the front view was covered.

Features that amounted to a great amount of detail required more cuts to fully define a shape, difficult areas like the nose, eyes and mouth needed attention. To make the 3D model nose, the faces over the tip of the nose vertices needed to be selected. From the side view the vertices were extruded outwards, these vertices were taken and lined up with the reference image. The vertices were then selected above the extrusion that was made and lined up with the bridge of the nose. The vertices were then tweaked in front view, this process was done every time an extrusion was made to line up the vertices perfectly to the reference image.

To create the nose nostril the base over the nostril was selected, then in Side view the base was extruded upwards. This base was scaled down to make the nostril taper as it went upwards. A loop cut was added around the mouth going across the tip of the nose and an additional loop cut going around the tip of the nose which would present more vertices on the nose. The reasoning for the varied amount of vertices was to create a more rounded area of manipulation instead of having a flat surface for the nostrils. The vertices were aligned again with the reference image so that they fitted the shape of the nose. The eyes and mouth needed definition too, requiring extra loop cuts for lips and eye lids. From this stage, the basics of the face were created with good topology but the rest of the head needed to be mapped out. To do this a loop cut was added on both the cheek and jaw bone mapping to the reference image. Then the vertices that were created thus far were tweaked in the Side view.

The cheek and jaw bone vertices were then extruded outwards towards the ear and covering the baby models side profile face to a couple other vertices to create the rest of the head. Where there was space between vertices, a fill or merge option was selected to fill in blank spaces. The vertices from the top half of the face going past the corner of the eye were then extruded up along the forehead. This can be seen in figure 22.

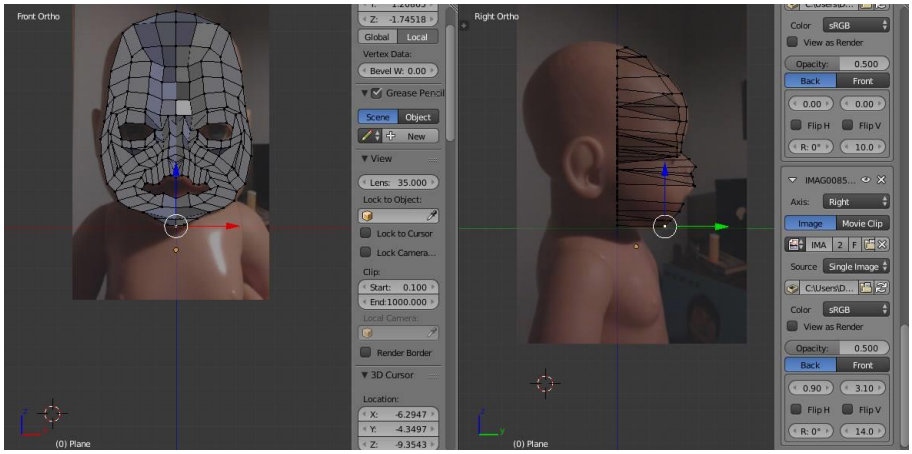



Figure 22: Front view and side view, 3D baby model head creation.

These vertices on the forehead were then aligned on a straight line and the entire edge of these vertices were extruded back all the way around the head rotating and extruding the vertices to align them the reference image. This extrusion was then connected with the front of the head by filling the vertices from the cheek and jaw. The vertices at the base up the back were then selected and extruded downwards. The vertices were then lined up so that the edges were straight up and down. The front of the chin was then extruded downwards to create the beginning of the neck. The vertices from the back of the head and those created from the chin were connected and then extruded downwards together to create the neck. The vertices were scaled to fit the neck in the reference image. The views were then changed once again to view the optimal proportions needed for accurate reference image representation. From the Front view the vertices created from the side view were tweaked and scaled to fit the reference image proportions. The main features of the baby model head were created from this point, shading of the model was then altered to smooth, to help visualize a higher poly. High and low polys refer to the number of polygons in a mesh for a 3D object. High poly 3D objects are very smooth whereas the low poly objects are jagged as you could visibly see the polygons. The difference in their use refers to the output and the medium they are used for.

High poly models need a long rendering time and a high processor to render the output, whereas the low-poly object renders very quickly. The use of low poly objects in gaming is very apparent as it takes little time for instant object response times. This however sacrifices the object's appearance. The processors for gaming platforms have developed nowadays to play high poly outputs but the speed at which these objects are rendered in development is still very slow.

In terms of the 3D baby head model any jagged lines were smoothed out to make a smooth curved mesh using the sculpt tool in Sculpt mode. Any vertices that were out of place were then lined up with the corresponding reference image for Front and Side View. After the initial editing, a subsurface modifier was applied to view the baby head in a smooth appearance.

This created more vertices on the full baby head model and created a more rounded result to mimic the reference images (this can be seen in figure 23).

The next property for the head were the ears, the ears required the use of a mesh known as an IcoSphere. This mesh was spherical is nature so the shape needed to be moulded to resemble the reference image ears. In the Edit mode, the icospheres vertices were dragged and aligned to become flush with the outline of the reference image ears. The Sculpt mode option was then required to mould the shape of the inside of the ears. When completed the ears were aligned with the baby head model and grouped together. As the head was generated and contained the majority of the features, the body was the next model to produce. To accurately depict the baby model body structure, the doll images were used as reference points again.

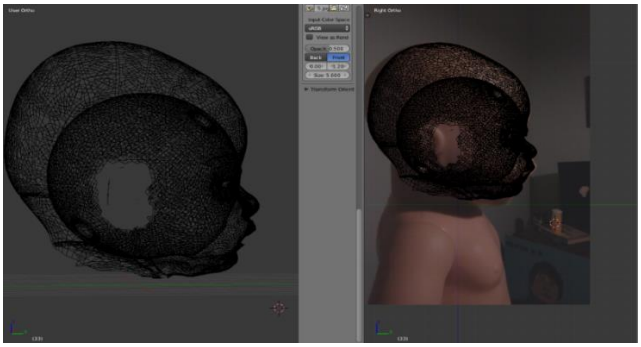


Figure 23: Subdivision surface of the 3D baby head guided to reference image.

This time, the images focused on the body of the baby doll. Instead of manipulating mesh planes, spherical meshes known as UV Spheres were added to the 3D environment and placed under the 3D baby head, extruded, deformed and scaled to create working shapes of the multiple body parts.

Like the facial structure and baby head, the body was created using a mirror modifier to create one half of a body and have the other half reflect or mirror it. Features of greater detail like hands and feet were excluded until a later time to be created using sculpting techniques like previously issued when constructing the ears. A subdivision surface was added to the body model to create a more rounded model and increase the amount of vertices.

The subdivision surface modifier creates more vertices (subdividing the mesh) in the selected model to give the mesh a smooth appearance with a higher poly. The higher the value of the subdivision is the smoother the object. The model was beginning to look more like the baby doll model, but without some detailing. The Sculpt mode was used to define the features and meld others together after the subdivision. These features like the bellybutton etc. were flattened in and inflated out to create a more realistic looking body shape (this can be seen in Figure 24).

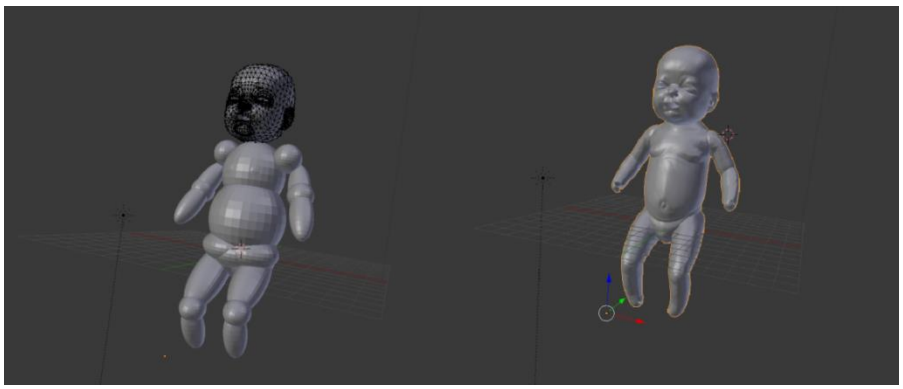


Figure 24: Right: Low poly body, Left: High poly body with detailing and subdivision.

The creation of the hands and feet was done separately focusing on the minute details attributed to each feature's extremity. Like the ears that preceded them, the hands and feet were created with a mixture of multiple spherical meshes with added nurb curves (curves created for unrestricted shapes). When the feet and hands matched a shape resembling the hands and feet of the reference images provided, a subdivision surface was added to further add definition to the objects. Once these objects had resembled the reference image in some manner, sculpting was conducted to for represent the features they are trying to resemble (can be seen in Figure 25).

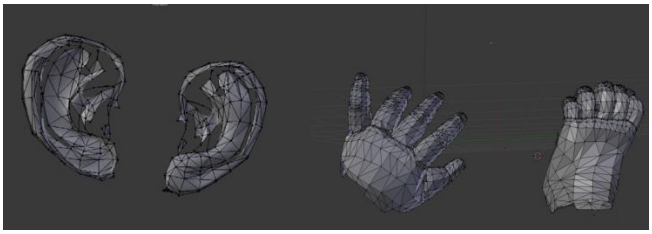


Figure 25: Outline and low poly created 3D models of ears, hand and foot.

Once all of the 3D body components were meticulously constructed, each component was merged together to form the full 3D baby model for further 3D interaction with other objects and applications.

#### *4.2.1.2 Texturing*

UV mapping was used initially in the creation of a texture for the recently created baby model character. To accurately texture the model, an unwrapping method was used to acquire a bump map image of the vertices of the model. To achieve this texturing method, the model was displayed as wireframe in order to unwrap the model properly. Unwrapping is a UV mapping process that outputs a flattened representation of the model. Seaming is a key process in the method of UV mapping and unwrapping, as the process involves highlighting or marking areas of the model that would be sectioned. Seams were created along the 3D baby object to flatten it out into a flat square 2D plane, for 2D texture manipulation.

Seaming the model into a flattened image is like creating a pattern for clothing, creating separate sections and then flattening those sections for separate manipulation. The flattened image was mirrored to the 3D model creating a 2D formatted layout of the structural features of the 3D baby model. Edge select mode was turned on from this point, to select the edges of the model creating the seams to flatten the particular sections of the 3D model. Sections of the model included the face, ears, and other sections with great about of textural detail. The head and the body were textured separately so that the unwrapped image would not be clustered. Once all the texturing was completed the two body parts were re-grouped once again. Seams were selected along the major outlines of the head and on the rest of the body. The first completed seam allocation was the head, so the whole model head was selected and unwrapped. The unwrapping presented the flattened image of the head with the seams outlining the difference parts of the head (can be seen in Figure 26).

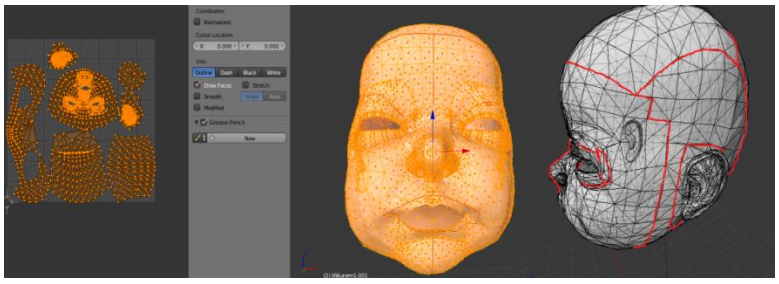


Figure 26: Unwrapped model, selected and seamed 3D baby model.

The layout for both the unwrapped head and body was presented in flattened images. These flattened images had the ability to be altered by external image processing programs. The unwrapped images were exported to be used for further image processing. To create the textures appearance, Photoshop was used to create a skin

like texture and depth. Darkened tones of skin colour were used for depth in features such as the eyes, ears and mouth. Once the colours were applied to the exported unwrapped image, the image was imported into Blender once again and applied against the models to create the textured look required. For further colour alteration the diffuse setting on the texture tone of the full model mesh was set to a colour resembling a skin tone. Once all of the separate textures and tweaks were applied to the individual meshes, all body part meshes were merged to create the full 3D baby model.

### 4.2.2 Amniotic Sac

The creation of the amniotic sac involved the deforming, bevelling and extruding of a spherical mesh. The internal aesthetic of the mesh needed to appear like it had a volume of liquid or amniotic fluid flowing in it. The size of the model needed to also be addressed, heeding to the ability to house the 3D baby model, placenta, umbilical cord and still be able to fit into the imported abdomen model.

#### *4.2.2.1 Model Creation*

The model creation involving the development of the amniotic sac model engaged the use of two identical deformed spheres with different textures and solid forms.

In a separate layer in Blender to the baby model, a UV Sphere was added to the 3D environment. In the edit mode of the program, the sphere was contoured and extruded out to form an oddly shaped sphere. The vertices were dragged and dropped according to the desirable shape.

The content that the amniotic sac would house was taken into account as the shape would enable movement of the baby model during the animation process. Once the vertices were allocated and extruded in the right areas, a subdivision surface was added to modify the appearance of the model, giving the sac a higher poly look. The model of the amniotic sac was then duplicated and the replicated model was scaled to fit into the original model to represent two layers.

This would highlight and visualise the amnion (membrane) separation from the amniotic cavity. The visible volumetric differences between the two models were created while texturing the model.

#### *4.2.2.2 Texturing*

The process of texturing the now created amniotic sac model did not require the unwrapping of the mesh. The reasoning behind not using the unwrapping UV mapping process for texturing the sac model, amounted to the lack of intricate detail needed to convey the finished model. The process of texturing used two techniques for accurate depiction, light diffusion and texture type. The light colour diffuse and texture type were collectively assigned to a material.

A material in Blender can be exported to various other 3D programming software as a blanket material to be applied to numerous objects. The material created for the amniotic sac texture was renamed and presented with the colour in the diffuse spectrum that resembled the reference images of real life amniotic sacs more. This colour threw a dark red hue with subtle tones of blue. This mimicked the vascularity of some skin or vessel appearances. The next step in texture or appearance accuracy was applying an image to the mesh. The process of applying a mesh involved the initiation of the texture type. From this option three different application measures were considered, cubical, spherical or plane application of the image to the mesh. The spherical option was chosen as the object was initially a sphere and would map relatively well to the texture configurations of a sphere. The same texture parameters were applied to the inner scaled down 3D amniotic sac object, but with minor changes to the texture type and modifiers applied.

The texture type for the duplicate sac object was changed from a solid form to a volumetric form, additionally a liquid physics modifier was applied to the object to create a fluid viscosity aesthetic apparent from the processing of rendered images of the completed object.

The final touch to the texture of the 3D object was its transparency. As the object would contain a number of 3D objects and these would have had functionality and animation, the objects needed to be seen to accurately achieve this. An opacity filter was adjusted to create transparency for the two 3D objects structuring the amniotic sac model. The 3D amniotic sac was completed and ready to retain the other 3D objects created.

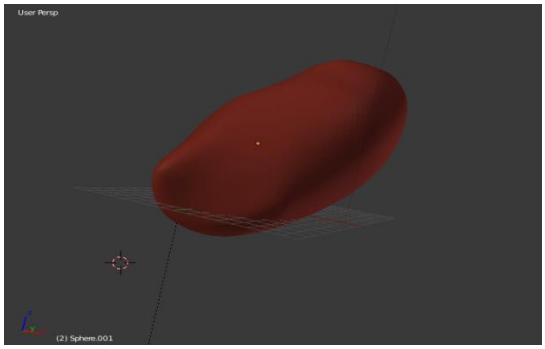



Figure 27: Placenta model constructed and textured.

### 4.2.3 Placenta and Umbilical Cord

The next models to be created for virtual 3D representation were the placenta and umbilical cord respectively. Like the amniotic sac the two 3D objects of placenta and the umbilical cord had no overly complex configuring equivalent to the creation of the baby model but still needed a lot of processing work to be applied. These two objects were different in their formation as the placenta was flat and hemi-spherical while the umbilical cord was twisted and knotted in appearance. Although the two 3D objects differed greatly in appearance, both objects needed to be joined as the two would be dependent on each other in the animation process.

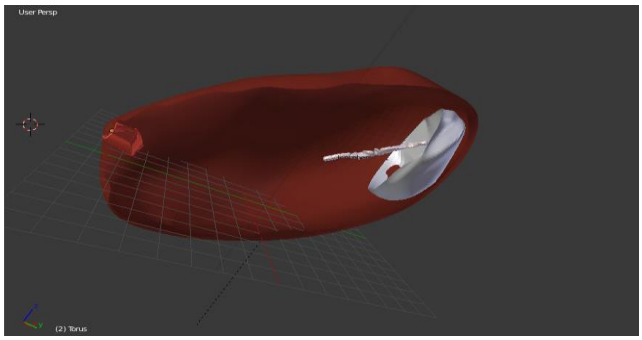



Figure 28: Umbilical cord and placenta placed in amniotic sac.

#### *4.2.3.1 Model Creation*

The models were created separately but in the same layer, created especially for the two models separate to the amniotic sac and baby model layers. The placenta was created first, to be able to perfectly align the umbilical cord to it once created.

To create the placenta, UV Sphere was generated and dissected in to two. One half was kept and the other deleted; the remaining mesh was tweaked in edit mode to spread out some outer radial vertices of the object.

To fully thicken the inside of the object the sculpting tool in sculpt mode was used. The centre of the object was inflated outwards and gradually the rims of the hemi-spherical object were puffed or inflated outwards too. There were varying degrees of inflation from the centre of the object to the outer most part of the object, having the rim of the hemisphere amounting to the highest affected level of inflation.

The umbilical cord was constructed using what is known as a Bezier curve. This curve presents a 2D curve with no 3D aspects. In the edit mode of this curve two control points are present at the start and end of each side of the curve. The bend or path between the control points is known as a segment and it is the main visual read of the manipulation from the control points.

To create an umbilical cord like structure the curve was extended out from the already created placenta, the amniotic sac layer was then made visible to estimate the size and width of the cord construct. Once the translational data was completed the deforming of the object was commenced. Multiple segments were created to generate varied bends in the structure of the object. The control points at each side were tweaked to also show variance in torque for animation later when grouped with the baby model. Once the entire structure mapping was conducted the curve was set to 3D creating an elongated band around the whole curve. To create more points of control the resolution of the curve was increased to generate a smoother curve. From the reference images accumulated, the umbilical cords appearance generally had a twisted or coiled appearance which needed to translate to the 3D object representation. As previously mentioned the 3D Curve had control points that were deliberated through xyz local translations. The curves normal was affected by the rotation on the x and y axes. The twist of the curve was calculated through rotation and populating the min/max values (amount of twists), alternating the tangent (geometric symmetry of curve) and tweaking the Z-Up (z axis orientation level) options attributed to the curve.

#### *4.2.3.2 Texturing*

In texturing, the two objects, the material used to texture the amniotic sac was used and altered for the two models (placenta and umbilical cord) and saved as separate dedicated textures. The material had a red/blue hue diffuse and a veiny textured image accompanying it.

For the placenta's texture the diffuse colour was changed to mimic a darker shade of red and blue, the colour brown was also incorporated to distinguish the placenta 3D object from the amniotic sac. The texture of the umbilical cord also mimicked the material of the amniotic sac still incorporating the vascular orientated image and some texture type settings. The departure from the materials origin for the umbilical cords texture was the diffuse colour separation. All the colours were given a lighter hue and contrasted with the introduction of a bright white to overlay of the textured image. After the last touches of texturing the models, the separate Blender layers were made visible to view the additional 3D models such as the baby model and amniotic sac. The models were then all placed together within the amniotic sac to judge the transparency levels of the sacs texture properties. After some minor tweaks to opacity, scale and orientation, the birthing construct was complete for program interaction and animation manipulation. The baby model needed to be posed into a fetal position to fit into the amniotic sac (as seen in figure 29). This will be discussed more in the Animation section.

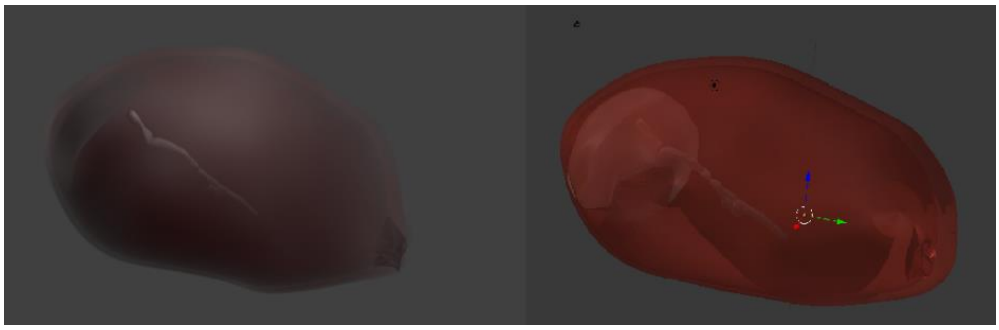


Figure 29: Amniotic sac, placenta, and umbilical cord rendered and unrendered 3D models.

### 4.2.4 Ventouse Cup

For the procedure of a normal delivery in Obstetrics the main 3D objects had been created that what accurately depicted the process. However, another type of delivery needed to be addressed. This delivery was a ventouse delivery. The ventouse delivery involves the use of a vacuum cup to assist delivery by pulling or enabling the fetal head to crown which leads to a normal delivery process.

To depict this process, a vacuum cup or ventouse cup needed to be created and textured for later use in programming and animation of a vacuum extraction (VE).

#### *4.2.4.1 Model Creation*

When creating the ventouse vacuum cup, a new layer was created to house the new 3D object development. The creation of the cup involved the grouping or merging of a series of standard shaped meshes like cylinders and cones.

The first mesh introduced into the environment was the cone shape, this mesh would ultimately be the cup segment of the ventouse device. The next shape added was the cylinder, this shape would construct part of the finished ventouse device handle. As the 3D environment contained the two objects, each had to be handled individually as the design for both differed greatly.

The cone shape was handled first, dealing with the design of the cup. In edit mode of the object the vertices residing on the radius of the cone were extruded on the y axis outwards, this was executed three times creating a jagged curve that resembled a crude outline of the cup. A loop cut was added around the circumference of the now cylindrical shape with a conical bottom. The new cuts created more vertices to tweak the shape of the cup. After tweaking the object in a cup-like with added lips, the conical bottom was scaled on the x and z axis to give the object a more rounded base. Once this was completed a subdivision surface modifier was added to the object to smoothen its aesthetic. This created a more rounded shape to compare to the reference images used as a basis of replication. The next addition to the vacuum cup was the handle, this inferred the extrusion of the added cylinder model in edit mode. To begin with the cylinder was scaled down to mimic the size of the handle, additionally to be far smaller than the vacuum cup. The cylinder model was then extruded on the x axis five times, the second and fourth cylinders were scaled to create a ribbed surface to complete the look of the handle. The handle object was then subject to subdivision surface modification, which rendered the object in a smoother texture. Once the handle and cup objects replicated the reference image, the two objected were combined and joined to one object. On closer inspection of the object as a whole, the object was missing one small detail and this was the tubing from the vacuum cups handle. To create this tubing and add it to the whole vacuum cup model, a Bezier curve had to be added to the 3D environment. Additionally, a cylinder was added to the environment and scaled to resemble a long stick.

The Bezier curve was applied to this cylinder as a path for which the cylinder could map its orientation translation.

Once the curve was applied to the cylinder it bended in the shape the curve was shaped in. In edit mode the curves bend could be tweaked and repositioned which did come in handy when animating the tubing. The cylinder was taken into edit mode and the circular bases at each end of the cylinder were removed creating a hollow pipeline within the object.

This resembled the tubing present in the reference image. When all of the components were ready the vacuum cup was combined, grouped and ready for use in animation and programming.

#### *4.2.3.2 Texturing*

Two materials were used for the texturing of the full vacuum model. The first material focused on the combination of cup and handle while the second material concentrated on the tubing.

The first or second material did not need a textural type image or additional creative pallets of colour. The two material used solid colours and diffuse colour to create the plastic aesthetic. The first material used a blue hue and lightened diffuse glow, this material was also slightly opaque to resemble plastic. The second material was more of a hard solid texture using a mixture of grey and white tones to resemble a tube. Once these textures were applied, the object was ready for integration.

Figure 30: Ventouse vacuum cup unrendered model.

### 4.2.5 Additional Models

The female abdomen model was given an added mesh to resemble a pregnant woman's abdomen. To be able to see the active models (baby model, amniotic sac, etc.) animate, the texture of the abdomen model had to be altered to assist the visibility of the other models.

The transparency of the model was tweaked to view the 3D model contents within. Another 3D model that was introduced and later removed was the pelvic bone model.

The model was rigged for animation and textured for low transparency to view the fetal delivery.

Although these measures were applied, the pelvic bone still caused obstruction to the visual experience of the procedure, so this model was later removed before animation.

## 4.3 3D Animation and Output

In terms of object functionality through programming interaction the objects were ready for exporting. But these objects needed to be subject to an animation process for a collaborative video effort which will be discussed further in a later chapter.

The animation process involved the setup of a virtual filming environment, the application of posable skeletal structures to the 3D objects, the key framing of procedural actions for animation and the final output exporting of the different delivery processes.

### 4.3.1 Cameras and Lighting

Prior to animating the delivery procedures, the 3D environment had to be set up for animation. This involved the inclusion of all the 3D objects created and introduction of them depending on the delivery procedure involved (Normal or Ventouse delivery).

The next environmental addition were the cameras and lights. With the objects positioned and ready for animation, the lights and cameras provided the capability of visible objects in the animation output. The lighting was centred on a typical three point lighting technique used in most photography photoshoots or films that focus on a single object or objects action. The lighting technique focused on three types of lighting positions and intensity. Three directional lights were used with an additional supporting area light. The three directional lights were the main source of active lighting for the animation scenes. The first of the directional lights “the key light” focused on the subject, the second light “the fill light” illuminated the shaded surfaces thesised by the key light and “the back light” gave the subject of focus a rim of light and highlighted their outline. The two key and fill lights were positioned at each side of the camera, having the fill light positioned lower on the y-axis to affect the key light at an angle.

The back light, as the name suggests, was positioned beyond the models in the scene. These positions created the main structure of a three point lit environment.

The area light was introduced to illuminate the whole scene. This light acted as a master light to affect key lighting segments within a particular point in animation.

Two cameras were added to the environment to enable the capture of the animation from two vantage points. The first camera was positioned from the side of the baby model and the abdomen to capture the baby movements in animation and have a clear view of a delivery process.

The second camera was positioned perpendicular to the first camera to capture procedural events such as the crowning of the fetal (baby) head. As the animation process when rendering only required one camera response at a time, the first camera was set as the active camera to capture the main processes. The active camera roles were fluctuated through the key points of the animation key framing.

### 4.3.2 Rigging models

To animate the objects, a process known as rigging needed to be performed on the 3D objects that presented intricate animated movement. The models that were rigged included baby model, abdomen model thighs/hip bones and the pelvic bone, which was later removed. The process of rigging involved the application of a skeletal structure called an armature to act as conduit from the model to the key framing process of animation. Once the models were rigged, they were ready to perform posed actions and they were keyed into the animation timeline. The first armature to develop was the fetal or baby model armature. The rigging of the models armature involved adding a single bone to the environment. This single bone was placed at the end of the models feet. The bone was set in the middle of the model's feet to act as an anchor to properly align the rest of the armature in development. The bone was duplicated, positioned in the middle of the models body (the fetal models chest) and rotated upwards towards the model's head. From this point on, each bone was given a label to identify which bone was active.

The structural layout of the armature mimics a typical skeletal humanoid biped structure. This meant creating a bone for each individual part of the body that was subject to adverse movement. From the single bone located in the middle of the fetal model which was labelled the "spinal" bone, two bones were extruded, one bone extruded upwards (chest bone) and one downwards (pelvis).

Another bone was extruded upwards towards the head and resized to fit the parameters of the fetal head labelled as the "head" bone.

Another bone was duplicated and laid flat beside the top bone representing the chest area. This bone was labelled as a shoulder and was the starting point of the arm structure.

Three bones were extruded down from the shoulder creating the upper arm, lower arm and hand. The lower part of the body, the spinal bone was also duplicated outwards and rotated downwards to create an upper leg bone. The upper leg bone was extruded downwards to create the lower leg and foot bones.

When it was time to create the shoulders, hip bones, arms, hands, legs and feet on the opposite side of the body, a mirror modifier was added to mirror all of the features to create a full bodied armature. To avoid the confusion of having duplicate labels on both sides of the armature, the letter "L" was added to the end of each bone to differentiate between the right and left armature features. As an additional helpful measure, the mirror modifier provided the exchange of letters once the bones were replicated to the other half of the armature. This caused the letter attributed to the individual bones and corresponding orientation to switch from "L" to "R".

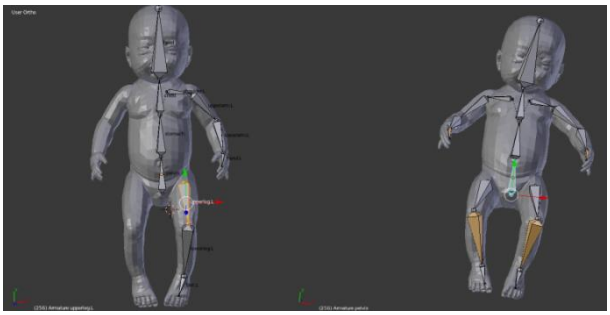


Figure 31: Armature half with labels and posed armature.

Once the armature was developed around the model, the model's mesh needed to be assigned to the newly created armature. To achieve this, the mesh needed to be selected and then the armature afterwards. When both were selected, weights were applied to the combination. When weights were applied, the mesh and the bones were linked where the bones were positioned. This caused the mesh to deform to the angle of the bone, which resulted in some of the mesh not being linked to the corresponding bones. To combat the residual mesh outliers, a mode in Blender known as the weight paint mode was used to apply mesh weights to particular bones.

In the weight paint mode, a red colour appeared on the body part mesh of the corresponding bone when selected and a blue colour represented the rest of the body not relating to the selected bone.

Using this mode, the meshes were painted to correspond to the right bones. After this was completed, the whole object was tested in another mode called pose mode. Pose mode offered the ability to translate the individual bones of the armature to create specific poses. This was a convenient medium, as the poses were essential to the animation process to create fluid motion in the fetal model's movements. The baby model was posed in the fetal position and positioned within the amniotic sac. The armature process was applied to the thighs of the abdomen model to insinuate the contractions in labour when animated.

To achieve the process, bones were added to each thigh and weights were applied. The weights were painted and then tested in pose mode to inspect for any mesh outliers. The models were then ready for animation and key framing.

### 4.3.3 Animation and Key Framing

In the creation of the normal and ventouse delivery animations some notable actions performed by the objects needed to be logged. Blender offered a timeline showing the amount of frames present in for the current scene, ready to fill in the logged positional, scalable and rotational data from each object. As the standard filming frame rate for footage is 24 frames per second (fps), creating a smoother picture (due to the amount of frames presented in one second), the frame rate for the exported animation was set to the same standard to benefit a clear and smooth output. There were three key forms of animation present in the creation of the delivery scene. These key forms were *LocRotScale* (location rotation scale – for object positioning), *pose keys* (for keying in armature poses in the timeline) and *shape keys* (which enabled the distortion of an object in animation). Every time an object was changed or altered for the purposes of animation the key icon was selected to log the data of the change within the timeline.

#### *4.3.3.1 Storyboarding and Key Frame Action*

Prior to creating the two delivery procedures, the scene needed to be storyboarded. This was to allow only the capture of the necessary scenes for narrative purposes. These scenes were: an idle animation; pushing and contracting; crowning; delivery of fetal head; restitution; shoulders/full delivery and ventouse extraction.

As rendering the animations was a long process, the scenes were shortened to accommodate a brief runtime that would later be edited and elongated in post-production as discussed in the video chapter (Chapter 5).

The elapsed time attributed to the rendering process was seven to ten hours for every minute of animation in the timeline, due to the number high poly models active in the environment.

The storyboards were created in pen to act as guides as to how the models would perform in each delivery process. The storyboards listed all of the actions and the amount of time needed to fully capture the scene. In terms of character animation in all aspects relating to key framing, each model was subjected to an animation tween. This notion of an animation tween presents a smooth transition from one model's state to another fluidly. When a model was initially key framed at one position or shaped in one particular state and then later key framed alternatively, the tween then creates a fluid transition from the initial starting key point to the other.

#### *4.3.3.2 Normal Delivery*

In creating the normal delivery animation, the key points were extracted from the storyboards actions. These involved the movement of the baby for idle animation using poses, the expanding and contracting of the amniotic sac, the emergence of the fetal head from the uterus, the delivery of the shoulder pins and then the full body delivery. To create the idle animation the fetal model was placed initially in a fetal position, key framing all the limbs in pose mode to the timeline to give the armature a pose to start with. For every few frames, the pose of the fetal armature was slightly tweaked to resemble a typical human like movement. This action was repeated and inverted to convey some variety in the fetal movement. The pose would enable the alteration of bone placement. For the process of expanding and contracting, the method of shape keying was used on the amniotic sac model. This method involved going into the models parameter and selecting a new shape key for every distortion that was going to be present in the model during animation. Two shape keys were created for the amniotic sac, one for the contractions and the other for the delivery. The first shape key was edited in edit mode bringing the back of the mesh forward reducing the size of the back of the object to convey a push. A unique feature offered by the shape key utility was its value system. The value system presented a min and max slider that went from zero to one (could be adapted to a longer value interval) of the intensity of the size reduction edit.

When set to zero, the object had no appearance of ever being altered for size reduction but when the slider was gradually dragged to the max value the edit created (size reduction) slowly tweened into visibility. To show this animation of the contraction process, the min and max values were key framed at different intervals to suggest pushing and retracting movements of the amniotic sac.

To create a cohesive animation the fetal model was then animated to react to the pushes simulated by the amniotic sac model. This involved the use of the LocRotScale key frame type. As the name suggests, the fetal model was key framed on orientation and positional data from the back of the amniotic sac pushing forward. This gave the illusion of the baby reacting to the mother's contractions. The next steps in normal delivery three dimensional re-creation combined the same processes of shape keying, pose keying and the LocRotScale type to complete the procedural simulation. The second shape key was created to extrude a mesh from the front of the amniotic sac to simulate the dilation of the cervix in preparation for delivery.

A shape was extruded and gradually expanded in light of the need to contain the fetal model on expulsion. Like the previous shape key, the min and max values were tweaked to have fluid animation progress across the timeline. The fetal model was then positioned towards the cervix and the armature was fine-tuned and pose keyed to show head tilts for proper delivery. Poses like shoulder pin placement for accurate delivery were used, as the process was imperative for teaching the student the correct way to deliver the baby. The other objects that were affected by the animation process were the placenta and umbilical cord. These objects both moved forward along the x axis following the expanding and contracting of the amniotic sac.

The actions were keyed to show a fluid motion for the two objects. This process of key framing individual framing types for specific actions continued to collectively accurately portray the desired scenes depicted in the storyboards for final rendering. Once the final scene of delivery was staged, an additional shape key was added to the umbilical cord object. This shape key animation enabled the umbilical cord to extend outwards with the fetal model as it was delivered. After the key frames were allocated the animation was ready to render for output.

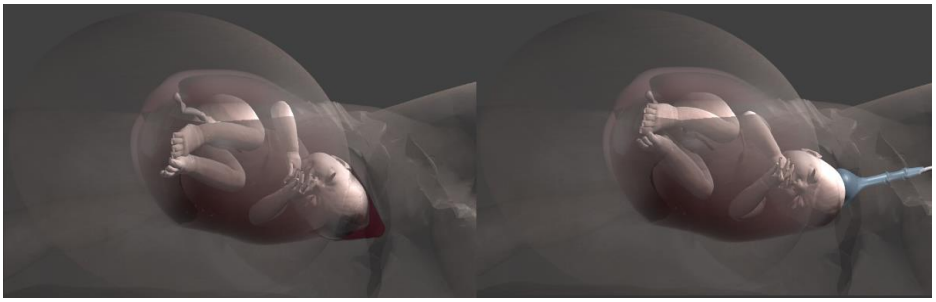


Figure 32: Normal delivery rendered image and ventouse delivery rendered image.

#### *4.3.3.3 Ventouse Delivery*

Much like the processes involved in the normal delivery, the ventouse delivery environment used a number of animation techniques to express the actions in a ventouse delivery procedure.

In order to conserve the amount of rendering needed to accurately depict the procedure, the scenes that did not involve the ventouse were extracted from the normal delivery renders. This left two main scenes to capture, fetal model head inability to move past cervix and ventouse cup introduction and extraction. The first scene was a scene that was further manipulated in post-production, which was elaborated further in the video chapter.

The second scenes were centred on mapping out the path of the fetal delivery, the ventouse object was given a LocRotScale type positional and orientation based animation from the off stage introduction to attaching the cup to the fetal head. The same key frame type was used to bring the fetal head past the cervix and remove the vacuum slowly from the stage. From this stage the normal delivery scenes were used as the fetal head was in restitution. As the ventouse scenes were all key framed and the timeline was populated, the ventouse delivery environment was ready for rendering and output.

## 4.4 Output

After the models were created and the setup for each procedural delivery animation was processed, these components needed to be exported as individual formats depending on their usage for later manipulation. All models were collectively selected and exported as .obj files and stored/labelled in a directory for later programing use. The obj file is a file format that is widely accepted by most 3D programming software. When exported, the obj file was attached to a .mat file which refers to the material associated with that particular object.

The animation setups were rendered out as H.264 mp4 format as this format is widely accepted by most video editing software. The rendering process time for both delivery procedures amounted to an elapsed time of seventeen hours.

## 4.5 Programming 3D Fixtures and Manipulation

After the full utilisation of the Blender utility and exporting the necessary data needed for manipulation, another 3D software was needed to manipulate this data in terms of physical interaction.

There was an array of different 3D software options available to program 3D models. Two notable programming heavy applications for 3D composition were Unity 3D and Unreal Engine 4 (UE4). Unity and UE4 both had perfect work stations for application development and both applications offered an abundance of 3D manipulation tools. In choosing the right program with which to progress, the end goal of the thesis needed to be addressed. One goal of the thesis was to use sensor driven external inputs to manipulate 3D data to progress a learning narrative for the obstetrics students. The use of sensors for 3D localisation was a vital aspect of the thesis, so the software used for developing the application needed to be very sensor driven and adapt to various forms of sensor input.

From research conducted for the sensor and simulation chapter (Chapter 6), the program most suited for sensor inputs and event handling through sensor integration was Unity 3D. Unity 3D's ability to retrieve, interpret and expend multiple forms of sensor data was a benefit when trying to find the perfect sensor to use for device and model orientation logging.

The next steps in 3D involvement and manipulation involved the creation of prototype applications that invoked minor interactions to offer some educational information in the process. These applications were developed to integrate the created models from Blender and utilise different interactive methods offered by Unity. The best methods of content or information delivery were then considered in the development of the final application for the learning resource. In order to fully program the 3D models in Unity, the models needed to be imported and sorted in a directory with a new Unity thesis. The benefits of having a thesis in Unity is that it facilitated the creation of numerous scenes that could hold self-contained 3D interaction examples. Each example was given their own scene so not to confuse the structure and the coding process when running the main application.

### 4.5.1 Fetal Head Application

When creating the baby or fetal head application, the idea was to offer a user the ability to select parts of a baby's head and have the name of that particular part of the head appear as a label. The user was also given the opportunity to rotate and position the head creating more activity and more views of the object. As the application would finally be distributed as mobile application, the fetal head application was developed for both online and mobile capability.

Before the development of the application, the fetal model was edited to highlight the segments of the baby model's head.

These segments were colour coded to differentiate them from each other. This was achieved through using Blender once again to select the corresponding segments of the mesh and give each segment a new texture which was just a solid colour. As the focus of the application was to identify each segment of the head, the rest of the model's body was removed to have a more directed object. This fetal head model was exported out from Blender as an .obj file to be later edited by Unity for platform, online and mobile applications.

#### *4.5.1.1 Online Development*

In developing the online application, the newly edited fetal head was introduced into the Unity 3D environment alongside a camera and one area light. The initial interactive idea for viewing the model from all angles was to use the mouse to rotate the model to view different parts of the object. To create this mouse movement interaction, some JavaScript code was written in Unity and applied to the fetal head model. This code called for an event to listen in for a mouse input, if a mouse input was registered the x and y axes were retrieved. After retrieving the axes, these values were transformed to usable quaternion rotation values. On the update of the code the rotational values of the model were applied to the mouse input. When the application was set to run, the fetal head tracked the curser and rotated on the mouse responses. Once this interaction was complete the 3D object was exported as a web player from the build settings in Unity. The rest of the interaction attributed to the application was conducted through the use of JavaScript and CSS on a web page but not on the 3D file exported by Unity. The webpage layout employed a panel with components for a dropdown menu quiz and beside this panel was the placeholder for the exported 3D model file.

The interaction on the web page involved six dropdown lists providing all six possible answers to the fetal head segment names. Six colour boxes resided beside the six mentioned dropdown lists corresponding to the colour segment on the fetal head. The website was given a submit and restart button to enter the values in the quiz. Once the values were either correct or incorrect a tick or cross was presented and replaced the corresponding colours.

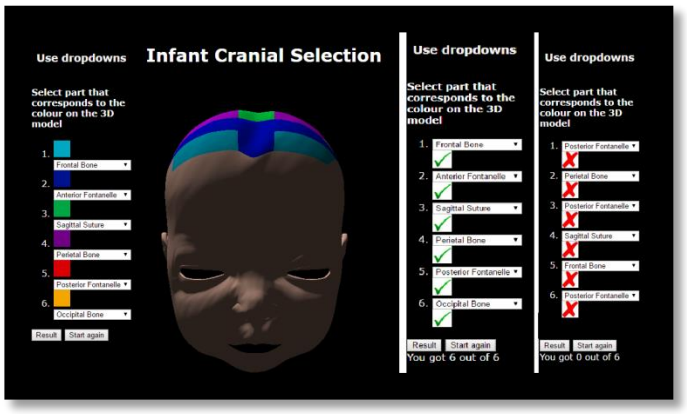



Figure 33: Fetal head online application, right and wrong answers.

In order to create the quiz on the webpage, the JavaScript syntax was used. A function called checkAnswers was created which listed the correct answers sequentially using their attributed variable name (e.g. question one's answer would be the variable "f" being the sixth sequential letter down and being the sixth answer in the dropdown "frontal bone"). In order for the right answer to be registered, a for loop was created to cycle through the drop down menus and assign a result to the individual questions. The score of the quiz was also incremented as the questions were answered correctly. The score was presented below the ticks and/or crosses along with a string presenting the user with a statement of their score out of six.

#### *4.5.1.2 Mobile Development*

When constructing the mobile application, the idea was to create an application that presented the head and had interactive positional/rotational tools alongside informative labels that would appear when a segment of the head was selected. If the application was exported or built for mobile support, the application would not run the right way. As the head was present in the Unity environment, it needed to be selected without rotating the model. This involved removing the previous script and replacing it with a touch event or click event listener script.

To enable the ability to affect the mobility buttons of the fetal head were generated onto the screen on runtime. These buttons were up, down, left, right and rotational options to veer right or left on the x axis. As each segment label of the head needed to be viewed individually from a touch input, each segment needed their dedicated script on selection. Each segment was provided with its very own empty GameObject (Unity object – can be any interactive object in the environment) and renamed to the corresponding colour and orientation of the segment (e.g. backR – back red). Components were added to each GameObject known as box colliders, these box colliders were cube-shaped bases used for collision detection.

The scripts assigned to each GameObject would have an event that would occur when a collision is detected. In the case of each GameObject the collision was the touch input. An "if" statement was generated to listen for a mouse click event, once the event processes that the collider has been clicked a function called OnGUI (referring to graphical user interface) displayed a GUI.label created with parameters judging the labels size, colour and orientation in the environment. The same code snippets were used for each separate GameObject but the labels were changed to fit the segment and collider they were attached to.

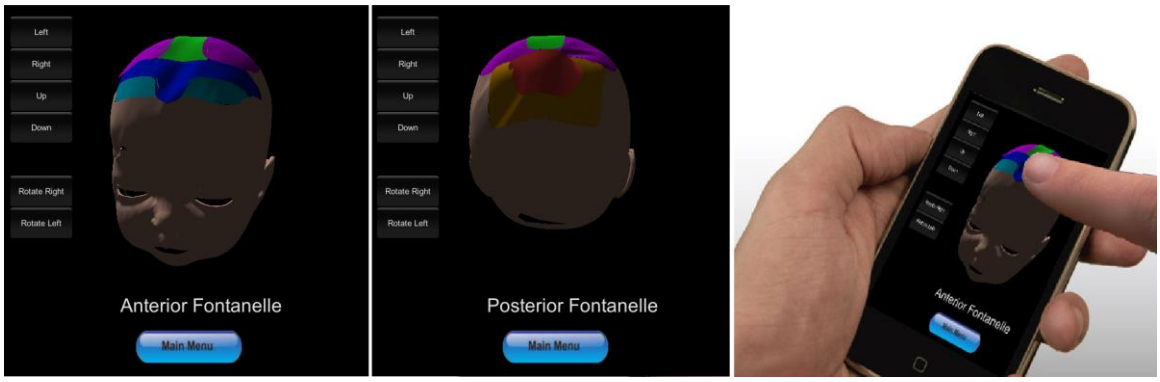



Figure 34: Mobile interaction of the basic functionality of the fetal head Application.

A script was added to the fetal head model to add the previously mentioned UI (user interface) buttons for 3D object directional, rotational and positional influence into the environment. This script was written in C# syntax as the coding practice cooperative well when developing for both android and iPhone devices. In the script, if statements were generated that transformed the model on the x and y axis by decrementing and incrementing the x and y position data for the model.

To rotate the model, the model was subject to the positive and negative effects of the rotation in the transform rotation parameters, meaning the minus and plus values assigned to the rotation process caused the model to rotate left and right on the x axis. The statements were called by the initialising of the condition of the "if" statement which were the individual GUI buttons that were generated also within the code. Once the scripting was completed the build settings were set for android development to view the example application on a phone.

### 4.5.2 Placenta Position

The next beta or example application created was the placenta position (PP, can also refer to placenta praevia) application. The idea for this sample application was to show different examples of where placenta could possibly be presented within the amniotic sac. Some positions shown were actual representations of placenta positions that were known to cause vaginal delivery difficulties or cause some form of distress during the gestation period or labour (Jang *et al.*, 2011). In some extreme cases, the position can cause uncontrollable bleeding or prevent normal delivery and resort to caesarean section (Gilliam et al., 2002). The positions chosen were partial (PP partially covers cervix), low-lying (PP on the edge of the cervix), marginal (placenta grows at the bottom of the cervix, pushes against cervix but does not cover it), and complete (PP completely covers the entire cervix). In the 3D environment, the placenta, umbilical cord, fetal model and amniotic sac were positioned in front of the camera. The placenta was the only object in this scene that would have any dynamic actions while the other models acted as static 3D representations.

The placenta had to be placed in the four position types but needed to be logged in animation. To present these positions, animated tweens between each position were created, accessed through GUI button input and displayed in the position corresponding to the button labelled with the same position. In Unity, the animation was limited to the location, rotation and scale parameters much like the LocRotScale type in Blender. As Unity was primarily a games engine, the focus on modelling or model deforming was non apparent. To animate the placenta in Unity the animation window was introduced. This window provided a timeline, record and stop symbols, when selecting the placenta object the option to record the animation was highlighted to suggest a new input in the window. Four animations were created in this window marking the positional movement on the x axis and rotation.

When calling these animations to be applied to the placenta, an animation component was added to the object with four elements attached relating to the newly created animations. Although the animations were attached, the animations needed to be triggered by initialisers in a script. Before a script was added to the placenta to run the animation process, all the animations playing capabilities were disabled to stop them all from playing at the same time when running the application. The animations were then called in the script by a GetComponent method which searched through the Unity directories to find animations.

Like the previous example the "if" statement was used to create conditions on the selection of particular GUI buttons after their initiation in the code. The buttons after selection would play the animations linked to them (buttons labelled as the PP animations) on selection. Similar to the fetal head, this application was then ready for export.

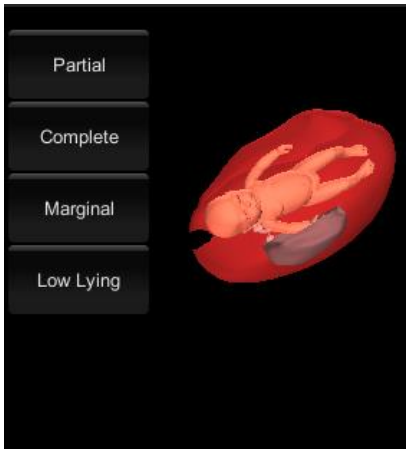



Figure 35: Placenta position mobile application still image.

### 4.5.3 Fetal Heart Rate

While the two previously examples of testing applications used varying degrees of information delivery through interaction of a minor level, the fetal heart rate application was sought to introduce sound manipulation and a heart model created from a previous research study. The idea was to be able to use the GUI buttons to increase and decrease the fetal heart rate. The heart rate was visualised by animating the fetal heart beating and palpitating when increased. Sound was added to the animation, which increased in tempo as the heart rate was increased. Two models were added to the environment, these were the fetal model and the heart model. The heart model was resized to fit in the baby model and placed on the chest to be able to view it when initialising the run time of the application.

To create more variability in the fetal model, the idle animation from Blender was applied to it. This was achieved by opening the Blender file within Unity, accessing the animation file containing the idle fetal model “Walk Cycle” (referring to a snippet of animation created to be repeated and represent a fluid action like walking) and adding it to the animation parameter of the fetal model present in the fetal heart rate scene. The animation was set to loop, so the fetal model would move its arms, legs and head slightly over time creating a realistic baby animation depiction.

In order to create the heart animation, the animation window was brought out once again to record the actions of the object and create an animation file. The file was referenced in an if statement on inclusion of a script from a GetComponent parameter. However, the animation was not only gathered from a directory to play on a loop, its speed needed to adjusted on the selection of two GUI buttons labelled increase and decrease. In the attached script, the heart rate was set to a controlled speed declaring a variable “i” to represent to number for the amount of speed attributed to the heart rate for possible changes in speed on GUI button interaction. The variable of “i” incremented as part of a conditional event on selecting of the increase button. It also decremented once the decrease button was interacted with.

To create the heart beat sound, a sound wave was retrieved from sample footage of an ultrasound. One segment of audio was cut from the footage to add to the animation in Unity.

The audio was given a snippet of code to call in as the animation would play, this synced the audio with the animation. To further elaborate the increase or decrease in heart rate (HR), a line of code present within the conditionals echoed a string issuing a warning at the level at which the heart is and the need for it to decrease. To achieve this, a condition was issued that sent the warning string text once the variable “i” referring to the speed of the heart was either greater than five (very fast HR) or less than 3 (very slow HR). Once the animations and sound were in place and the animations responding to the GUI input, the application was ready for export.

Figure 36: Fetal heart rate mobile application still image.

### 4.6 Trial Application Testing

The reasoning behind the creation of all the 3D examples was to test some obstetric material on key 3D interactions utilising important factors that were going to be present in the final resource. For example, in the final resource, the fetal baby was moved by an input, a sensor device, the change or alteration in scripting only refers to the means of input data selection. The other examples present additional object interaction in the final resource as the placenta and HR played a vital role in assessing the baby before full delivery. The example applications provided the opportunity to sample some processes before amalgamating all the key processes for testing. Each example application was exported as an android APK (android application package) and this file was an executable file for android phones. The reason for distributing the applications for android development was that the android phones offered the ability to install APK's that were not approved by the Google Play store, whereas the iPhones process takes a lot longer (iPhone emulators were later used in the resource development for error testing). The applications were installed on an android device and tested to view any irregularities. Some minor aspect ratio issues were apparent but did not ultimately break the interactive experience.

### Summary

In this chapter the background of 3D and its introduction into society was discussed. From the literature and from the examples shown, 3D plays a vital or important role in the visualisation of unseen procedural scenarios and enables users to immerse themselves in a virtual environment and train with no risk of patient morbidity. Similar work shows that the use of 3D in obstetrics holds a great deal of educational value, presenting work that has few interactive attributes.

Other medical fields have cornered some virtual reality or interactive platforms, consequently the obstetrics field needs to emulate these other disciplines to have a more interactive learning experience without affecting patient safety when training (especially when working with patients who are pregnant). The model creation and animation was discussed in great detail, as the models and the animations involved were key features in later simulation development and alteration in the simulation chapter. The applications developed created an understanding of how the applications looked outside of the 3D editing software and enabled mobile use of the applications. Overall, the 3D aspect establishes a creative way of visualising and interacting with learning material.

# Chapter 5. Video Platform Creation and 3D Amalgam

In this chapter video, its production and delivery, its influence on education and the medical field will be discussed. This chapter will also establish the creation of an online video orientated resource and discuss its influence on obstetric students after utilising usability testing. The significance of this chapter is in its utilisation of the fundamental learning concepts and designs from the results of student learning styles and from UI results in the previous chapter, to create an accessible online learning platform and form a theoretical basis for the finalised simulation learning platform. The incorporation of the 3D and video interrelation created a novel way of teaching the students obstetric procedures that are usually unseen by the naked eye and presenting them using multiple visual aids and informative interactions in an educational constructive narrative container (Coffey *et al.*, 2014). The use of these two technologies presents the information to students in a fashion that relates to their learning preferences and elevates the educational standard by presenting information in an adaptive nature while accepting more digital/computational inputs. The results and findings in this chapter ultimately led to influencing the simulation concepts and designs on the simulation chapter.

## 5.1 Video Background

Video is an electronic medium for the recording, copying, playback, broadcasting, and display of moving visual media. Video systems contrast significantly in the resolution of a videos display and other aspects referring to size (aspect ratio). They can also be supported or stored on a variety of media, including tapes, DVDs, computer files and stored on the web. In terms of video functionality, frame rate refers to the number of still pictures per unit of time of video, it ranges from six or eight frames per second (fps) for old cameras to 120 or more fps for new professional cameras (Sivasubramanian et al., 2016). Film for any visual platform is shot at the slower frame rate of 24 frames per second (Ushikubo, 2002). The minimum frame rate to achieve a secure impression of a moving image is roughly sixteen fps which is used in some animation software like Adobe Flash. Aspect ratio in video describes the dimensions of video screens and video picture elements. All of the main video formats are rectilinear, and consequently can be labelled by a ratio between width and height (Google, 2016).

The screen aspect ratio of a traditional television screen is 4:3, whereas a HD (High definition) televisions use an aspect ratio of 16:9. Uncompressed video delivers the highest quality, but with a very high data rate (Cao *et al.,* 2009). An array of approaches are used to compress video streams, with the most effective methods reducing redundant spaces and temporal sequences. Many analogue and digital recording formats are used today, digital video clips can also be stored on a computer file system as files, which also have their own formats. In recent decades, digital video has been extensively utilised as an efficient media format, not simply for personal communications, but also for business to employee contact, business to business contact, business to consumers contact and college interactions through video conferencing applications (Leeds et al.,2009). Video seems more appealing than other fixed data forms like text and imagery, as it's fundamentally rich in content and it carries a message easily and effectively. Multimedia documents are more readily available these days, owing to the prompt growth of the Internet and its ability to connect people. The public has grown increasingly interested in online multimedia rich applications.

## 5.2 Video on the Web

The Internet has shown that it is ready to support an increasingly large amount of video content online traffic. The web has developed into the main delivery platform for distributing television (TV) content and has unlocked innovative ways for finding, sharing, and utilising media content from home, work and college. Over 80% of Internet users now watch video or TV online, while 20% of these users still watch videos from analogue platforms (statista, 2016). Authoring platforms for real-time delivery of animation during streaming videos had become accessible. These authoring platforms allowed multimedia-style animation and interactive controls to be linked with filming approaches of the audio and video. In the early part of this decade, equipment and software used in the multimedia production of these platforms were frequently not as fully developed as products in the more established computer desktop applications. As a consequence, there were often compatibility issues with browsers and other devices on formats and ability to play. After the rise of peer to peer (P2P) systems, Internet video started to quickly become the key source of traffic on the web (Barskar *et al.,* 2016).

According to CISCO, IP video traffic will be 82 percent of all consumer Internet traffic by 2020. The web is notably fixing to adopt these developments in video, drawing a fresh line for new standards in video (CISCO *et al.*, 2016). HTML5 is the fundamental plan that forms the next open web setting. While HTML5 has not yet become a full browser wide accepted web standard, latest versions of web browsers have begun to employ and execute vital components of HTML5. For instance, the majority of desktop web browsers like Google Chrome, Mozilla Firefox and Microsoft Edge now support the video tag (<video>). This was a key idea in HTML5 to gradually integrate video on the web. The video tag has unlocked the prospect of video manipulation within a fixed web page. The video tag also offers innovative user interfaces (UI) that fuse video and other content, which enable their creation without having to resort to devoted video plug-ins.

Nowadays, the video tag does not explicitly need support for codecs and streaming technologies (Conklin *et al*., 2001). Regulation on and standardising these technologies is needed to fully appreciate the potential of videos place on the web as well as to integrate web tools on devices that stream video. Before the use of the video tag, video on the web had been mostly the tools of browser-specific applications or third-party plug-ins such as Adobe Flash Player or Apple QuickTime (Hoy, 2011). These plug-ins were triggered through the use of the object tag in HTML. Trusting third-party plug-ins to render and display video worked for the most part for a variety of small video thesis but it did have its complications. Since the videos were rendered in an object tag confined to a black box from the web browser's viewpoint, the CSS (cascading style sheet) could not be used to style the video, or to apply alterations. Additionally, the vector image format SVG (scalable vector graphics) could not be used to add masks and filters on the videos.

In summary, visual effects cannot be attained using regular web tools. Moreover, there is no typical way to control the box created by using the object tag through javascript either. Therefore, there is no way to modify the aesthetic and function of the video playback user interface from within a page. Lastly, these plug-ins are hardly ever available on mobile tablets, smart phones or other devices that are not fixed to a desktop computer. The video tag introduced by HTML5 improves on the ease of video use and irradicates most problems associated with video hosted online in the past.

Subsequently once video became a regular tag such as the container “div” tag, it has openly integrated itself within the excess of the web site, being linked with CSS

(cascading style sheet) used to style and transform the video box. The HTML5 specifications API (application programming interface) allows access and control to the video from JavaScript. The API opens up the potential of the UI using HTML, SVG, CSS, and Javascript to create interactive interfaces (Hagino, 2011). The HTML5 specifications don't impede the list of video formats and codecs that some browsers support, lending itself for open formats in the future. The video tag features a contingency plan where substitute sources can be identified, using diverse formats or codecs. Iterations of supported files would be shown in the browser if one was not supported. As it stands the current state of support among main desktop browsers is presently MP4 supported by Internet Explorer 9.0, Safari, and Google Chrome (Purnamasari et al., 2014).

## 5.3 Medical Educational Impact

Video is an influential and powerful teaching and learning tool because it can guide knowledge, skills, and attitude development successfully. Additionally, it can reach learners with various learning and communication styles, pedagogically, technically, and through interactions. Lecturers through the teaching process in college source suitable videos, select effective video segments, apply various strategies for incorporating video triggers into the overall educational classes. Video use in medical education has increased a great deal in the past decade. *Medicalvideos* and *Medtube* were two online resources created to include simple subject matter and medical skills for preliminary lessons lately. Medtube is an online video-centric education and communication platform for healthcare professionals created by Michał Wszoła and Rafał Kieszek (MedTube, 2016).

The online platform is free to use by to the public and medical professionals, yet, registration is compulsory to use the website's functionalities. MEDtube was created in appreciation of a rapid growth of communication technology. Also MEDtube removes traditional communication obstacles like distance and language to facilitate the trade of information and skills using video manipulation content. Medicalvideos is another online video resource. This resource is much like the MedTube in its ability to provide videos with ease using a web integration. Although unlike the MedTube platform, the Medicalvideos platform is free to use without registration. Apart from the array of videos offered in the library on the platform, the resource has very little to offer in interactivity (Medicalvideos, 2016). The aesthetic of the resource does not

respond well as an interaction site, having limited navigation and few points of interest. In addition, YouTube videos have also been commonly used in medical education. Stylish videos provide medical students with the flexibility to evaluate information at their own speed, to focus on their separate learning styles under this structure. Prior research, as discussed in the literature review (Chapter 2), on the effective use of video technology in education, shows that instructors need to be not only authorities on the material, but also have a factual or observational comprehension of the technology to be utilised. Videos can bring traditional lectures to medical students before class and change didactic classroom teaching into more student-centred activities. Online libraries offer some minor videos in obstetric procedures, although when presenting these procedures, the narratives were informal and uninformative, creating a visual experience without general procedural context of what things were or the clinical context to individual processes.

The videos were of normal deliveries but the video standards were quite low creating poor quality. The existing libraries focused more on the supplementary textual information on the site and the videos could not have been incorporated into the potential video resource for this thesis as they did not encompass a direct video narrative needed to inform the students. Therefore, procedural footage needed to be captured in house and provided for this thesis.

## 5.4 Capturing the Procedural Footage

To begin the process of constructing a visual and audible obstetric procedure narrative, the content needed to be acquired and editing to fully create a sound visual description. Both video and audio was obtained from the department of Obstetrics and Gynecology. The video content obtained from the department held five key individual educational obstetric procedures which were recorded in complete anonymity and with consent of participants. These obstetric procedures included normal delivery, ventouse delivery, caesarean section, placenta removal and placenta examination. Each video contained audio of the practitioners conversing, and theatre room ambient environment sounds and lighting interference. To fully understand the method of footage acquisition and proper practice of recording through the birthing process. Each video procedure is discussed in the next sections.

### 5.4.1 Procedural Capture Setup

To setup the capture of the individual procedures, there was one fixed static positioned camera pointed below the mother's pelvis. The camera was mounted on a tripod stand to minimise shifts in orientation and to avoid potential deviations in position and avoid shakes through the recording process. The camera was then positioned two metres away the area as to avoid obstruction through each process. The camera was tilted at a 45° angle and positioned to veer from the right hand side of the procedure to view the mother, practitioners and pending delivery clearly. This camera setup enabled a clear view of each procedure without causing obstruction and maintaining the settings needed to record the procedure. To fully capture the point of interest (cervix), the aspect dimensions of the camera were tweaked change the focal length to fit the POI (point of interest) into the FOV (field of view). This meant zooming into a FFL (fixed focal length) for the duration of the process. This FFL was tweaked for variances in processes during each procedure. The next important feature of capturing the procedure was the lighting setup. As lighting practice involves the setup of three key lighting formations, key light, fill light and back light, the room needed to accommodate the necessary settings needed for a vivid picture. The procedural theatre used possessed a great deal of lighting fixtures that enabled a great light setting. The theatre light setup enabled two key lighting formations including fill and back light. And additional light was introduced as a fill to brighten the area of the cervix were the majority of the process was taking place. The process of procedural capture was unique to each procedure documented. Each procedure had variances in FOV and FFL due to the alteration of the specific POI. Key differences and general events of these procedural process captures are presented below.

### 5.4.2 Normal Delivery Capture

The normal delivery was captured using the setup previously mentioned. Each active process of the delivery was captured and logged for further examination. The logging process captured the time taken for each process and minimised the length through time-coding. The processes involved in the normal delivery included active pushing, crowning, delivery of the fetal head, restitution, shoulder and subsequent full delivery. These processes held two variances in FFL, these variances occurred through three sections of the process of delivery.

The first FFL known as a WS (wide shot) was the initial fixed viewpoint of the cervix, the mother's abdomen, the mother's lower body and the practitioner's arms from the elbow down. This FFL was essential for the processes of active pushing which had been time-coded to one minute of the footage captured. Beyond this one minute time-coded mark the FFL increased to include a FOV from the mother's inner thighs. This new FFL known as a CU (close up) captured the cervix and the practitioner's hands. This FFL was essential to capture an up-close view of the processes of crowning and subsequent processes. The first FFL was then established once again to finalise the full delivery. Once fully captured rough storyboards were created to map the individual movements and methods alongside the time-codes created for the processes. These storyboards and time-codes were essential in accurately presenting the material for the editing process.

### 5.4.3 Ventouse Delivery

The ventouse delivery used variances in the initial setup and free hand or handheld recording. The processes of the delivery were captured and logged for further examination presenting the time-codes for each. The processes included active pushing, inspection, the ventouse vacuum cup insertion, vacuum cup placement, vacuum cup fixing and the extraction of the fetal head. The subsequent processes that followed matched the processes involved in the normal delivery.

The processes held three distinct FFL variances, the variances occurred during three sections of the process. The initial FFL was a CU viewing the cervix and the practitioner's hands. This FFL was essential for the processes of active pushing (view dilation) and the inspection before the insertion of the vacuum cup. The FFL was then additionally increased to create an ECU (extreme close up) FOV to accurately show the proper insertion of the vacuum cup. This ECU FOV captured free hand the careful insertion, the placement on the cup on the fetal head and the careful fixing of the cup's orientation within the mother. The FFL was then reverted back to the CU FOV to capture the full view of the processes of crowning and subsequent processes of delivery. The reason for the change of FFL for these processes was to capture the main POI without zooming in too close. The WS FFL was then established to finalise the full delivery. Storyboards were also created in the ventouse delivery to plot processes alongside the time-codes.

### 5.4.4 Caesarean Section

The caesarean section differed from the initial setup due to the lighting needed for the procedure. The C-section (caesarean section) is a surgical procedure, so the light involved is mainly focused on the POI for the surgeons concerned. The room itself was dark to avoid obstructive light for the surgeon and the fixed lighting focused on the area of potential incision. The camera setup did not change, only in its variances of FFL. The processes captured and time-coded were the preparation, incision, cleaning of the area, the delivery and eventual stitching of the wound.

Two variances of FFL were initialised to capture the procedure. As it is a delicate procedure the FFL was not changed until the final stitching process was commenced. The main FOV was a CU focus of all the interactions; the FFL was then changed to ECU to accommodate the viewpoint of the stitching process. Additional Storyboards were also created for this surgical procedure to structure these processes alongside the time-codes.

### 5.4.5 Placenta Examination and Removal

The placenta removal was a short procedure to capture as the extraction time-coded to one minute due to ease of placenta withdrawal. Due to the short length of the procedure only one process was viewed (extraction) from one FOV. The FFL was an ECU of the cervix as the placenta was slowly extracted. The process was still time-coded from controlled umbilical cord traction to full placenta delivery, utilising storyboards for each event. The examination was shorter but has two processes and FOVs, inspection of the amniotic sac and inspection of the umbilical cord.

The two processes were short but had two distinct FFLs. The amniotic sac had a CU FFL and the umbilical cord had an ECU FFL for the inspection. The processes were time-coded and storyboarded for later editing.

## 5.5 Editing Videos for Web Integration

From the captured footage, procedural dialogue audio and 3D clips exported from Blender, the videos had enough material to create a cohesive narrative (besides some explanatory imagery in some aspects). The following process involved the structuring of these elements to create the content needed to display for the potential interactive video player.

The method of editing and delivery began with the structuring and editing of the procedural footage and the dialogue audio to present crucial events to mimic in the 3D comparison. The 3D videos were created next to coincide with the time-codes and events of the procedural footage narrative. As the process of 3D rendering was time consuming, only two out of the five procedures were presented for comparison. These 3D video clips generated were the normal delivery and the ventouse delivery. The right format was chosen for web integration and the sequences created were rendered to allow for exporting. The inner processes of the editing practice are described below.

### 5.5.1 Editing the Procedural Footage

The next step in creating the procedural videos was to edit the footage previously captured. The footage was edited by using the video editing software Final Cut Pro. The footage was logged and transferred to Final Cut as digital file formats for editing access. The Final Cut's interface design allows non-computerised editing workflows, with four focal windows that function as methods of categorising, viewing and editing video media. It offers a browser which is a directory of media imported for editing. A view window, for viewing individual media files and preview edits.

The canvas window shows the edited material and processes conducted to the material in real time. The final window is the timeline, where media are collected into a sequence. The material is dragged onto the timeline and edited using toolbox components and an array of effects. The editing software essentially orders and edits the material together and composites the material into one video format file. In the case of the procedural footage, all videos captured were imported into the directory folder to be viewed in the browser window. These files were then filed to suit individual videos which were to be created. Five videos were created using the software matching the five clips of footage acquired from the procedures.

These five videos were normal delivery, ventouse delivery, C-section, placenta removal and examination. To properly craft the narrative the storyboards and time-codes were presented for each clip of footage that in turn was displayed for the individual videos. The audio was additionally added to the directories. For each video the audio tracks were positioned below the video tracks on the timeline, cut and positioned on the timeline to match to synchronise with the narrative.

Some audio narratives were important but had no video aid, so images were created through photo editing software (Photoshop) to visualise the audio references and progress the narrative. The visual imagery differed for each video.

For example, as the audio described a Mity Vac (type of ventouse vacuum cup), the image was set to appear on the audio cue. Other imagery aids included explaining the OA (occiput anterior) and OP (occiput posterior) labour patterns before the birthing process using comparative images of both positions, further explanation of proper delivery practice and spinal anaesthesia before a C-section. The only video devoid of additional audio and imagery support was the placenta examination which showed the practitioner explain the process from the footages audio. The audio directory held audio tracks for each procedure except the placenta examination.

This however was not a setback, as the footage audio had the vital information needed. Each video was structured to house the particular narratives for each process adhering to the storyboards and time-codes attributed to them. Any unnecessary audio dead air or needless lengthy visual moments were cut to create a more fluid runtime for each video. Once the videos were edited, rendered and in sequence each video was ready for output.

### 5.5.2 Editing the 3D Videos

Similar to the footage, the 3D videos were edited through the use of FCP, but unlike the previous procedural footage, the storyboards were substituted for the mapping of the captured footage. Each 3D video had to follow the same narrative timeline as the corresponding procedural video to mimic the events that occurred through each process. The editing process corresponded to the clips exported from Blender that mimic a few seconds of either event mirroring or idle animation. The inner processes of the editing practice for each 3D video are described below.

#### *5.5.2.1 Normal Delivery*

In the instance of the normal delivery 3D video, all the 3D clips rendered out from Blender were imported into the directory folder to be viewed in the browser window. These clips were then filed to match the labelled videos which were to be created. The clips imported involved an idle animation, active pushing, delivery of the fetal head, restitution, shoulder pin delivery animation and full delivery animation.

Along with the 3D clips the completed normal procedural video was also imported into the directory. Once imported into the corresponding directories the 3D animation clips were dragged into the timeline. One of many features of the FCP is its ability to display and host multiple video and audio tracks on the timeline.

Using this feature, the imported procedural video was dragged into the timeline video track above the 3D clip. The tracks in FCP work in layers, presenting highest picture or video track on the timeline to the front of the screen. So as it stood, the procedural video was overlaid on the 3D clip. The videos aspect ratios were distorted from each other and corrected to completing flush in the composite window.

This action completely obscured the 3D clip as the video preview was completely obscured. Both videos needed to accurately align the 3D clips to the events occurring in the procedural video. To tackle this, the transparency of the procedural video was altered to view the 3D clip more clearly. This was achieved through the use of the opacity effect in FCP granting varied degrees of transparency.

Once the 3D clip was visible, the rest of the 3D animation clips were added to the second video track on the timeline. The 3D clips that matched the events on the procedural video were placed in their corresponding timeline positions in accordance to the audio/video in the procedural video and the time-codes. The track was left with gaps creating blank space between actions on the timeline. To rectify this, the clips were cloned and repeated where actions formed a repetitive nature.

For example, in the first few seconds of the normal delivery procedural video where the active pushing had not commenced, the 3D clip of idle fetal animation was added and repeated to stretch the longevity of the event as the 3D clip was too short.

This process was repeated for various scenarios like active pushing and restitution before shoulder delivery. To create fluid animation, after using multiple cloned clips in succession, every second animation clip was reversed to repeat the changeable animated event and repeat. This was possible using a speed modification effect toggling the options of normal playback and reverse playback. Each sequence of 3D clips was selected and rendered for export once they were ordered and matched to the procedural video. The procedural video was then deleted from the timeline prevent it from appearing in the final 3D normal delivery export.

Once the normal delivery 3D video was edited, rendered and in sequence the video was ready for an output.

Figure 37: Normal delivery 3D animation still.

#### *5.5.2.2 Ventouse Delivery*

In the instance of the ventouse delivery 3D video, all the 3D clips rendered out from Blender were imported into the directory folder to be viewed in the browser window. These clips were then filed to match the labelled videos which were to be created. The 3D animation clips imported involved the ventouse introduction, the insertion of the vacuum cup, the placement on the fetal head and the gradual extraction of the fetal head. The normal delivery clips were then used as the finalising full delivery which included the idle animation, active pushing, and delivery of the fetal head, restitution, shoulder pin delivery animation and full delivery animation. Like the editing process involved in the 3D normal delivery, the procedural ventouse delivery video was imported and dragged onto the timeline above the ventouse 3D clips nested in the timeline. This procedural video was also translucent due to an opacity effect application. The positioning and ordering of each clip was also following by filling in the blank spaces with the cloning method. In terms of the ventouse interactions, some points in the 3D clips events the ventouse needed to ease into actions. This meant slowing down certain processes, like the insertion. To achieve this, the speed modifier was used once again to slow certain segments of each clip of vacuum cup interaction. Each sequence of 3D clips was selected and rendered for export after they were arranged and fitted to the procedural video.

Like the earlier 3D normal video process, the procedural video was deleted from the timeline to prevent it from showing up in the final export. Once the ventouse delivery 3D video was edited, rendered and in sequence the video was ready for output.

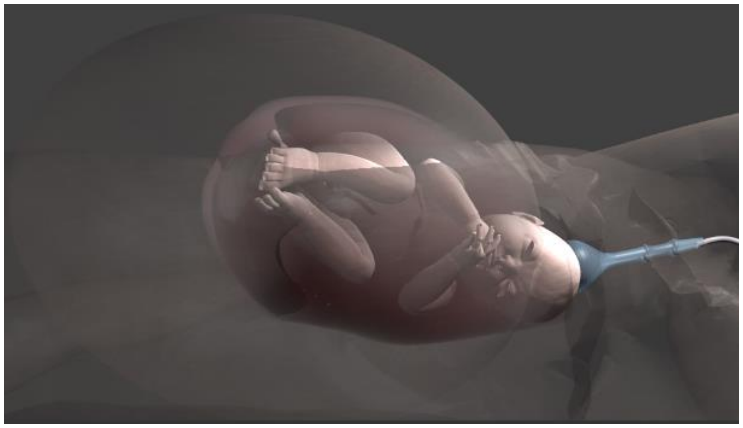


Figure 38: Ventouse delivery 3D animation still.

#### *5.5.2.3 Output*

After the clips of footage were captured, collected, edited, rendered and sequenced, the process of exporting for the web was the next port of call. The FCP (Final Cut pro) program offered an array of media formats ranging from Symbian phone video quality (3gpp) to HD (high definition) or Blu-ray. To find an applicable format for internet integration, the export configuration options needed to be inspected.

To export all of the timelines sequences, the master file had to be exported.

This avoided the separation of video clips within the sequence upon exporting the full video. The process of exporting the master file was applied to all of the procedural videos made. The video codecs offered by FCP limited the video files to compress to a H.264 .mov file for each video. The .mov file offers itself for web integration and is one of the formats accepted by the html5 video tag. Although used as a key video tag format, the .mp4 has more widespread support including adaptability to mobile devices (Zambelli, 2016). The files were considered for conversion prior to the configuration of the settings. From the settings of each video in the master file, there were tweaks to parameters to create ease of web integration. These parameters of these settings were: resolution, file size and frame rate.

The resolution was set to match those adapted for videos on YouTube of medium quality, so the resolution was set at 480p. This maintained that the file size would be significantly lower. The original file needed to be compressed to be easily viewed online, a large video file size causes slow buffering of the video. Once the video file size was smaller, still held a decent amount of quality for viewing and audio coherence while creating faster viewing speeds. The frame rate of the videos was kept to the film standard of 24 fps (frames per second).

After the full configuration, each video was exported to one directory and labelled as their corresponding procedure. As previously mentioned, the files were .mov and needed to change to .mp4 to have more support from multiple devices. Adobe media encoder was used to convert the files from .mov to .mp4, this process was conducted for each video within the procedure directory. Once all the procedural video files were converted into the right web integration format, the 3D videos were collected for data logging and editing and repeated the exporting and formatting process.

## 5.6 Online Video Application Development

After capturing and editing the procedural footage and 3D clips into formatted videos, the next step was to develop an online presence for the videos in the form of an interactive video player. This player was created using multiple API (application programming interfaces) and syntaxes to generate the interactive functionality.

All processes needed to create the full interactive online unit also needed to be mapped out to follow a consistent structure. The structure map involved the charting of each possible component and element within the player. The map helped visualise the way in which the player would function and how the navigation would work. The map consisted of the procedures created and how they would be displayed. The design of the player, its functionality and its integration into the web will be fully discussed below.

### 5.6.1 Interface Structure, Navigation and Design

Multiple impactful elements influenced the design, structure and navigation of the player. These elements were born from ease of accessibility, minimal time spent on medial tasks due to poor navigation, learner UI preference and the learning styles of the obstetric students.

The learning styles results as presented in Chapter 3, enabled the use of 3D, video and interactive content as it suited the learning styles of the majority of the students involved. The other aspects of physical interaction did not apply here and needed physical simulations to enable this interaction. The simulations and their integration into the wider resource will be discussed in the next chapter. In terms of the student UI preferences, from the results in the previous e-learning and learning styles chapter (Chapter 3), the students had a clear understanding on how the UI of the resource would appear and function.

The UI preferences results presented distinct design preferences issued by the students. The students wanted a resource with a light colour, minimalistic or simplified interface (not clustered) and the menu or any information to be presented from the top of the resource. The navigation was set focus on one page, to limit the amount of page hopping and poor navigational orientation. The idea was to create a minimised CMS (content management system) focusing on four elements visuals audio, text and interaction. The CMS compacted the necessary design, navigation and functionality of the resource. To visually aid the construction of the site and player's aesthetic, a guideline and blueprint was drawn out. This blueprint incorporated all the elements gathered from the students and the general UI construction foundations (mobile adaptability and ease of coding integration).

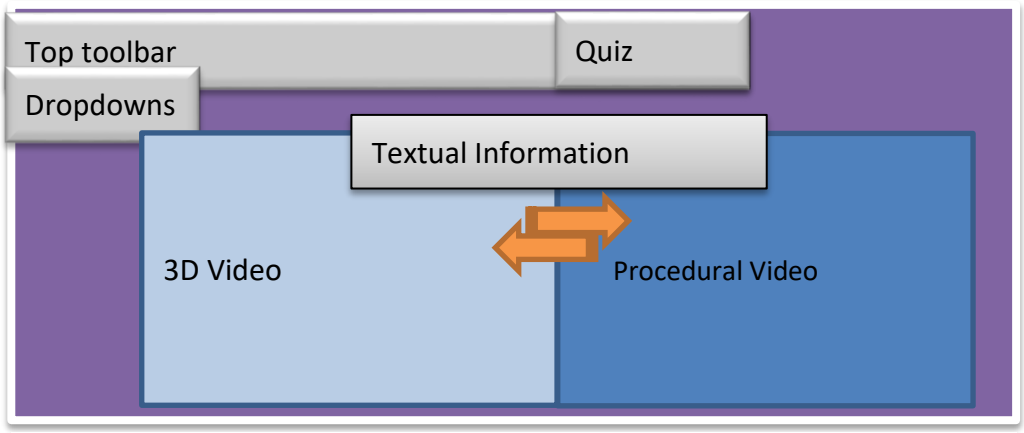



Figure 39: Video resource design blueprint.

From the basic blueprint, the students were presented with a minimalistic layout with the key navigational components, functions and the video aspects were the central focal point. The design created a more focused look at the key components needed in the full functionality of the resource for the students.

From a learning styles standpoint, the resource design integrated the key visual/verbal components needed in creating an auditory and visual experience with textual information. To fashion the most effective interactive video player for the obstetric students, key design and development components needed to be integrated. These components and aspects included the UI preferences, the video and 3D content, the textual information, and assessment, all through an easy to use system. After mapping out the design concepts, the functionality needed to be discussed.

The functionality involved having both the 3D and procedural video content work together and play out a narrative cohesively. In order to achieve this cohesive narrative, the videos needed to play linearly and connect through timeline markers.

The process of this connectivity was drawn in the blueprints for later deliberation in the development of the whole resource. The top bar provided the choice of selecting the type of procedural video and presenting the corresponding video components. The top bar navigation also provided students with the guided option of navigating video key points or cues. For example, there was an option for viewing the crowning within the normal delivery option. Dropdowns were added to the blueprint design of the potential video resource to compartmentalise the various points of interest in each section of a procedure. In terms of assessment, the idea of the quiz was added as a self-motivated testing option for the students involved in the resource.

This quiz option was reflected upon and questions were generated from different points of information in each videos narrative. The textual information acted as a reflective information bar labelling each stage of labour adhering to key points in the timeline. The resource needed to adhere to the student's preferences and have a fluid navigational and educational method of presentation. The main focus points of functionality were tested and deliberated on in the creation of the interface and the subsequent programming of the functionality. Before using and upon finishing their introduction into the video content, assessment and auditory examples, the student would be introduced to a pre-test and Likert scale satisfaction test. These tests were designed to be placed as fluidly as the rest of the resource. The usage and results of these tests will be further discussed in the usability section.

### 5.6.2 Generating the Resource Design

The online video application was created on the basis of the student input and the blueprint design created in light of the inputted measures. In order to create the separate areas of design and functionality, the individual steps of resource conception needed to be created and structured in a linear path. These steps included fashioning the design from the blueprints, providing the functionality to individual resource components, producing the pre-test and post-test online questions through external web analytical software and creating the assessment quiz aspect. The majority of the components created, were manipulated through the use of html5 in conjunction with css3 and javascript. Some other aspects of data retrieval was conducted using external surveys, usability software and websites.

To begin, the design was mimicked from the blueprint design created from the preferences and other student inputted factors.

Three initial files were created in one directory, a html file, JS (javascript) and a CSS (cascading style sheet) file. These files were separated into two individual folders labelled JS and CSS except for the html file which was stored in the main root directory. Each file was labelled with their signature function, the html file was labelled index.html, the JS file was labelled script.js and the CSS file was labelled style. To recreate the design, three different CSS styles were used to achieve it. Two styles were imported into the html file from the CSS directory and additional style code was added into the html file itself. The two imported CSS files were both CSS plugins focusing on icon design (info, help, home etc icons) and the other CSS file focused on suitable menu formations for UIs. The CSS code immersed within the rest of the data within the html file focused on the functionality alongside the javascript file.

Between these CSS files the orientation, colour scheme, position, margins and font were all attributed to individual components. This was achieved using tags alerting the syntax of placeholders like divs or classes. Each panel or layout within the design had its own div which is a block-level element (taking over space of its parent element) acting as a container for each component. Divs separated aspects like the top toolbar, videos (3D and procedural) and information or info bar. This separation helped create separate styles for each component or element. The background colour of the resource was changed in the CSS code too, changing it to the light purple design sought in the blueprints. Other panels or containers followed suit embracing the colours attributed to them in the blueprint design. The html file was intermitted woven into the production of the styles as the top toolbar menu was created to visualise the CSS's progress. The menu was created in html using a UI panel design to create a linear pattern of all the options to pick from the toolbar.

At this stage the text or strings needed to be added to each panel indicating what the panel was and the potential functionality it had. Once each component was positioned and given the right style attribute, the content and functionality needed to be added to the online resource.

### 5.6.3 Incorporating the video components and structuring the content

The content integrated into the resource was already exported into compatible online mp4 formats. The next step was to build around this content and produce an interactive narrative.

The videos were all integrated into the html file by using the video tag offered by html5. This tag granted the resource access to view and play the videos within the tag. The video container div had already been created in anticipation for the video content. Within this video container the videos were displayed and shown to have inherited attributes from the video tag. These attributes included a play/pause button, volume, an interactive timeline and a full screen option. These attributes were granted to every video holding the tag. As it stood, the video container displayed all procedural and 3D videos at the same time. The strategy proposed to integrate the videos intended to only display videos once the corresponding the toolbar menu item (e.g. normal delivery or ventouse delivery) was selected. The intention was to have the video categorised and capable of presenting the narrative on the command of the user (the students participating). To achieve this, javascript and html code was incorporated to mask the appearance of the video through click event intervals.

This was a first attempt at assimilating functionality within the resource. Creating this functionality involved giving each video a unique identifier (ID) in html, the identifier was then called in through javascript. The script declared each video by using each videos unique ID creating variables that could be used throughout the coding process. Each video was given easily retainable variables to make the coding practice easier. The variables given to the videos incremented from the variable “V1” onwards in light of their succession within the menu.

To mask the video the script needed to identify each variables style and prompt whether or not the video would be visible or hidden. To test the accuracy of the code, the resource was tested intermittently. The variables and subsequent actions of the variables were all presented in a function called an onload function. This function enabled the actions of any baby object within the function to initialise. The onload function was attributed to the browser window and initialised all actions within the function on entering the webpage. A test was conducted to view the competency of the visibility code used, the hidden attribute was applied to all video variables.

When the script was initialised, the web page containing the online resource presented the created style and the toolbar menu. The videos were missing from the browser window indicating the success of the employed coding example which had functions to hide the videos not necessary when initialising the page. As the resource was an online application, the page needed videos to open initially, as it was a form of landing page for the students.

As the normal delivery was the first procedure labelled on the menu, the styles for the variables attributed to the 3D normal delivery video and the procedural normal delivery video were set to be visible. When viewing both videos the ideal of user interaction was considered when viewing the videos simultaneously. As it stood, when the students desired to view the narrative through both 3D and footage representation to show some form of video synchronisation they needed to attempt playing both videos at the same time. This action was not acceptable and served as more of an inconvenience to those participating. The action needed to be rectified through integration of a video synchronisation function to fully enable the interactive educational storytelling aspect of the video player. Making the video sync function involved mapping one videos timeline to another. The chosen video to map to in terms of the normal delivery was the 3D video. This meant granting all timeline controls to the 3D video over the procedural video, which involved removing the "controls" attribute from the normal delivery procedural video.

The removal of the controls also prevented the access to the procedural videos controls by the user which prevented the potential disruption of the video syncing process. To achieve the next step in video syncing an event listener needed to be added to the script identifying the videos that warranted the syncing functionality.

The event listener method attaches an event handler (processes actions like a key press or mouse click) to the web document. In this case the event listener processed whether or not the 3D video was playing, paused, seeking or seeked (timeline inputs). The significance of acquiring these processing inputs presented the exact times at which the video would conduct the processes. The event listener then identified the procedural video and applied the play and pause controls to the video under the action of the 3D video. This enabled the videos to play and pause at the same time. For the seeking and seeked a different action was conducted.

Using the property currentTime, the timeline markers were accessed and applied to the procedural video under the seeking and seeking event listener methods of the 3D video. On inspection of the resource after running the script, the videos matched and presented in sync throughout the videos narrative. The videos originally, from the editing stages, were developed to match each other in narrative and in video timeline length. This created a more consistent fluid narrative flow. The videos at this point were in sync and presented no other integrated interactive aspect. This is where the integration of the procedural process dropdown list was introduced.

Before integrating the dropdown list, key aspects of the videos narrative needed to be logged and time-coded. The logs and time-codes from previous video interactions were not considered as they were relevant only to the 3D and procedural videos before the editing process. The new time-codes and labels only needed to log five key methods or actions present in the videos. The five key actions logged from the normal delivery videos were active pushing, crowning, delivery of the baby's head, restitution, and delivery of the shoulders/full delivery. These actions all had specific starting points in the videos which were logged. These timeline markers were very important in the next step of video player interactivity.

The next interactive control granted the user to select an action during the delivery process from the dropdown list and the video player timeline pointer moves to the timeline marker of that particular event. Initially the labels were added to the dropdown list in forms of separate divs representing each action with a corresponding time-code awaiting functionality. In the script a switch case statement was created to perform different actions based on different conditions triggered the potential interactive of the actions presented.

A function named "PlayFromVideomarker" was created to house the switch case statement. Before the switch case statement the 3D video needed to be declared once again and given the name video-player within the PlayFromVideomarker function. Each case within the switch case statement was given a unique identifier incrementing for the label vm (video marker, vm1++). Within each case was the property currentTime was introduced once again, in this case instead of directly matching the time of one video to the other, the time was adjusted separately outside of the video tag to match a determined time marked time-code. The currentTime property accepted the individual time markers in seconds, so each video had to be marked ranging in three digit numbers registering without the use of a colon usually associated with brackets of time. For example the active pushing action within the videos was set to start at 0h.0m.12s amounting to 12 for the currentTime property in the vm4 case, whereas the shoulder and full delivery action within the video was set to start at 0h.4m.15s amounting to 255 for the currentTime property in the vm5 case. An onClick function was attributed to each action label in each div linked to the action within the dropdown list of the menu.

The five cases were already created to correspond to the five actions that would theoretically affect the timeline of the videos.

The onClick function much like the onload function where it performs an action once initialised but unlike the onload function it listened for a mouse click on the selected div to perform the action. Alongside the corresponding function within each label of the dropdown list appeared the name of each case. These case names appeared in brackets within the onClick function PlayFromVideomarker within the divs of the actions in the 3D video and procedural video sync.

When running the resource after the recent interactive player updates, the action selection from the dropdown list was checked. The selection process worked, playing from the point in the timeline where a certain action is perform on the selection of that particular action labelled in the menu. Additionally, as the procedural video was synced and linked through an event using currentTime, the procedural video responded to the change in timeline on each selection too.

After developing the video player around the synchronisation of the two videos (3D and procedural) and adjusting the menu to their timeline markers, the other videos needed to be introduced. The method of introduction of these videos involved the creation of multiple click functions within the script. These click functions actions involved the hiding, showing, playing and pausing of the particular videos.

Each click function was linked to a certain div relating to a particular video. On selection of a particular video link, the click function would hide the unconnected videos and pause their playback. The connected videos were then revealed and controls were enabled. The only other 3D representative procedure other than the normal delivery was the ventouse delivery. This procedure needed to have the same guided functionality as the normal delivery. As the ventouse videos needed to re-enact the synchronous functionality of the normal delivery setup, the same function needed to be applied to the ventouse video setup. To achieve this, an “if” statement was introduced into the onload function which dealt with the aspect of div selection. The “if” statement suggested the arguments of whether a certain div was selected and which action needed to be performed once the div was selected.

Two variables were created called 3DVid and proVid, these variables were declared initially as the normal deliveries 3D video and procedural video components. The declaration of the two variables were self-contained within separate parts of the if statement. To realise the new functionality, the if statement declared the 3DVid and proVid as the ventouse setup videos on the result of selection of the ventouse div.

This process enabled the videos synchronised function to swap video setups on selection of a different procedure. The normal and ventouse delivery setups were the only two video setups affected by the integration of this functionality. As an example of the potential the full online video resource had to offer, the minimum of three procedural videos were shown, two of which had synchronised video playbacks.

The other video introduced in the menu was the c-section. This videos style was kept hidden for the landing page just like the ventouse video setup.

An individual onClick function was added to the resource to support the functionality of the c-section video. This functions action paused both video setups for the normal and ventouse delivery, while simultaneously hiding the container divs for each video setup, presenting only the c-section video. This function was initialised by the selection of the c-section menu item in the toolbar within the procedural dropdown list. Additionally, another function was generated alongside corresponding div menu inputs. This function was instigated by three created key menu selections within a dropdown list called view. The view list had three options 3D, Video and Both. The three options gave the students the opportunity to hide components in when video the video setup. For example, if a student wanted to view the 3D allow with the corresponding audio narrative playing, the student would pick the 3D option and the procedural video would be hidden. To attain this, the div was given an on click function much like the previous examples, this function helped toggle between the visibility of each aspect of the normal delivery video setup.

From this point the main video examples were present and provided key functionality when interacting with the menu toolbar. The syncing videos provided the fluid educational narrative needed to explain each procedure.

The video player resource was still lacking some minor aspects that would push the interaction of the resource to a higher quality level. These aspects included the integration of textual information and the introduction of some form of student self-assessment or review after cycling through the video material presented to the students. The first aspect was the textual information integration, this meant having a panel that fed textual information to the student through resource inputs and navigational prompts. From the blueprint design created originally for the resource, the textual information was to be placed above the video horizontally providing some minor information on a selected topic.

To create the orientation and style associated with the textual information appearing as it did in the design blueprint, a style aspect was created within the CSS script of the html file presenting the necessary margins and positions necessary for proper resource placement and linearity. In the script, the textual information was given a div container and a unique identifier called infobar. This infobar was given a placeholder text and an information icon to fill the div with initial information.

The information icon was generated using the inbuilt web application icon database. The database housed a number a key online symbols, three of which were based on the information symbol, one of the information symbols was chosen for the infobar integration. The reason for choosing this form of icon integration instead of creating an original icon from scratch or jpg image, was that the icons provided in this icon database were all vector based images. The fact that the images were vector based meant that the icon would not deteriorate in quality when scaled up or down.

When infobar was visually integrated the functionality of the bar needed to be established. The infobar needed to generate text for every procedure or action selected by the user. As the bar already had a textual placeholder, the text would not have to change unless the user inputted a selection of a procedure or action within a procedure. To generate this textual appearance, the infobar needed to have some functionality within the script. Divs were created for each action and procedure providing the string of texts for each of them. The divs were given unique identifiers to separate the actions and procedures on selection.

The unique identifiers were labelled apDialog (representing the applications dialog or textual input) and the subsequent divs were labelled in with the same ID but shown with numbered ends incrementally presented e.g. apDialog1++. In order to have the text present on the selection of the individual actions, the apDialog divs needed to be linked to the timeline functions attributed to each action or procedure. For the individual actions the divs were assimilated into the PlayFromVideomaker function. This function, as previously mentioned, provided a switch case statement which pin pointed a marked time in the timeline once a case was initialised by a div selection. In order to introduce the infobar into the function, each case was analysed to establish which case corresponded to which action. Once the actions within the cases were established, the apDialog divs were references within events to show and hide the divs. These events used the fade in and fade out methods to gradually have the text appear once the div was selected.

The apDialog div references were also used in the onClick functions generated by the procedure divs. These apDialog references were introduced here to present the textual information about the procedure once selected. The infobar was completed once the all divs and corresponding functions were established.

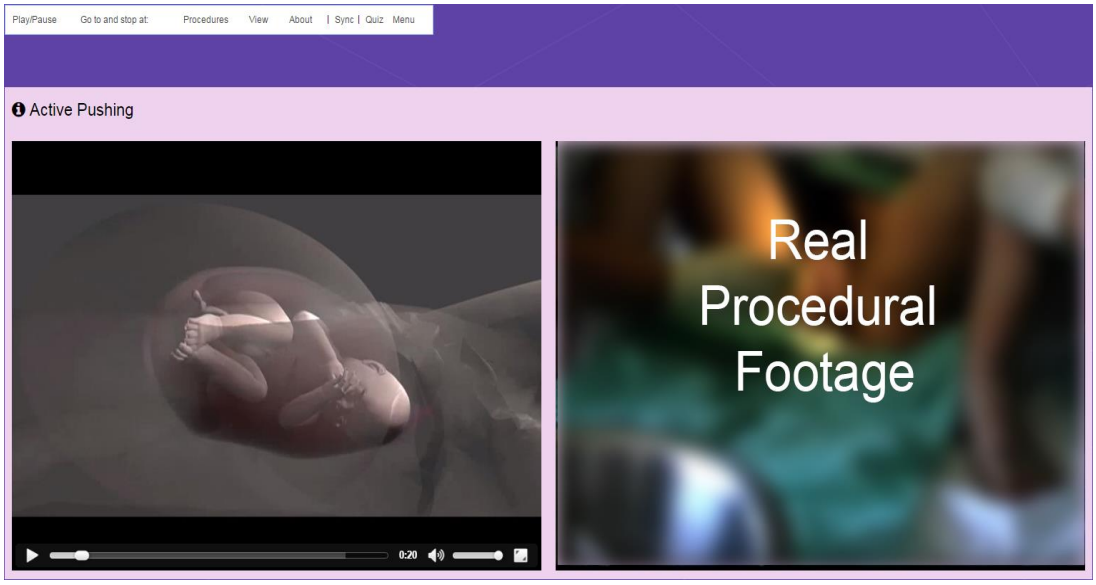



Figure 40: Video resource example with syncing 3D and procedural videos.

On running the resource after the last function was created, the window of the browser was minimised and some of the video content was not seen. To tackle this, a scalable attribute was added to the style of both the videos and the containers in the resource. This created a more adaptable interface and a more mobile friendly navigation. After establishing most of the prototype functionality of the resource the next step was to integrate an assessment mechanism within the resource.

To achieve this, the questions formulated in the design from was taught in the videos needed to be integrated into script, be accessible online, provide a straight forward questioning system and let the students review the questions on completion. All of this functionality needed to be generated for html5 to be accepted into the html5 compliant video resource already created. To attain the possible goal of introducing an assessment mechanism like a quiz into the created resource, a software known as adobe Captivate was used to develop the questions, style, and output needed to plausibly fuse this quiz with the video resource. The Captivate program offered object orientated programming, granting drag and drop capabilities for certain actions needed to convey on a site. In the Captivate program the tools available were centred on user interactions and feedback.

The program enabled the use of multiple media formats and creative inputs. The only process or use in using the Captivate program for the video resource was to create a quiz or assessment, so the media or other interactive tools were not taken into account. When creating the quiz on Captivate, the thesis within the program needed to have a starting point. The program displayed its content like a Microsoft PowerPoint presentation, creating pages in a linear fashion using slides and slide orientated user navigation (forward, back, play and pause). The unique difference between Captivate on the PowerPoint presentation was the different types of slides presented within the program. Captivate boasted seven individual slide types, these types were: content slide, question slide, video demo slide, presentation slide, software simulation slide, knowledge check slide and the default blank slide.

For the video resources quiz, the focus was on implementing questions relating to the videos content and presented material, so the question slide was chosen to be the master slide of the thesis. This meant that any slides generated after the initial slide who inherit the question slide style. The colour scheme and fonts were carefully chosen to match the tone created for the video resources design.

The colour purple was darkened for the background of the slide and a normal light tone (that matched the colour scheme of the video resource) was presented for the background of each question and its input components like radio buttons, text fields and other textual information. Once a question slide was created in Captivate there were an array of options for slide types. These options included methods of question presentation including, short answers, true or false, multiple choice and fill in the blanks. In creating the questions within each slide, the different methods of question presentation were considered and randomly attached to the question slides.

The questions were structured and generated during the design of the resource, this was achieved through viewing the individual videos and acquiring points of information to use. The question slides grew to eleven in their totality without yet having an introduction or results slide added. These slides were sectioned into three parts associating with the different procedural videos normal delivery, ventouse delivery and caesarean section. The normal delivery section had four questions slides, the ventouse delivery section had five slides and the caesarean section had two question slides. The number of slides attributed to each section depended on the length of the videos and the amount of information presented by the narrative of these videos.

The answers to each question were highlighted within their corresponding slides for later deliberation in the results slide. Once the questions were labelled and presented linearly in the slide formation the extra slides were added. These slides included the introduction slide and the results slide.

A content slide was generated for the introduction slide to enable the incorporation of text content in the slide. As this slide acted as a splash page (the page a user sees first before being given the option to continue to the main content) for the quiz, informative material was presented to update the students of what was being presented in the quiz. This entailed presenting what types of information were being questioned, where to source the information and the number of questions that would be present in the quiz. The students were also informed about the reviewing process built into the quiz that enabled the act of self-evaluation. The results slide was generated by selecting all the questions listed in the thesis structure and selecting output. The answers that were highlight were generated alongside these questions. The slide was filled with statements awaiting user response on completion of a quiz. The labels shown within this slide informed the students of their final score, their correct answers, possible max score, accuracy and the number of attempts the students had on the quiz. Once the content was created within the Captivate program the full quiz was ready to be exported as a html5 directory.

Once exported the quiz html5 directory and its files were inspected. The html index file on inspection was drawing the questions and answers from an external text files working on metadata. To integrate these files and the quiz into the resource the directory was placed into the video resources directory. From there, the video resources html file was accessed once again and the quizzes html index file was displayed above the video container using the iframe tag. The iframe tag helps embed another html document within the current html document. When using the iframe tag the external quiz index file was visible within a small frame. The iframe style was subsequently changed to accommodate the proportions of the video player. Another obstacle that arose when using the iframe was its appearance in the resource while the videos were visible.

To rectify this, a separate div and unique identifier was created for the iframe component. The quiz menu tab on the top toolbar was additionally given an onClick function. This function like the functions already established by the videos process the ability to hide all content in the resource except for the quiz and the toolbar.

On running the resource as a whole the quiz was presented as the selection of the quiz tab was made. This signified the resources readiness for usability testing.

## 5.7 Usability Testing

A usability test was conducted using a usability testing structure. This structure involved a heuristic evaluation, meaning the usability testing process involved a pre-test questions, usability testing and post-test questions. The heuristic emphasis meant that there needed to be a moderator present to log the interactions as they played out. The structure began with a declaration to the participating students indicating what the testing was for, how it benefits them and that the students were going to appear anonymous. The pre-test questions to the students involved acquiring the student's expectations of the resource and other notable prerequisite queries before testing the video resource. The test itself gave students tasks ranging in difficulty, their progress was marked on how long it took for a student to complete each task and whether or not the students needed assistance on a particular question etc.

The post-test questions used Likert scale questions based on satisfaction, with accepted comments from students. The results were analysed to show the performance levels in contrast with the levels of task difficulty. Each process was documented using three documents covering the main aspects of the user experience (UX) and formalities for later discussion. The three documents were the UX study overview, the consent form, and the report of the usability test.

The UX study overview provided a background to the video resource and its connection to a wider resource, the acquisition of user input from the students was also mentioned with the emphasis on interactive educational instrument betterment. The consent form also provided a little information on the background of the full study and requested the student's participation on the video resource. The last document used was the usability test report. This report established many different aspects of the test including describing the summary of the goals or rationale, number of participating students, methodology, pre-test questions and responses, the tasks and the student performances and the post-test.

### 5.7.1 Conducting the Usability Test

As the video resource needed to be usability tested, students needed to access to take part in the study.

The students were advised that their names and identification were anonymous, so there were no detailed personal student attachments to the documentation of the resource. As the process of screening the resource and including pre and post-tests used up a lot of time, there needed to be a small number of participants to finish the usability testing within a short space of time. Forty- five students took part in the usability testing, three of which were obstetric students (the others being fourth year medical students). Students were assessed separately to avoid inaccurate results due to other student influence. Each process or test within the whole usability testing process involved separate sources of implementation.

Both the pre-test and the post-test questions were crafted in the site surveymonkey which provided a visual look at commented input of each student who participated. The questions asked for each test only amounted to between four and six and were weighted on textfield input from the students. In the case of the post-test, the textfield was substituted for radio buttons in a likert scale. Instead of having the students leave the resource page initially to fill out a pre-test form, the form was generated to load when the window opened and appear within a popup. This enabled the students to view both the resource and the popup pre-test at the same time. The questions within the popup referred to the resource which helped the students in answering the questions when the resource appeared in the background. The popup had the ability to be closed at any point not to shy users away from the resource, although the title of the pop pre-test asks students to participate. The pre-test questions included questions like:

- What are your expectations of the resource from the description?
- What do you think the resource is trying to achieve?
- What kind of information do you think will be presented in this resource?
- What kind of media do you think the resource will present?

The usability test itself was monitored in a setting which involved each student carrying out tasks on the resource while a moderator tracked the necessary details including time taken on tasks, interest in aspects and satisfaction while navigating the resource. The moderator also provided guidance if the student needed help. The students expressed what they liked and disliked while progressing through the test. Three scenarios or tasks were performed by the individual students.

These three tasks performed by the students involved interaction with the resource and student commentary. The tasks performed were as follows:

- Navigate through each stage of the normal delivery videos, find and stop at the restitution stage.
- Toggle between the displays and procedures, view just the 3D video of a ventouse procedure.
- Participate in the quiz and review your answers.

The post-test was based on a likert scale and also conducted through surveymonkey. This time the embedded survey drew scores of satisfaction from the students. The post-test was accessed once the student pressed the exit button on the toolbar. The questions asked were based on a scale of satisfaction plus a few questions which were text input specific. These questions were:

- What is your overall impression of the video resource? (none – high)
- The video and 3D aspects helped in the learning process (strongly disagree – strongly agree)
- The video and 3D aspects should be introduced for more medical examples (strongly disagree – strongly agree)
- The assessment section (quiz) provided a helpful way to assess knowledge learned through watching the videos (strongly disagree – strongly agree)
- The resource components work well together to create a cohesive learning platform (strongly disagree – strongly agree)
- What did you like best about the resource? (Student comment feedback – text input)
- What did you like least about the resource? (Student comment feedback – text input)

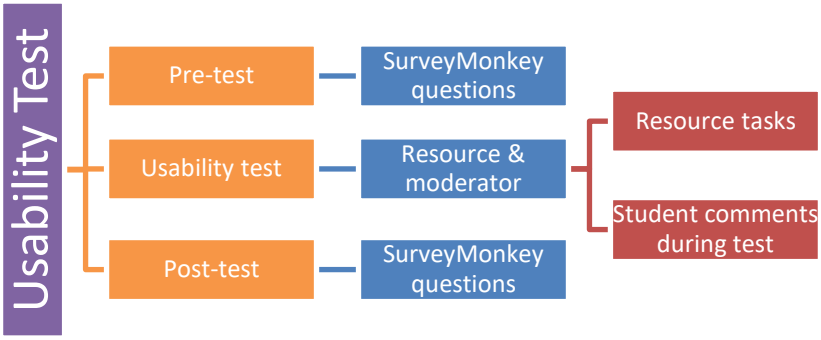



Figure 41: Video resource usability test structure.

To process this test on surveymonkey a matrix rating scale was added for each question to create a likert scale like test. Each question had its own list of possible answers of satisfaction and agreeance with the topic suggested. Each question also had a weighted points system, meaning on selection of an option a point was added to an end result. The more positive options like “High” or “Strongly agree” were given higher weighted points than those on the negative scale. These points were added up for each student and compared to the highest acquired points. This would ultimately present a student’s positive or negative reaction to the resource.

Once the post-test was completed, the students were thanked for their participation. The results from all the aspects of the usability test were then analysed.

### 5.7.2 Results of the usability test

Upon retrieving the data through survey inputs and student user comments, the usability test was reviewed collecting each students experience and melding the responses together to create a general consensus over particular questions raised in each section of the usability test. In the pre-test the students were asked about their expectations of the resource, what the resources purpose was, the information presented in the resource and what kind of media the resource would present. All the students who participated surmised that videos had a vital role in the functionality of the resource. The students also deduced that the resource was an educational tool, it was also clear to all the students that the videos presented were of obstetric procedures (having one student refer to the information as childbirth related). When asked to comment about the media presented every student wrote, either variances of text, video, and imagery. Forty of the forty five students also wrote 3D, as the 3D video was seen to the side of the popup screen.

These results were positive as students could identify what the resource was and what its intensions were from the first look at the aesthetic. Having five students overlook the 3D option might have been due to these students accepting the 3D video as just a video component. During the main usability test the students adhered to three main tasks: navigate through each stage of the normal delivery videos, find and stop at the restitution stage; toggle between the displays and procedures, view just the 3D video of a ventouse procedure and participate in the quiz/ review your answers. Initially all the students breezed through the toolbar options, one student deviated from the first part of the first step and tried to find the restitution action within the video quickly realising the two videos were in sync.

This student asked for instruction and the student was instructed to the "go to and stop at" tab. The other students after first inspecting the toolbar had found the restitution action within the "go to and stop at" tab, playing the restitution action on both videos showing the students the videos syncing. The next task confused two of the students initially; this task involved showing just the 3D video of the ventouse procedure. All of the students found the ventouse procedure (as the toolbar had labelled a tab "procedures") but the two students who found themselves delayed in the task took some time deliberating over the videos displays (checking the videos themselves for a close option). The comments from the students after completing the task suggested changing the label of the "view" tab holding the video view options to a clearer label like "video display options" or "video display".

The last task was straight forward for each student as the quiz button was on the toolbar and the slide based quiz lent itself for intuitive user responses. The students commented that the quizzes review option was a great form of learning from mistakes.

The next results to analyse were the results taken from the post-test. These results, as previously stated in the previous section were collected and weighted by a points system. The maximum amount of points attributed to each student was twenty with a maximum of eighty for the whole group. The higher the points the more positively favoured the resource was.

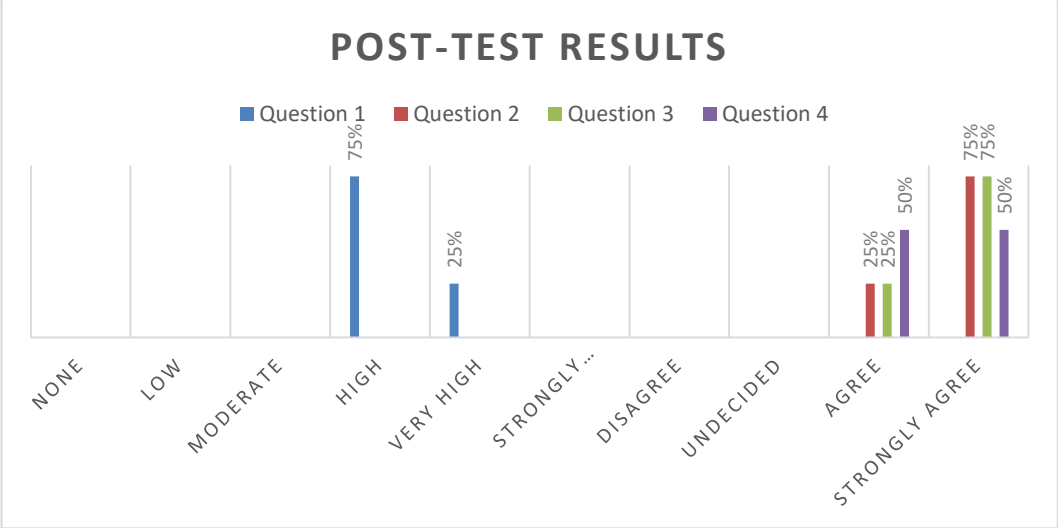



Figure 42: Post-test results separated by likert scale numbered questions.

From the results of the first question which asked the students about their overall impression of the resource, the response was positive having 75% rating the resource at a high level and 25% of the students rating the resource at a very high level.

The second questions response was similarly positive. This question garnered a statement which students would either agree or disagree with, the statement referred the video and 3D aspects helping the learning process. 75% of the students strongly agreed with the statement, while the 25% agreed that these video and 3D aspect were beneficial learning instruments. The next question was another statement built on student acceptance of the statement. The statement referred to the helpfulness of the quiz to assess the topics discussed in the procedural/3D videos. The students agreed once more with the statement having 75% percent strongly agree and 25% agree. The last question was another statement in which the students had to either agree or disagree on. The statement referred to the how all the component used worked well together to create a cohesive learning platform. The results showed a 50/50 percentage score between both strongly agreeing and agreeing, which still was a very positive reaction from the students. The next two questions were student feedback questions warranting likes and dislikes of the resources. In terms of the likes omitted by the student's feedback, three key features were praised.

These three features were the 3D and video syncing narrative and general 3D integration, the minimalistic design that focused on the main components of interest and the quiz which the students enjoyed due to its capability of providing a self-directed review.

The dislikes for the resource were all very similar, one student input referred to some of the labels in the menu as being misleading, other students preferred to have icons as it would provide more space and their function would become more recognised after more use. One comment stated the lack of procedures, the lack of procedures was ultimately due to the time constraints and the resource would hopefully incorporate more procedures once fully integrated into a wider resource in the future. The general comments from the students were also positive stating how the 3D brings a more interesting visual aid to the educational video and audio supplied in the resource. The students also went on to suggest the full virtual integration. The students were also interested upon hearing about the contents of the video resources integration into a wider resource containing fully immersive interactive simulation.

**Summary**

The video medium is a helpful learning tool that has been applied in medicine with much success. As stated in this chapter the video medium is very important in education today especially in medical education. Most procedural techniques need to be taught using visual representation, this would be through real-life practice. Alternatively video offers the visual aid needed to those who need to practice these techniques that do not have round the clock access to the procedures. The video resource created and discussed in this chapter sought to show that video could be manipulated into a learning resource that could teach obstetric procedural techniques, provide self-assessment, integrate multiple learning media and have ease of mobile access to students. From the usability testing of the resource, the results were favourable with a few minor dislikes of the user interface in some aspects to be taken into account in the creation of the wider simulation learning resource.

# Chapter 6. Simulation Development and Utilisation

In this chapter simulation, its development and utilisation, its impact on medical education and the obstetric field will be discussed. Within the chapter, the formation of a fully interactive simulation resource will be described and after utilising resource its effect on obstetric students will be examined. This chapter is significant as it amalgamates and utilises the knowledge and data derived from previous chapters to generate a useable resource with interactive information. The multitude of sources that helped to create the final resource have individual beneficial properties that assist both obstetric students and lecturers to further their knowledge and understanding of procedures and also their competency (Coffey *et al.,* 2016). The resource and findings in this chapter led to an answer to the original research question posed by this thesis, within the conclusion chapter. The structure of this chapter is presented with a greater length and additional research/examples than previous chapters, as it holds the weight of the previous chapter's subject matter and amalgamation of all their resolutions. This chapter outlines the progression of the resource and its adoption of the many aspects created in the previous chapters and following the student preferences

## 6.1 Simulation

Simulations are a form of mimicked reality. This imitated or mirrored reality can be in the form of a system or environment that contains instructional elements that help a learner discover, navigate or attain information about that environment which would not normally be learnt from simple testing. Instructional simulations which are the basis of the final product, are characteristically goal oriented, to motivate learners on particular details, models, or purposes of the system or environment. Some simulations provide endless possibilities for unseen aspects presentations and remote learning tools. Virtual learning environments (VLE's) allow users to access learning at their own pace and time without physically moving to a learning facility or networking face to face with an instructor in real time. Such VLEs vary widely in interactivity and scope (Pattanasith *et al.,* 2015). Simulation is the action of emulating the performance of a physical or abstract structure, like an outcome, condition or procedure that can or might occur. Simulation is not a new style of learning or practice training.

Cadavers continue to be used in anatomy training or in surgical skills labs, while actor patients have been and are still used in OSCEs (Objective Structured Clinical Exams) (Issenberg *et al.,* 2001).

Outside of medicine and anatomy other types of simulation have used VREs (virtual reality environments), for example, in flight and driving simulation. Low-cost, service grounded gadgets such as computers, sensors, haptic devices, immersive virtual reality displays together with rising web availability are helping to refine simulation technologies into inexpensive and additionally reachable outlets of accessible learning (Ott, 2013). The growing focus on educational outcomes and the push to have students pass courses assessing broader competencies more rigorously has led to an increase in the interest in simulation. Simulation technologies demonstrate significant tools for effective proficiency grounded education and aptitude. Aptitude is characteristically outlined as the information, qualities, abilities, manners, and approaches that allow users to achieve a detailed series of objectives to a specified criterion.

The practice of simulation for effectively enhancing the aptitudes of users has been conventionally utilised in circumstances where considerable risk may be related to the abilities or actions performed. The emphasis on progression and evaluation of aptitudes is evolving into every feature of education. Therefore, the application of simulation technologies in education and assessment has also grown in tandem.

As discussed in the previous chapters, the learning style of a student can affect their approaches to learning and hence the outcomes of an application. As the learning styles have been acquired from the potential Obstetric student users in this thesis, this potentially creates a prosperous SLE (Simulated Learning Environment) framework.

### 6.1.1 Educational Simulation

Educators usually expect the information, actions, and skills learned in the lecture theatre or lab to be successfully mirrored in applicable everyday situations. Not every situation is equal, but it is frequently acknowledged that repeatedly performing skills with supervision and in a simulated environment encourages a successful transferral of skills to environments in the real world. Skilled expertise in any field of study characteristically necessitates careful and dedicated practice.

Deliberate practice is used as a form of skill performance monitoring by supervision, which is highly used in simulated education (McGaghie *et al.*, 2010).

The process also involves evaluating a student's results and relaying advice on student betterment. In most fields of study (obstetrics included), access to this degree of practical experience is often not useful or suitable, which leads to the growing use of simulation technologies as significant resources for both practitioners and students. Developments in computation, imagining and sensor mechanisms are nurturing a speedy evolution in computer centred simulation for training and education. This hastened evolution is motivated by necessities of safety in a many disciplines including health care. These necessities derive from concerns about patient safety and risk while fostering a dependable learning environment. Consequently, computer centred simulators are currently integrated into the curricula of medical, nursing, dental, and other health professional education at a small capacity but seeing steady advances (Knowles *et al.,* 2005). In the early stages display orientated situation simulations were adopted, granting users with an accessible form of computer simulation technology.

These display or screen based commodities brought mobile education and assessment to classrooms and became an integral part of remote student learning. The simulations that are of interest to this study and pivotal elements to the end resource are, VR (virtual reality) simulators and computer-enhanced mannequins. The VR simulators are predominantly used as procedural simulators, using instruments such as laparoscopes and endoscopes to grant accurate interactions with virtual reality environments to return favourable training environments and experiences (Semeraro *et al.,* 2008).

The VR simulators are proficient in simulating anatomical distinctions in addition to numerous situational obstacles. The majority of these VR technologies rely heavily on the use of 3D video, high resolution video demonstrations and engaging VR technologies (Giannopoulos *et al.,* 2014). Internet centred VR technologies have made significant advances into expanding the potential for the use of simulation in healthcare and higher education. Health and Medical Games offer educational VR for students and there are a number of these formats online for students and interested parties. One example "Fatworld" provides online simulations dedicated to teaching users how nutrition, socioeconomics, and culture are connected.

Health conditions, predispositions, diet, exercise, and more, can be selected to discover results on the user's whole health outlook (Persuasive Games, 2016). Another serious online health orientated simulation serious game is "HumanSim".

This game allows health care professionals to practice uncommon, multifaceted, or high-risk procedures virtually, instead of using real people so they can become capable and prepared when a human really needs assistance (Healthysimulation.com, 2016). "The Magi and the Sleeping Star" serious online game is adapted to both adolescents and adults with Type 1 diabetes. Users are responsible for a protagonist avatar in the game, who has Type 1 diabetes and the user is obligated to regulate or control this avatar's blood sugar level.

The users earn skills and upgrades as they manage and maintain their own blood sugar levels in real life (I Am A Type 1 Diabetic, 2013). "Re-Mission", another serious game which is accessed online is a game which is an FPS (first person shooter) game that provides users with the opportunity to shoot malignant cancer cells. The game was designed by practitioners and also sufferers of cancer themselves. The game reportedly provides those affected by cancer an occasion where they feel some control over their cancer (Re-mission2.org, 2016).

Virtual worlds are effective in education because students identify with the virtual avatar representations and the situations portrayed. Identifying with these avatars makes the students become active contributors to the actions unfolding on the screen. The learning outcomes from these virtual experiences have the ability to transfer over into real life applications. Experience in these virtual worlds prepares students for more successful and informed introduction to the real environments.

An example of a virtual world is the UCC Virtual Tour, which is an online virtual tour which incorporates a virtual environment (VE) resembling the physical setting of University College Cork constructed with interactive panoramic and immersive imagery. The virtual tour was constructed to explore how the campus could be viewed through a virtual environment and enhance the learning outcomes of campus navigation. This example is primitive in comparison to a similar virtual tour hosted by the Carleton University. The Carleton Virtual is an online game which resembles a tour and incorporates a virtual environment (VE) resembling the physical setting of Carleton University in Ottawa. The game was constructed to explore how virtual environments can be used to enhance learning.

The differences between the two virtual environments are in the ability for Carleton University to convey a seamless narrative through a Google Maps like navigation component. UCC's tour offers the panoramic imagery but with minimal navigation. In addition to the highlighted navigation, audio is added to describe the facilities

offered in each department tabbed in the tour's component navigation (Carleton.edu, 2016). Serious games have taken advantage of the quick growth and success of the computer gaming industry. Serious games are those that have been designed with a purpose other than pure entertainment. These games link the amusement and recreational value of computer games with clear educational, training, or procedural aims. An array of studies and research as previously reviewed the literature review (Chapter 2) have revealed that serious gaming is an effective learning tool and that students appreciate this method of education and training.

Thus Virtual reality technologies and serious gaming are gaining informative ground in higher education. Regardless of the fact that these technologies are still primitive and at the early stage of development, their potential is vast. As original in expensive devices are developed that provide learners with even more accurate interactions with virtual environments (VE), the use of these technologies through dedicated computer systems and over wireless connections via internet or Bluetooth connection will certainly increase.

### 6.1.2 Simulation in Medicine

Education is a dynamic and expensive sector of medical practice, which traditionally emphasises student's knowledge, skills and personal views. Recently, medical simulation has been incorporated into many training programs to instruct not only medical knowledge but also non-technical skills like guidance, interaction and collaboration. This is owing to the growing demands for patient safety in training, demands for proficiency in ever growing new technologies and the increasing prominence placed on cost effectiveness. SBT (simulation based training) embraces a range of technology envisioned for training purposes.

Simulation generally, is any synthetic environment that is generated to supervise an individual or group of student's experiences with reality. SBT can be abstracted as any artificial training environment that is created in order to communicate skills that would progress a trainee's performance.

SBT is just one training method with a main emphasis on providing learners with opportunities to grow and practice their essential skills and obtain advice.

The range of existing medical SBT methods are usually assembled into three main groups; comprising of roleplaying simulations, physical based simulations and computer based simulations.

University College Cork (UCC) conforms to these groups and utilises both roleplaying simulations and physical simulations in their medical and nurse education training. Roleplaying does not use any kind of computer program or technology, but in its place necessitates students to involve themselves in fictional situations. These types of simulations typically do not necessitate any kind of physical apparatus and rely on imitating realistic difficulties for the students to tackle socially. Medical education has traditionally focused on individual knowledge, skills and attitudes. Teaching methods have relied on auto didacticism and teacher motivated learning methods like lectures and performing procedures on real patients. Education has been steered in a sequestered way, by occupation and medical specialty, although the recent increased focus on patient safety has initiated a change in attitude towards medical education away from single healthcare professionals towards a more systematic approach.

Attitudes have also changed from practising first time procedures on patients towards the use of other learning methods such as simulation. According to the WHO (World Health Organisation), human factors play a significant role in patient safety, having estimated that up to seventy percent of incidents are owing to human factors (Who.int, 2016). Lowering or reducing difficulties instigated by human error by avoiding their occurrence, making it easier to identify them or by diminishing their consequences requires improved knowledge and skills of human factors. Therefore, healthcare employees require training in technical skills not only through real patient interaction but also through simulated environments.

Mannequin based simulators like HPS (Human Patient Simulators) embody the full body of a detailed patient in relation to anatomy and physiology. Various models epitomize different age groups like new-borns, children or adults and are often setup in an area to resemble the pertinent medical environment. A standard medical scenario can last from ten or forty minutes and is audio and visually recorded. VR (virtual reality) simulators are also used in most medical specialties especially surgery.

They include visual systems and haptic feedback and some have been proven effective for training. Simulated patients are used extensively in medical training having medical students learn rudimentary stages in patient interaction.

As well as the medical students, experienced healthcare professionals would benefit from assistance in contemplating interaction patterns in difficult scenarios that are set out.

An amalgam form of these simulations include medical student's role playing patients, according to a script and so involve the participants in interactions with the HPS (Human Patient Simulators). In addition, medical details like heart rate and other vital signs are usually displayed using the simulation technology.

The growth of interest in SBME (Simulation Based Medical Education) has been driven by numerous influences, one being the awareness of medical errors in healthcare environments and awareness of theoretically preventing causes of patient morbidity and mortality. This topic of awareness is very relevant, as reducing the likelihood of error in medicine is now a clinical imperative for all general practitioners. Similarly, the recent technological developments and the decrease in the rate device (PC/Mobile) processor power, memory/storage and video processing has now granted precise duplicates of simulated clinical procedures with adequate fidelity for accurate scenario reproduction (Todd *et al.*, 2008).

SBME delivers a dependable and secure learning environment that can include many multifaceted components of significant clinical scenarios. The central model behind health care has advanced over time from having a sole general practitioner to mostly team focused unified health care. This development over time brings new obstacles such as communication faults which are now the most shared cause of medical error in most healthcare systems (Leape and Berwick, 2005).

SBME is exceedingly appropriate for training and development of communication skills among healthcare professionals. The foundation for SBME of physicians is beneficial as medical care is often a high risk for patients, with medical errors frequently resulting from consistent errors in decision making or method. Moreover, various infrequent and serious clinical circumstances are commonly not seen by students and practitioners in training. Thus the growing application of simulations in general medical education possesses unlimited potential in demonstrations of higher levels of efficacy in these clinical circumstances and environments.

Although simulation, as a mechanism for physician training in healthcare remains commonly observed to be a comparatively novel concept as additional technologies are continuously added and updated, SBME generally has been used to educate and teach generations of medical professionals and includes a varied display of practises from role-playing and variances in clinical scenarios.

The importance of simulation using all of the mentioned methods is the ability to simulate a real patient clinical scenario using a process which is contributes to learning without patient risk. Computer based mannequins of high fidelity like HPS, are computer controlled clinical mannequins that have been commercially available for over a decade. As previously mentioned, these mannequins replicate many of the characteristics of serious life threatening diseases but often have technical and hardware restrictions, thus missing the chance of having a flawless optimal simulation of a clinical reality. These types of mannequin based simulations are offered by the University will be discussed in a later section.

### 6.1.3 Learning Platform Concepts and Simulation Structure

Whatever the resource or simulation method selected, there are shared fundamental themes from each. From what has already been established, simulation involves and effects separate functions becoming a blanket term involving the simulator (that provides the interface), the simulation mechanism (which is the computer programme or HPS (human patient simulator) and the simulation scenario for an outlined scripted procedure. In terms of the final resource, several thematic aspects of simulation are adopted to create a platform that more closely resembled the features required by the students when conducting the learning style research.

As previously mentioned in the linearity of the thesis progression, the final resource enables multi-capable media to enhance individual learning traits sourced from the learning traits acquired from the obstetric student collective.

The e-learning chapter discussed and described the creation of an interface design/application and the main factorials needed to achieve a beneficial all-encompassing learning platform. The 3D chapter discussed the enablement of the visualisation and manipulation of an unseen environment for the obstetric students and the video chapter provided the background for enablement of the comparative visual aid of real life scenarios and the 3D enabled design for further constructive visual cues for the students.

From the output of the learning styles acquisition, the students needed additional interaction based on ‘learn by doing’ and as the physical simulation environments are a part of their curricular structure and learning progression currently, the introduction of simulation into a hybrid multi-visually aided platform grants the students the haptic aspects needed to create the resource the students have clearly suggested from the results. From this knowledge, HPS simulations needed to be assessed to find a suitable physical simulation addition to the full resource.

This HPS needed to focus on obstetric education and simultaneously and fluidly integrate into a resource that had obstetric orientated 3D interactive content, obstetric procedural videos and a dedicated student mapped user interface.

Therefore, as the potential structure stands, the resource in its entirety allows obstetric student interaction through multimedia and enhanced haptic inputs.

The video aspects along with some 3D comparatives allow a form of revision of a procedural topic (normal/ventouse deliveries) while the 3D and simulation show real-time haptic interaction of a particular procedure through practice or assessment. The UI (user interface) allows the separation of these two segments and grants additional access to the practitioners or lecturers reviewing student results or experience.

## 6.2 Physical Medical Simulator Examination

As part of the structure set for the completion of the final resource, the HPS offered in UCC were observed and examined. Computer regulated mannequins like these HPS (Human Patient Simulators) offered by UCC are a key type of high fidelity simulator which are mainly used in health education. The HPS offered in UCC occur in adult, child and infant models and they efficiently simulate many physical roles and functions. These functions and roles include breathing, pulses, heart rate, and other procedures through sensor interactions. A SPM (Simulated Patient Monitor) is also used to display physiologic data, with a computer controlling the mannequin’s numerous routines. This computer control centre has many features at its disposal as it acts as the controlling factor in affecting the HPS (depending on the type of HPS used, like more advanced models), recording scenarios, logging and marking scenes in real-time and ultimately presenting this information to the examiner or student depending on the assessment type. This approach effectively enables the student to receive feedback on any errors without any human error factors or patient risk.

The room to improve approach is an approach which was improved upon and minimised to fit the final resource. These adaptive simulators respond to numerous forms of intervention, with the aforementioned advanced models displaying suitable reactions to change within the structure of the procedure including reacting to an injection, pain and discomfort. Some models presented in the simulation centre also simulated some forms of anatomical difference, such as airway structure physically represented through aesthetic and robotics. Mannequins like these have been effectively used to communicate simple physiological theories and concepts as well as to deliver teaching through the management of countless medical scenarios.

They have also established themselves to be vital for team based training, where skills such as communication and teamwork can be developed. Employing simulated learning and assessment in the current educational programs within the college, generally focuses on the numbers and types of courses or other requirements a student needs to be completed (Herrington *et al.,* 2004).

UCC has recently been open to and given much attention to developing simulation platforms between cross-disciplines to develop and mix skill sets and develop other areas such as writing and communication skills or critical thinking, enabling students to have a more global outlook in their training. The use of simulations will only cultivate more, as it has begun to be used regularly for assessing student performance, understanding assessments or challenges concerning students' communication skills, critical thinking, and the application of their acquired knowledge. As stated, simulation technologies are strong educational tools that are becoming more extensively utilised due to their value in delivering influential learning experiences. The usual practice of simulation use is for developmental assessments, where individuals or teams are given constructive feedback on their performance within a given scenario in a simulated environment operated from the computer control rooms. Although simulation garners much positive praise, simulation is only a substitute for a real environment and a student's willingness to suspend their disbelief could influence their actions and performance. An important positive factor associated with simulations however, is the ability of simulations to be stopped and to grant the users freedom in an allocated time slot, where this is not a commodity provided to them in real life procedures.

Stopping or resting on a scenario allocates more time for students to evaluate the procedural actions needed and their current situational predicaments.

Regardless of any issues identified, simulation technologies are a suitable educational infrastructure for assessing difficult skills to acquire, in addition to positively effecting cost and safety elements of the learning environments.

Computer based environments that rely on user interface structures have been the simplest form of learning environment to adapt to provide a meaningful assessment environment for the students, but this environment is still in its infancy in UCC. Laparoscopic surgical procedures are commonly practiced globally using simulated environments, although these surgeries are still being adapted in UCC's simulation centres. These simulated environments that support learning have a tendency to simulate an action virtually which resembles a real action or process so accurately that the lines are sometimes blurred. The actions can be simulated so well that there are only minor differences between the simulated environment and the real environment. This also has its setbacks in terms of virtual representations created to look real. A term coined for 3D and VR respectively is the "uncanny valley" which refers to the visual likeness of a virtual creation to its real life counterpart creating an unease from the users when interacting with the object. This can be seen in 3D orientated media everywhere including movies, robotics and simulations, having creators tone down realism in their computer generated objects to positively affect the users potentially interacting with them. Generally, the phenomenon has middle ground when referring to medical apparatus or simulations, although most simulators like the HPS focus on one general aspect of a particular object depending on the procedural functionality (Gardner, 2015). For example, in a HPS dealing with a normal fetal delivery in Obstetrics, the HPS itself would only show from the models abdomen to a cut-off point before meeting what would have been the models knees focusing on the key point of attention and functionality (the delivery).

These simulations are hands-on resources focusing on learning by doing methods and staged difficult scenarios, involving students so they grow to be contributors, instead of spectators. Students learn better from their own experiences in performing than by having other's experiences thesised onto them. Student participation in the procedures are usually so involved, that interest in learning more about the procedures or their subject matter matures and grows over time in these simulated environments.

Typically, when simulations are designed specifically for students, like the resource created for the Obstetrics students, developmental necessities are reflected upon.

Unlike most instructional classes that pertain to demonstration without participation, in simulation student input is appreciated and actions are designed to encourage students to contribute their own thoughts and methods when deliberating on simulated methods. Due to this new dynamic most lecturers have recognised that their role is altering, as simulations add a new compositional spectrum to the learning experience and create a more dynamic engaging role for the lecturer or trainer. Simulations engage students with techniques that are uncommon and involve students in ways other educational processes cannot.

Simulations are formulated and structured to fit specific learning outcomes particular medical course modules and highlight not only on students' practical capability but also on their skills such in communication, cognitive reasoning, problem solving and cooperation with fellow students. These proficiencies are accepted as significant components of any medical education and vital aspects in most medical professions.

### 6.2.1 Obstetric Orientated Simulation Examples and Inspection

In light of the simulation research and the need for HPS interaction, the simulation centre in UCC was approached. The simulation centre in UCC offered similar HPS mentioned in the examples in the previous section. These HPS examples matched adult models and children models. The examples had functionality that rested on robotic processes manipulated manually either via examining practitioners or a simulation command centre. The robotic processes emulate human responses including facial tics, patient sounds and simulated pulse. As the final simulation resource focuses on obstetric procedures, the key simulations of interest in the simulation centre were of obstetric orientation. The Obstetric simulation representations present were of a demonstrative aesthetic used for visual cues and anatomical portrayal. The simulator which showed promise in its ability to represent the Obstetric delivery processes and might have application for potential sensor and computational integration was the PROMPT birthing simulator.

The PROMPT (Practical Obstetric Multi-Professional Training) Birthing Simulator allows practitioners and lecturers to efficiently communicate the difficulties and intricacies related to the birthing process (Laerdal.com, 2016).

The standardized patient allows for realistic human interaction and communication while the PROMPT simulator maintains the execution of obstetrical competences.

The PROMPT simulator offers a detachable abdominal and perineal skin which enables visualisation of internal manoeuvres and fetal positioning during training. Students can see how manoeuvres influence the fetus in the womb (in-utero).

The simulation has an anatomically accurate perineum and pelvic floor muscles, with bony pelvis modelled from CT scan data. The PROMPT simulation also offers a detachable placenta with cord. The model also allows for multiple delivery positions and techniques like Normal delivery, Breech delivery, Vacuum delivery, Shoulder dystocia management and Forceps delivery of placenta.

This access to an array of techniques helps in creating an ease of multimedia integration for technique visualisation variances. The simulation also offers force monitoring which provides visualisation for appropriately aided delivery. Students can also see and feel the suitable force necessary with hands-on experience and response. Students experience childbirth and practice the skills required for successful deliveries. The simulation also offers an articulating baby that can be presented in multiple positions to represent difficult and routine deliveries educationally efficient, and easily integrated into obstetrical training.

The fact that the baby model offers multi-positional and articulated freedom grants access to multi-sensor tracking of the baby's body parts in real time with potential to visualise multiple limb data tracking. The practitioners use the hybrid simulation employing the PROMPT Birthing Simulator to add practically and realism to scenarios. This educational schedule and emergency care for obstetrical patients is attained by merging the PROMPT simulator with a standardized patient (student actress). Assimilating further apparatus like the previously mentioned 3D, video, and sensor components into obstetrical simulation enhances the overall learning and training experience. Similarly, integrating additional simulators, standardized patients or task trainers allows instructors to build complexity and tailor the simulation to their learners.

The simulation amalgam is potentially educationally effective for multi-professional team training by targeting main skills for obstetrical care. One sensory output from this PROMPT simulation is the force data it relays to a dedicated CT simulated emulation called the Force Monitor. The Force Monitor system provides both instant feedback and graphical records as to the force applied to the baby during delivery. The data can be also retrieved via PC connection through aux I/O, on the client side, software is introduced through dedicated CD-ROM.

On this software the force data is displayed on reserved graphs with a key representing peeks in pressure. This data was not open to manipulation but offered quick responses. The introduction of additional data and cataloguing to this external simulated PROMPT platform would enable effective educational interaction and immersion for obstetric students. Another factor that was of interest when inspecting the PROMPT simulator was its stable position, being a wide and bearing apparatus, the simulator was not easily shifted from its original position. This was important to note as the PROMPT simulator more closely matched a sensor friendly environment where the position would need to be configured for a static position.

The introduction of positional sensors within the model would rely on the marking of environmental space and have a static location for each sensor node used.

The introduction of a sensor or multiple sensor nodes will be later discussed in later sections. Apart from these aspects attributed to PROMPT, the simulator was used manually relying on human input at all times. The special freedom in the PROMPT simulation is also limited to the inside of the abdomen model. However, after further inspection of the simulated environments housed in the simulation centre, it was apparent that the PROMPT simulator would grant the most beneficial addition to a fully realised multimedia obstetric learning experience for the students.

## 6.3 Sensor Technology Interaction and Integration

In the original concept of sensor and haptic interaction, many different sensor technologies are researched to find the perfect comprehensive form of object tracking and localisation. These forms of sensor interactions are researched and compared to fully understand their capability of logging localisation, positioning, rotation data and their ability to integrate into local PC created applications. Sensors connect to a computer using a series of cables and adapters and can also be found through Bluetooth, or standard internet protocols. Once there is a communication between the sensors and the CPU (central processing unit), using programming the position of the models can be established and displayed as 3D simulations of the live model interactions alongside educational narrated videos as suggested by the platform created for this research.

A sensor is a converter that measures a physical quantity and converts it into a signal which can be read by an observer or by an instrument (Klein and Lehner, 2009).

Sensors we use for every day data signal recognition and interpretation include: red light cameras, automatic door openers, cameras and GPS (Global Positioning System, that provides location and time information) to name a few.

Sensors have been used in mobile phones since they were invented. These are in-built in their schematics noticeably in the microphone and number keys.

Since the smart phone has become more common in the general populous, other sensors emerged to form a more interactive experience for the users, utilising touchscreens, accelerometers, gyroscopes, GPS and cameras. Instead of having to contend with ten distinct devices to incorporate several functionalities, now the users just need one multipurpose device. Sensors have been also used for distance and range like IR (Infrared) Sensors. These sensors contain an infrared emitter, and an infrared detector that work by emitting a specified amount of infrared light and registering the amount of light is recalled back. The use of IR sensors would not bode well with the actions needed to map out an objects rotation and position accurately. Even with a multitude of these sensors, the output would not result in precise coordinates (Michahelles *et al.,* 2005).

There are not many other infrared sources nowadays that would tolerate light interference. For example, if visible light were used, light bulbs, computer screens, smart phone screens, would all interfere with the reading depth, although these IR sensors are effective at measuring shorter distances. IR sensors are present in touchless Switches (toilets) and well used in the gaming industry with the introduction of the Microsoft Kinect. Another type of sensor is the Gyroscope. This sensor measures orientation or rotation. Therefore, if an object is moving along one axis, and it is rotated above another, it will feel a Coriolis (inertia) force in the third axial direction (Kirkko-Jaakkola *et al.,* 2012). A gyroscope will have a mass dithering back and forth along the first axis and plates on either side of the mass in the third direction which would be the direction of the Coriolis force (Schopp *et al.,* 2009). When rotation is detected around the second direction, the capacitance changes. When a gyroscope is paired with an accelerometer the created device has six degrees of freedom, this sensor amalgam is known as an IMU (Inertial Measurement Unit).

The gyroscope as previously mentioned, grants an opulence of rotational data which is key in the localisation of the obstetric model in the finished piece. In light of this, a sensor with an integrated gyroscope offered the vital orientation data needed.

Examples of the use of both the gyroscope and accelerometer is the Nintendo's Wiimote, Orientation sensing in smart phones, Image Stabilization in cameras, Collision detection in cars and Pedometers (e.g. Fit Bit). These IMU sensor types had value in their ability to track orientation and realise position, two obtainable IMU sources for the thesis were the Wiimote and a smart phone.

Both of these devices were obtained for later analytical use in contrast to similar devices. Other sensors ultimately used in response to mobile tablet use were touchscreens sensors. The advantages of having touchscreen sensors are that they are inexpensive and do not always require finger input or some other conductive input. As mentioned previously, sensors like GPS Sensors are used for localization and are generally used to track the whereabouts of an active user of the technology. GPS receivers are usually passive devices and they do not transmit data back to the satellites that operate with them. GPS uses twenty-four operational GPS satellites at all times, operated by USAF (United States Air Force). These are synchronized using atomic clocks at specific synchronous intervals and they each emit a signal containing their current position and the time of the emission (Montana.edu, 2016). A receiver will receive multiple signals from different satellites at different times, depending on the distance to each satellite. When a receiver receives a transmission, based on the time it takes to get the packet, it can determine how far it is from the satellite. Originally, when pitching the localisation of an object and representing it in 3D space, RFID tags were considered as a means of tracking the data.

Radio frequency identification or RFID tags are intelligent bar codes that can communicate to a networked system to track products similar to those placed in online shopping carts. RFID tags are used to track vehicles, airline passengers, patients with dementia and pets. These tags have a radio-frequency electromagnetic field coil that modulates an external magnetic field to transfer a coded identification number when queried by a reader device.

Originally these RFID tags were going to be attached to focal parts of the simulator baby model that would respond to the readers within the female abdomen model of the simulation. Data would be retrieved in a format recognized by a created local program that would in turn present coherent data to the user.

Results of live actions (in graphical representation) would have been issued alongside optional hints for instruction.

The software involved would have developed to have multiple users input to further develop the user's ability to complete the tasks in parameters set (these would be logged for every interaction made). Scenarios would have been set so that different types of deliveries would be completed. Once these scenarios were completed, the results would have shown how the actions of the user matched those of the guidelines set by the program.

Multiple guidelines would have been generated by the program and the user could select a type of delivery from the GUI provided by the program. These different processes would then have captured the actions involved in normal delivery or any other methods. As promising as the RFID tags would have appeared, multiple issues would have arisen from the use of these structures.

For instance, the amount of RFID tags needed would have been too much to fully realise movement, there would have been a delay in data retrieval and most importantly this delay and retrieval of set data markers would have resulted in non-fluid movement when moving the models and receiving a corresponding 3D action. The most amenable outlet for visualising and formatting this simulator model to 3D model movement response was to integrate the use of IMU sensors. Before outsourcing IMU sensors specifically for the use in the end product, obtainable IMU based devices were used to test the acceptance of these sensors and adaptability through programming locally. These IMU sources that were tested were the Wiimote and smart phone.

### 6.3.1 Wiimote Use and Test Programming

A Wiimote was sourced from a game store at a reasonable price along with its accessories like the Numchuk, and Wii Plus mote add-on which added additional accurate readings of orientation and functionality (especially the Wii Plus). The Wii gaming console was not sourced as this product didn't offer the functionality needed and in addition the Wiimote had the capability to connect to a PC or MAC computer. The Wiimote has limited data when compared to what is offered by Microsoft Kinect or PlayStation Move but it is cheaper and much smaller and compact to incorporate into the final piece. Nintendo's Wii controller is an interesting piece of technology.

The Wiimote has 3-axis accelerometer which transform a user's physical motions to activities in a virtual environment.

There are 12 buttons on the Wii remote which would have the capacity for multiple event input. The Wii-mote is also equipped with a speaker to enable any midi sounds which could ask as a precursor to a prompt mechanism. A very simple mechanism provides haptic feedback through vibration. It has an IR sensor and is connected to a computer via a Bluetooth wireless link.

A tracking system is used for acquiring the user's head position and orientation.

Wiimote controllers naturally allow a "point and click" style interaction with large display screens which has confirmed to be a good source for object selection tasks, although these functions were not taken into consideration as the orientation mechanisms were the key focus of the use of the device. The Wiimote device was to be inserted into a mannequin fetal doll to hide the plain view of the controller to draw focus to the fetal doll and not the Wiimote.

As the Wiimote controller contains traditional control buttons and an infrared tracking camera, these functions would have no means of functionality once inside the doll. The three-axis accelerometer in-built in the device was still accessible once in the doll. As the Wiimotes report position, orientation and button data to a game console via a wireless Bluetooth connection, the same connection needed to be established to a computer.

To establish a connection from the Wiimote to the computer via Bluetooth, the Wiimote was first switched into discovery mode. The blue lights at the bottom of the Wiimote flashed to show the device was looking for a grounded local connection. From the PC, Bluetooth Devices window was opened to search for the Wiimote device and when the device was shown, it was added to the computers list of recognised devices. This created a basic connection between the computer and the device. The insertion of the Wiimote into the fetal doll was an aesthetic process and was not necessary through the development stages. As the Wiimote needed to be able to move a 3D model, the connection needed to be established within a 3D programming platform.

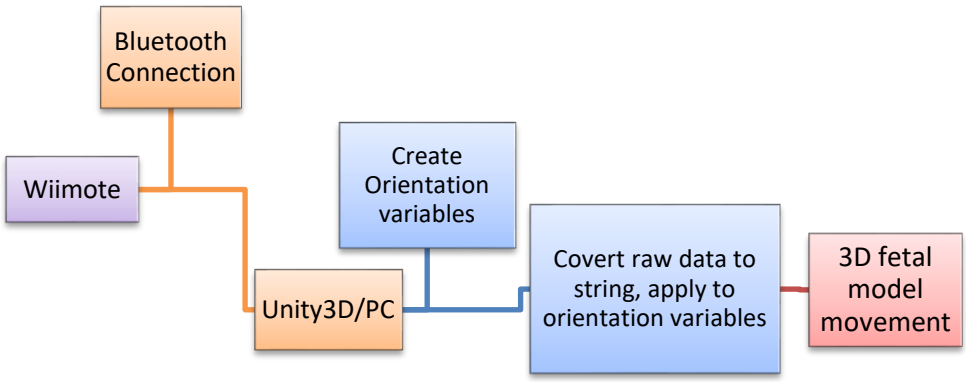



Figure 43: Wiimote connection, orientation configuration and operational processes

The platform that was used was Unity3D, as the 3D objects had already been created to in light of a potential sensor integration. One possible way of remote Wiimote device to Unity3D connection was through a shared library of Bluetooth protocol connections. The shared library or DLL (Dynamic Link Library) was downloaded and added to the Assets of the Unity3D thesis. The API (Application Programming Interface) involved granted access to the array of outputs created by the Wiimote Device, from the library, the orientation data needed to be retrieved and linked to that of a fetal 3D model imported into the 3D environment. As a test, the fetal 3D model was placed in the 3D space within a new Unity3D thesis. In this space, the 3D model was presented as a GameController which is a top hierarchy object within the API of Unity. To program functionality between Unity3D and the Wiimote, C# syntax was used as it lends itself to an abundance of external protocols.

A new C# script was created within the Assets folder of the thesis, once created the script was dragged to the fetal 3D model in the 3D environment. Within the created script variables are generated to establish orientation values, from these variables the accelerometer and gyroscope properties are obtained and set.

Within the code presented the model is represented as Vector3 as the code is linked to the fetal 3D object. The Vector3 structure is a representation of the 3D vectors and points. This structure is used throughout Unity to pass 3D positions and directions around. It also contains functions for doing common vector operations (Unity, 2016). For example the operations used with this structure in terms of its use in this thesis were to manipulate the Quaternion values for rotation to affect the fetal 3D models orientation.

Once the orientation values were set to the 3D object within the 3D environment, the objects interaction with the Wiimote needed to be tested. On completion the thesis build was run.

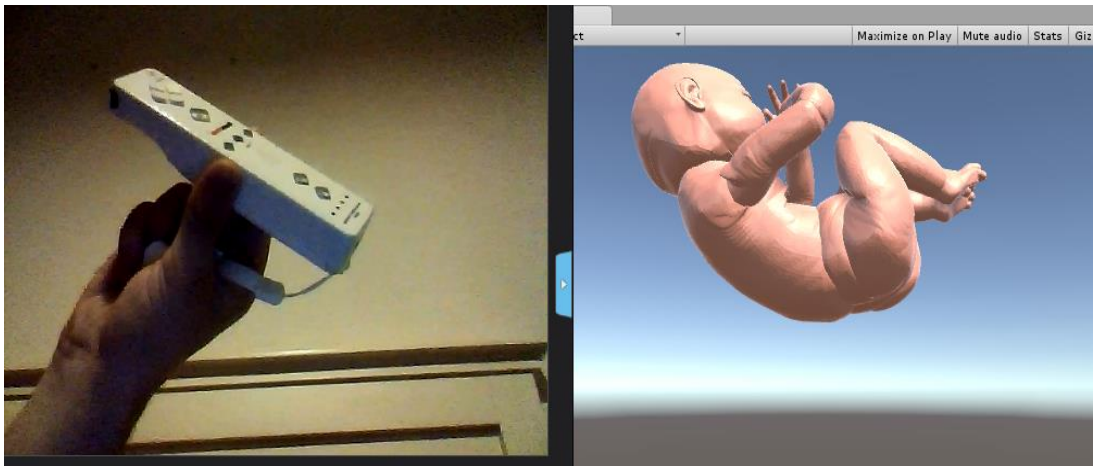



Figure 44: Wiimote, 3D model connection and orientation manipulation.

The connection from both the Wiimote to the 3D environment was sound. The 3D object started to move as the Wiimote was moved in relative positions and rotations. Although there was movement of the 3D fetal model when using the Wiimote, the movement was erratic and had very little stability. The accelerometer didn't judge the position accurately enough to fixate an exact translational orientation. As the final resource was mapped on having exact positional and rotational markers in a 3D space from an external input, the Wiimote fell short of the necessary prerequisites. The next port of call for mapping external inputs to manipulate the 3D objects orientation was the mobile IMU connection.

### 6.3.2 IMU Use and Mobile Device Testing

The next Accelerometer and Gyroscope combination IMU that was tested was through the use of mobile phone technology. A mobile phone was sourced that incorporated both an active Accelerometer and Gyroscope, this phone was a Samsung Galaxy S3 mini. The phones size and specifications suited the specific parameters needed to suitably incorporate into the resource. The phone attitude gave the 3D orientation of the phone regarding an earth coordinate system (Pun et al., 2011). This orientation retrieval is an important input to many phone applications including mobile gaming, gesture and activity recognition, localization and navigation (Shoaib et al., 2014).

The MEMS (Microelectromechanical systems) gyroscope within the phone, capable of measuring the 3 dimensional velocities, has been used to estimate phone attitude in an array of applications for gaming and stabilisation applications. Nevertheless, the MEMS gyroscope has been generally attributed to poor accuracy in contrast to high accuracy gyroscopes used in navigation in sailing or robotic systems and aviation (Vorbrich, 2011). This difficulty becomes largely problematic in practice as an inaccurate orientation from the MEMS causes an inaccurate functionality in the final resource. Straight forward sensor fusion similar to Kalman-based (Caron et al., 2006) methods with unrefined sensor input, cannot guarantee high accuracy. The Android API (which would be the operating system for the Samsung phone) getRotationMatrixFromVector() directly adopts existing Kalman-based sensor fusion algorithms to calculate the phone attitude (Developer.android.com, 2016).

In order to test a Mobile IMU connection to a PC before creating a Unity3D connection, a particular protocol needed to be established for a basic connection to be recognised. In order to establish this protocol connection, two parameters needed to be generated both locally on a PC and on the mobile device. The parameter set on the mobile device involved downloading a sensor fusion app that accumulated the IMU data (accelerometer, gyroscope and magnetometer) and prime it for potential PC protocol relay. The application used to provide this connection protocol was "Sensor Fusion and IMU" developed by Johansson *et al.*, in the Department of Automatic Control, Lund University Education. The sensor fusion and IMU application sampled data from the accelerometer, gyroscope and magnetometer featured in the mobile phone. It calculated angles and rotation and perform on-board, real-time sensor fusion using high-pass/low-pass and complementary filter.

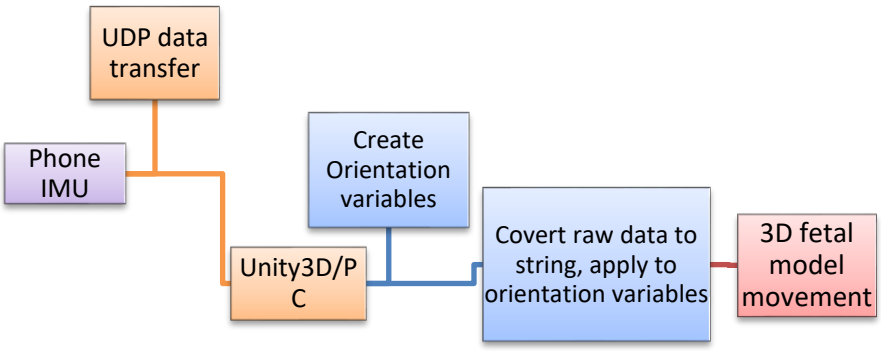



Figure 45: Phone IMU connection, configuration and operation of orientation data

The data was plotted visually on a graph device-side and streamed via Wi-Fi (Johansson et al., 2016). On the client-side (PC) a Python command was generated which listened for potential data information through a UDP (User Datagram Protocol) link. To correctly establish the connection, the Python mark-up needed to determine the host, port and run a particular function to resemble the functionality needed to view the orientation data. The host and port were retrieved from the WIFI settings of the network that were in use at the time.

To view the data on output in the console and view the data as separate coordinate values (X, Y and Z – position, Roll, Pitch and Yaw – rotation), the function within the script needed to separate the values in an array. The first lines of Python code established the connection while the next few lines retrieved the data. The next lines of code split the data segments with a comma value, variables were created for each set of data intervals corresponding to their orientation coordinates. The variables were matched to incremented items in the dataset array depending on the hierarchy of the orientation data when sent client-side from the mobile application. Once split, the data was deployed to the console and displayed the values.

The mobile sensor fusion streamed the containing sensor values in CSV (comma separated values) format by WLAN (wireless local access network) to the client. This was a raw feed of IMU data from the device to the client. This test showed a clear uninterrupted connection between the mobile device and the PC and tracked the mobile orientations in real time. Though, the raw information needed to be registered as feasible orientation data for a 3D model client side when manipulating orientation in Unity. On the client side the mark-up was created using a mixture of C# and JavaScript mark-up languages to retrieve the raw IMU data. The JavaScript informed the minor UI components while the C# code tackled the majority of interaction and functionality. Three separate C# scripts were generated to house separate functionalities, the scripts entailed the connection to the mobile device/assigning of variables, manipulation of rotational values, and of translational values.

The main script tackled the connection between computer and mobile device. Like the previous Python script which established a connection and assigned variables, this script did the same thing by creating access to the raw sensor data and segmenting the data with CSV, but this data was unusable as Unity could not process and establish functions around raw data.

To avert this problem, the raw data was converted into individual corresponding strings and presented as usable values for the variables created for X, Y, Z(position), Roll, Pitch and Yaw(rotation) respectively. The other scripts imported the class created to establish the connection, to import the variables created for orientation. From this point the variables were generated as the position and rotation parameters, assigning the imported variables to the Quaternion and positional parameters of the 3D fetal model. The 3D fetal model was also fitted with weights and the parameters applied to mesh to link it the IMU emitting mobile device. The thesis application was then tested to view and determine the feasibility of the mobile device use.

Figure 46: Movement of mobile device (attached to fetal doll) in correspondence to the 3D fetal object.

The 3D fetal object corresponded well with the mobile devices feed, the Accelerometers positional data granted enough freedom to move the model in a limited space. The gyroscope provided some freedom of rotation but was not able to fully rotate the model. On closer inspection the data decremented on one revolution attempt, reverting the 3D fetal object back to its original state. This phenomenon is known as a gimbal lock which is the loss of one degree of freedom in a three-dimensional, three-gimbal mechanism that occurs when the axes of two of the three gimbals are driven into a parallel configuration, "locking" the system into rotation in a degenerate two-dimensional space (Brennan et al., 2011).

As the gimbal lock would prevent a full 360 degree rotation, if used the mobile device would not provide the necessary visual rotation needed to represent the interaction in the final resource. As the rotation within the final resource was a key feature, the use of the mobile device was not continued as it didn’t provide these features fully.

As the IMU structure had integrated well into the Unity thesis construct and the 3D object visually reacted to the IMU inputs, IMUs were researched for their integration into the thesis and compared in their likelihood of successful thesis integration.
Once having selected the successful IMU candidate, the IMU was set against a learning application structure in the thesis.

### 6.3.3 Industry Sensor Sourcing, Employment and Management

Taking into account the sensor valuations of both the Wiimote and the in-built IMU structure of the mobile device, it was established that an IMU device that identified with the resource solely needed to be sourced. Two institutions were approached first to retrieve workable and adaptable sensors. These institutions were Tyndall Institute and the Rubicon hub, where they both had sensor work and nodes presented in-house. Tyndall possessed its' own created IMU sensor known as the Planar WIMU (Wireless Inertial Measurement Unit). This WIMU sensor is a 6 DOF IMU module, which is made up of an array of inertial sensors coupled with a high resolution ADC (analogue to digital converter). The inertial sensor array consists of three single axis gyroscopes, two dual axis accelerometers, and two dual axis magnetometers. The sensor array was designed with a new 3D spatial structure, which produces the 6 required DOF (degrees of freedom) necessary to determine position (Tyndall Institute, 2016). This thesis did not continue with this device.
The Rubicon hub was approached to source sensor nodes to track positional and rotational data like the documented WIMUs and IMUs. The representatives in the Rubicon presented multiple sensor nodes that were created for positional data realisation. These nodes were known as Sunspots. These Sunspot sensor nodes were for a wireless sensor network developed by Sun Microsystems and then subsequently adopted by the Oracle Corporation. Its sensor board included a three-axis accelerometer, temperature sensor, light sensor, 8 tri-colour LEDs plus analogue and digital inputs. These sensors were small, wireless, battery powered experimental platforms that had the ability to be used in a variety of different applications.
The representatives provided fives of these Sunspot sensors for the thesis and general testing. Although this was a great footing in the progression of the thesis and the potential visualisation of proper sensor/PC interaction, upon inspecting and researching the sensor nodes it was soon found out that Oracle had dropped support for the sensors and had no trace of an SDK (software development kit).

Without the SDK or the supplementary API (application program interface) for the Sunspot sensors, the sensors could not be recognised and consequently could not be used. This was a minor setback in the retrieval of a quality sensor but the acquisition didn't end after these unsatisfactory sensor node procurements. The sensor nodes needed to be procured online through an establishing contact with IMU node developers and companies to attain the sensors needed. To retrieve the perfect IMU capable sensor, a robust search was carried out on different search platforms.

This method enabled the tracking of a suitable sensor candidate and presented a variety of sensor forms, capabilities and types. Upon research of the prospective sensor devices and nodes needed, several sensors were found. From these sensor search results the following devices were found: Motion Node Bus, MyoMotion IMU, LPMS- B 9 axis, Perception Neuron, Pasco Sensor, X-BIMU, and Texas Instruments. Each sensor was inspected online and the creators or companies associated with each one were contacted for prospective affiliation with the end resource. Different parameters were taken into account when finding an IMU derivative sensor that would best suit the end result resource.

These parameters were compared and contrasted between each sensor researched. The parameters involved:

1. Whether it would integrate well with 3D visualised objects or software and could the sensor potentially manipulate a 3D object?
2. Could the sensor connect to a mobile device?
3. Is there a possibility of having multiple sensor access form one sensor example?
4. Is the compatible with multiple different operating systems, online or local platforms etc.?
5. Is the sensor wireless
6. Are the sensors small enough to hide from view in the Simulation?
7. And finally whether there was granted access to use the specific sensors and connected SDKs?

These parameters and results were compared on a scale of poor to strong capabilities and marked whether or not the specific attribute or parameter was available in the particular sensor.

In addition, the access to the sensors and the price were taken into account as they were key factor in the ability of retrieving the sensors. The price range ranged from Cheap (which represented the affordable nature of the sensor in comparison to the other sensor – not judging the quality) Expensive (Out of the bounds of the budget of the resource). In between the two ranged markers was Moderate referring to the moderate affordability of the product.

| Comparison Matrix of Industry IMU sensors (Levels of aspect involvement - key) | | | |
|---|---|---|---|
| 🔴 | Strong Capabilities | ✓ | Available |
| 🟢 | Moderate Capabilities | × | Not Available |
| 🔵 | Poor Capabilities | | |

| | **Tyndall WIMU** | **Motion Node Bus** | **Myo Motion IMU** | **LPMS- B** | **Perception Neuron** | **Pasco Sensor** | **X-BIMU** | **Texas Inst.** |
|---|---|---|---|---|---|---|---|---|
| **3D Interact** | | ✓🟢 | ✓🔵 | ✓🔴 | ✓🔴 | × | ✓🔵 | ✓🔴 |
| **Mobile acc** | ✓🟢 | ✓🟢 | ✓🔵 | ✓🔴 | ✓🔴 | × | ✓🔵 | ✓🔴 |
| **Multi-Sens** | ✓🔴 | ✓🔴 | × | ✓🔴 | ✓🔴 | ✓🟢 | ✓🔵 | ✓🔴 |
| **Multi – platform** | ✓🔴 | ✓🔴 | ✓🔵 | ✓🔴 | ✓🔴 | × | ✓🔵 | ✓🔴 |
| **Wireless** | ✓🔴 | ✓🔴 | ✓🔵 | ✓🔴 | ✓🔴 | ✓🟢 | ✓🔴 | ✓🔴 |
| **Small sensors** | ✓🔴 | ✓🔴 | ✓🔴 | ✓🔴 | × | × | ✓🔴 | ✓🔴 |
| **Access Granted** | × | × | ✓🔴 | × | ✓🔴 | ✓🔴 | ✓🔴 | ✓🔴 |
| **Price** | N/A | Dear | Moderate | Cheap | Dear | Dear | Cheap | Cheap |

Figure 47: Comparative matrix of the IMU derivative options.

The first IMU sensor found online was the Motion Node Bus. The Motion Node Bus is a wearable network of 3-DOF inertial measurement units (IMU) for use in motion capture applications.

The system is compact, easy to use, and yields accurate orientation tracking results (MotionNode, 2016). The bus hosted a wired network of Motion Node MIMUs (Miniature Inertial Measurement Units). The bus controller received and collected data from all connected sensors and published it in real-time.

The bus was configurable to support one to twenty sensors which was intriguing as the prospective resource needed to map a fetal model that could potentially need individual anatomical position. Each Motion Node module in the network used nine high quality sensors to compute an accurate and stable orientation.

One accelerometer, one gyroscope, and one magnetometer contribute real-time data for each of the three axes like most IMU sensors. Orientation data was available for export to a number of formats which made the platform very desirable in light of its potential positive connection to Unity 3D. The SDK attached to the sensors lend themselves to several scripting syntax including C++, C#, Java, and Python programming languages. Sadly this company or group was contacted and did not reply or show any form of interest in any process of association or collaboration.

The thesis did not continue with these sensors due to their price and other preventing aspects. Most of these sensors also worked off a controller or base station module to connect to multiple sensor nodes.

The next sensor system inspected was the Myo Motion from the Noraxon group. Through correspondence with Noraxon, the company referred to the Myo Motion as a kinematic analysis system incorporating MEMS technology to reproduce 9 degrees of freedom with the Accelerometer, Gyroscope and magnetometer (Noraxon USA, 2016). When deliberating the SDK, it was mentioned that the SDK was in its infancy which was not ideal when trying to incorporate the sensor into the Unity3D environment. Another aspect was its early incorporation of multi-sensors having a weak response in comparison to other sensors found. Apart from the lack of some features the system was a possible candidate and was kept on file in case no other sensor device matched the criteria perfectly. The next sensor to be inspected and researched was the LPMS- B sensor developed by the Life Performance research group. Like the previous sensors this sensor had nine degrees of freedom with a 3 axis Accelerometer, 3 axis Gyroscope and 3 axis magnetometer. It mode of connection involved Bluetooth data relaying.

This device would have had a beneficial effect on the thesis as from the specifications the sensors were compatible with most scripting languages, had their own dedicated interface for tracking the data client side before manipulating the code. Although the specifications hail this sensor as an acceptable sensor for thesis integration, there was no means of retrieving the product, so another sensor outlet needed to be sourced. One other sensor system that was found was the perception neuron. This system was very intriguing as it was a system that used Mocap (motion capture) to track an object in real-time, this entailed multiple nodes scattered around an anatomical suit that placed nodes on key points on a person's body like head, shoulders, arms, hands, torso and the lower half of the body.

The modular system is based on the company created NEURON, an IMU (Inertial Measurement Unit) composed of a 3-axis gyroscope, 3-axis accelerometer and 3-axis magnetometer (Perception Neuron, 2016). The most interesting part of this system apart from the technical IMU devices incorporated into the system, was its own personal software which acted as an active plugin into Unity3D.

This active plugin would remove any difficulties with trying to connect sensors to the thesis client-side application. Most of the sensors discussed had to be connected to the Unity thesis by using a combination of read-line script and converting raw data to retrieve stringed coordinates, and from these coordinates are applied to objects in the 3D virtual environment. Most of the preferences were met but there was one major problem. As the finished thesis would map out the actions of a fetal model the nodes would need to be attached to this dummy model.

This was not ideal in the case of the Neuron's structure, as the Neuron's anatomical structure only mapped a human body and was limited to these structures. The Neuron was not capable of representing a smaller object like the fetal model. This was a shame as the plugin API provided by Neuron was readily accessible and easy to used and would have integrated perfectly into the finished thesis.

The use of the Neuron sensor was not considered after these deliberations as it wouldn't have been able to accurately map to the fetal model and create a seamless fluid animated motion from this interaction. The next interaction with a motion sensor device was when attending a demonstration by Pasco Scientific and hosted by Lennox Educational. There were many sensor iterations on display by the representatives from Pasco, either displaying some form of light, PH, or fluid sensor example.

The only example that resembled the attributes produced by most IMU sensor products researched was the force Motion Sensor which measured position, velocity, and acceleration of a target. This product lacked the rotational values needed to map the 360 degree freedom in 3D virtual space provided by Unity3D.

The sensors were robust and were large objects not capable of hiding within a simulation example. Apart from this the sensors were wireless and connected through Bluetooth with little delay or latency. The Pasco sensors were all provided with a dedicated software which displayed the raw data inputted into a graphical representation either a bar chart or graph of differences in volumes etc. The system works by using an electrostatic transducer in the face of the Motion Sensor which transmits a burst of 16 ultrasonic pulses with a frequency of about 49 kHz. The ultrasonic pulses reflect off a target and return to the face of the sensor. The target indicator flashes when the transducer detects an echo. The sensor measures the time between the trigger rising edge and the echo rising edge. It uses this time and the speed of sound to calculate the distance to the object. To determine velocity, it used consecutive position measurements to calculate the rate of change of position. Similarly, determines acceleration by using consecutive velocity measurements. Which is all tracked on the dedicated Pasco software, through Bluetooth adapter connection. Apart from this retrieval of information or data and the quick ability of data relaying through Bluetooth input, the Pasco motion sensors did not provide any backward compatibility or any form of open source scripting possibilities.

This would not help in the manipulation of data from the sensor to a possible 3D object in Unity. The thesis was also informed from the representatives that the data inputted could only be represented through the software and not used for any other purposes, generally used for laboratory experiments to teach students about force and acceleration in Physics. Because of this, the Pasco sensors were not chosen as the sensor group to proceed with in the creation of the finalised sensor for the thesis.

The next sensor researched was the X-BIMU, which was a low latency Bluetooth enabled wireless sensor. The next sensor tested was the X-BIMU, which was a low latency Bluetooth enabled wireless sensor. The X-BIMU sensor is a versatile IMU and AHRS specifically designed to interface to XBee (radio modules that structure analogue to digital conversion from Digi International) style wired and wireless communication modules.

The sensors have on-board sensors and algorithms to provide both inertial sensor data and a real-time measurement of orientation relative to the Earth The sensor is also optimised to operate with XBee wireless modules to achieve its best low-power and low-latency performance but is compatible with any serial-based interface (e.g. Bluetooth and serial breakout). A simple communication protocol uses either ASCII or binary packets and provides access to all settings through serial commands using any serial terminal. The sensors use C++ syntax to enable any manipulation of a digital environment. The sensor is calibrated with gyroscope (±2000°/s), accelerometer (±16 g) and magnetometer. The company linked to the creation of the X-BIMU were contacted, X-IO technologies. The sensor would not have been able to produce the real-time manoeuvres needed to visualise the baby movements in the prospective simulation. The subsequent sensor investigated was the SimpleLink Multi-Standard (CC260) sensor tag from Texas Instruments.

The Texas Instruments (TI) CC2650 sensor tag is a pocket-sized compact development platform intended for representing Bluetooth Low Energy (BLE) applications, with a specific importance on relating to and interacting with remote access and mobile phone applications. The sensor tag was built around the TI CC2650 SOC (system on chip). This chip features an ARM Cortex M3 processor, 2.4GHz transceiver and an embedded BLE (Bluetooth low energy) controller. The chip also features a 12-bit ADC (analogue to digital) and multiple GPIOs (General-purpose inputs/outputs) with embedded serial interfaces. The sensor tags board holds a number of beneficial sensors critical for optimised localisation and position tracking. These sensors present on the board include but are not limited to an InvenSense MPU9250 Accelerometer, Gyroscope & Magnetometer, a Bosch BMP280 Pressure Sensor and a TI OPT3001 Optical Sensor.

This sensor was easy to access as the Engineering Department in UCC had been provided with the sensors for use of the sensor tag's pressure and optical capabilities. The Department was contacted for use of the sensor tag and a tag was provided for this thesis. The specifications of the sensor tag matched the conditions needed to create the finalised system, so having a working sensor tag to experiment with was a great jumping off point in the pipeline of the end result structure. As this sensor tag had the perquisite features and could be accessed, it was tested and chosen to prototype the hybrid simulation connection and subsequent user haptic experience.

## 6.4 Finalised Sensor Approach and Framework

As the sensor tag was selected to become the key sensor in terms of tracking positional and orientation data, the sensor needed to be fully identified along with its specifications before testing the sensors connection to the PC, the Unity 3D connection and fully integrating it into the final resource. On inspection of the design and specification documents the SimpleLink Multi-Standard sensor tag offered from Texas Instruments had 10 different low-power MEMS sensors in one small unit.

The sensor tag was based on the CC2650 wireless MCU. Like previously mentioned the CC2650 device was a wireless MCU targeting Bluetooth Smart, ZigBee controlled applications. The device was part of the CC26xx group of cheap, very low power, 2.4-GHz radio frequency (RF) devices. On examination the sensor had very low active RF, MCU (microcontrollers) current and a low-power mode consumption that delivers superb battery life and permits this process on small cell batteries.

The CC2650 TI Sensor Tag device also contained a 32-bit ARM Cortex-M3 processor that ran at 48 MHz. This sensor controller was perfect for interfacing external sensors and for collecting analogue and digital data autonomously while the rest of the system was in sleep mode. Therefore, the TI Sensor Tag CC2650 device is ideal for applications within a whole range of products including industrial, consumer electronics, and medical.

The Bluetooth Low Energy controller and the IEEE 802.15.4 MAC are embedded into ROM and partially run on a separate ARM Cortex-M0 processor. This architecture improves the overall system performance and power consumption and frees up flash memory for the application.

The BLE protocol stack residing in this sensor tag comprised of two units: the controller and the host. The HCI (host control interface) layer within this stack provided a means of communication between the host and controller via a standardized interface. This layer can be implemented through a software API, which is the method preferably used in creating the manipulation in Unity 3D.

BLE (also known as Bluetooth 4.0) is a version of Bluetooth optimised for lower energy Internet of Things applications. It standardizes the application architecture in the form of a GATT (Generic Attribute Profile) server, which relays information from the sensor hardware to a client (typically a smartphone).

By standardizing the transmission of information to the client, the development of client applications across platforms is greatly simplified.

The GATT server defined a set number of data values termed characteristics, which can be grouped as services according to their purpose.

Data could be transmitted asynchronously by the server as a notification, or directly accessed by the client. All of the internal architecture can be seen in figure 49.

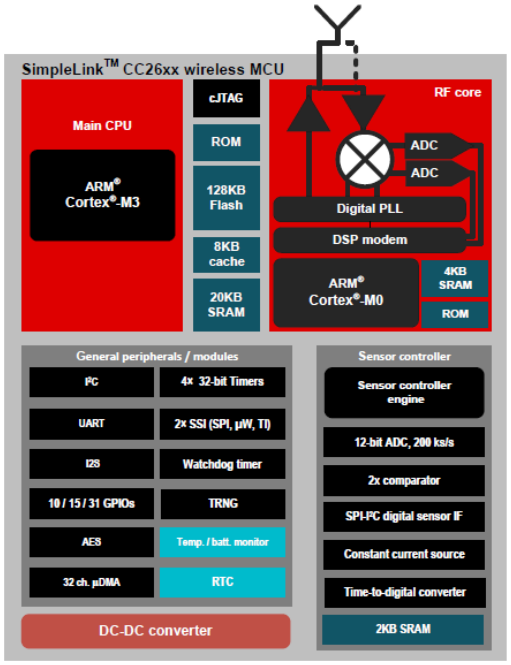



Figure 48: CC260 Sensor Tag architecture.

### 6.4.1 Linking Sensor Tag with PC

The sensor tag needed to be connected to the PC as the data was meant to relay to Unity which resided client-side (on the PC). To achieve this the Bluetooth is enabled on the PC and the device was turned on. An LED on the sensor flashed when the sensor was active, from the PC side the Bluetooth device manager was initiated to search for active Bluetooth enabled devices like the sensor. The sensor appeared on the device list and was selected for pairing, creating a link between the PC and sensor device whenever each device (sensor or PC) was enabled.

The pairing did not recap the results needed to actively pair the devices, although from the documentation attached to the sensor, if a sensor was not able to actively connect to a PC or other devices, a Bluetooth 4.0 dongle was needed. To further enable this pairing, a Bluetooth 4.0 dongle was sourced and installed on the PC, once established the sensor pairing was commenced once again this time with unbalanced results. The sensor was paired as the label on the Bluetooth manager read “connected”.

Even though the sensor was connected there was no positive flow of data communication between the sensor and the PC. After more research into the chosen sensor, the PC does not natively support the BLE sensors and needed a special BLE adaptor. Even after sourcing two separate BLE and Bluetooth 4.1 adaptors the connection between PC or MAC and the Sensor Tag used a multitude of separate techniques which wielded poor returns (Texas Instruments Community, 2016). These returns were in the form of graphical representation and did not lend themselves for data manipulation (which was needed in for Unity 3D interaction). As the TI Sensor Tag showed more promise in its specifications then the other sensor products researched, there needed to be an alternative method sourced to visualise the sensor connection both on Unity through a PC connection and on a mobile device. After investigating possible outlets, two methods of presentation were apparent. One of these methods was the use of a cloud connection, sending and retrieving data via an IoT (Internet of Things) service. The second was the use of a mobile device configuration from Unity 3D and subsequent thesision of the mobile devices screen on a PC.

### 6.4.2 Connecting Sensor Tag with Unity 3D

After establishing the methods of PC connection, each connection was tested for its ease of integration into the Unity platform and for its ability to move the test fetal model using the data from the TI Sensor Tag. The first method was the use of the IoT cloud service. The sensor tags were issued with an IOS application which visualised the sensor data which included the key orientation data needed and an array of additional light, temperature and humidity data. Another feature of this dedicated application from Texas Industries was its ability to send data to a number of cloud services. As direct connection between the sensor and PC was not possible, the cloud service offered an alternative method of communication of data between PC and sensor through the use of the internet. One of these cloud services known as “Dweet” (Dweet.io, 2016) was used to host the data online so that the data could be used in the Unity platform. Dweet presented the all of the data relaying from the sensor in JSON (JavaScript Object Notation) format. This format offered the data online (server-side) but there needed to be a method of data collection from the client-side (PC). In order to achieve this, the JSON data was parsed (in C# syntax within Unity 3D) into an array and the relevant components of the array identifying orientation were isolated.

Once isolated these orientation objects were converted into string and declared as variables for rotation manipulation within the Unity thesis. As the Dweet data did not automatically update online, the data needed to be updated from the associated script. In order to do this, a time interval was set to refresh the function of data retrieval every millisecond. This in turn enabled the fetal object to react to the change in variable data. Although the connection was established and reaction of the 3D model to the sensor was created, the movement was severely slow due to the multitude of connections from sensor to device, device to cloud, cloud to PC and PC to Unity thesis. These connections caused latency in the 3D model movements and were not reliable on real-time interaction. The second PC connection alternative involved direct mobile interaction and then thesision to the PC. This enabled a large PC view with the additional mobility advantage of the mobile device. As the sensor tag could connect to mobile devices with greater ease due to the presence of BLE compatibility, a BLE Unity application plugin was used to establish a retrieval of the specific orientation datasets from the sensor to the BLE enabled mobile device.

A Unity thesis was created with the intention of android deployment (creating an android application), this thesis contained scripts that listened for BLE sensor inputs whilst simultaneously assigning these incoming inputs into blank variables for the fetal models orientation. From these scripts, the data received was mapped against the same structure found in the Android IMU example. This sample structure like the Android IMU API, retrieved the raw data from the sensor, converted it into usable string, and linked these string units to variables referring to object orientation.

Like the Python code before it, the data was segmented so that only the Accelerometer, Gyroscope, and Magnetometer data was submitted. In the script assigning the orientation values a GameObject parameter was added so it would be utilised when linked to a 3D environment object. Once created the scripts were submitted to the asset folder of the example thesis. To establish a connection between the script processes and the 3D fetal object, the scripts were dragged onto the fetal object in the hierarchy window, this created orientation functionality for that object. Once the connection was recognised between the 3D object and the Bluetooth orientation scripts, the functionality needed to be tested. This test was conducted by deploying the Unity thesis to an android application, transferring the application file (APK) onto the mobile device and running the application on the device while switching on the sensor tag.

Once on, the sensor tag device was able to rotate the 3D fetal model 360 degrees from the Gyroscope, with some position allocation from the Acceleration but in a limited capacity.

This was not a draw-back as the space in which the physical model would reside in (PROMPT simulator, HPS – Abdomen Model) would offer limited space. To make the application viewable on the PC, a mobile to PC screen mirroring tool known as Vysor (Vysor.io, 2016) was used to mimic the visuals represented on the mobile device onto the PC. This tool enabled clear enlarged viewing of the mobile application (including the 3D model rotation) with added PC interaction of the emulated mobile window. This mobile and PC enabled Unity thesis provided a clear example of the possible interactions users could be presented with during 3D model manipulation.

As this functionality was present, the design and structure of the application and HPS incorporation needed to be created around the example to finalise the final resource prototype.

## 6.5 Final Simulation: Physical and Digital Amalgamation

To create the final hybrid simulation resource that accumulated the multimedia from previous chapters and the focused learning style results from the Obstetric students, the sensor tag manipulation needed to be amalgamated with the client-side procedural focused application and the physical HPS simulation. To continue developing the resource, each stage needed to be fully realised, this meant creating the application design, framework and connecting it to the HPS.

Additionally, to export this application a solid platform was needed to display its content, so an Android Smart Tablet was used to house the content for roaming freedom. This full setup also needed to be beta tested to conclude that the prototype was going to work and be fully functional for obstetric student used.

### 6.5.1 Design and framework

The aesthetic and framework of the final resource was outlined around the functionality created using the sensor tag. This design was also shaped from the UI preferences and learning styles of the Obstetric students, crafting a user interface reminiscent of the concepts drawn for the previous video and 3D resources.

Applications created in the previous chapters for 3D and Video were incorporated in some fashion into the application, this creating a more linear construct to the development of the final piece. When constructing scenarios for the main procedural focus, the 3D applications previously created were taken into account.

As the main procedural test focused on the orientation of the 3D baby during a delivery and most of the interaction was haptic using the sensor activated fetal model, the touch screen was still ripe for interaction too. To inform this interaction, the 3D applications were integrated into the 3D fetal model and initialised on selection of a particular fetal body part, for example on selection of the fetal head the students were presented with the "Fetal Head Examination" (fetal head selection – FHE) application, similarly with the "Placenta Position" (placenta selection - PP) or "Fetal Heart Rate" (fetal chest selection - FHR).

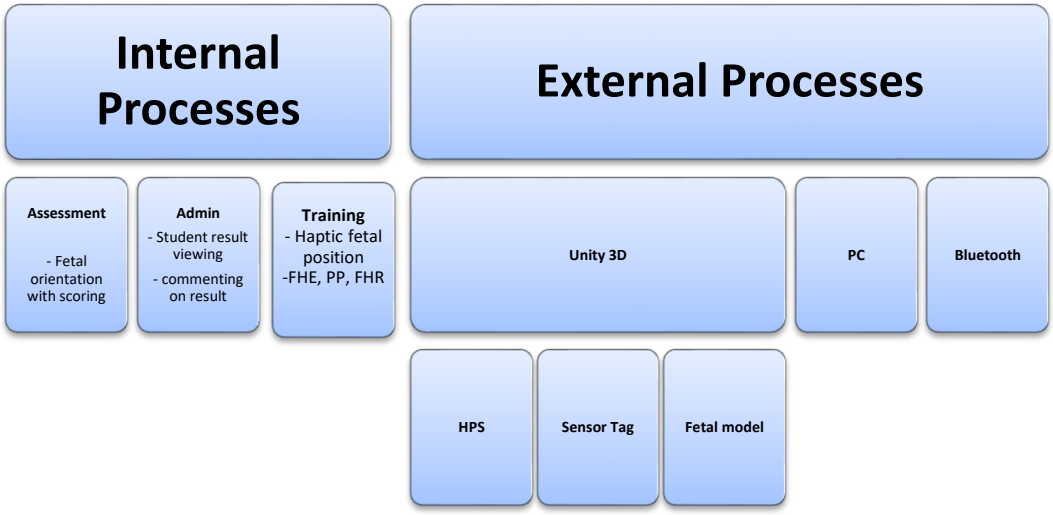



Figure 49: Final resource Internal and External structures.

As illustrated in the mesh graph seen in Figure 50, the structure of the concurrent processes attributed to the resource system. Externally the physical models and sensor are presented as they are enabled for data transfer via Bluetooth to the PC and subsequently Unity 3D.

Illustrated in the internal processes are the different user interaction sections including the Training area which enables the orientation haptic feed training and the series of 3D applications tasks (FHE, PP, and FHR), the Assessment area were a series of parameters are set for the students to conduct a certain type of Obstetric delivery procedure and the Administrative area for the staff to tally the students results and review.

### 6.5.2 Internal Content Construction and Scene Creation

In order to create this internal content, three separate scenes were created and added to the example Unity thesis which later became the finished Unity thesis. Unity scenes contain the objects of a game or application in a Unity thesis. They can be used to create a main menu, individual levels, and other components.

The three scenes created consisted of the key internal structure components e.g. the Training, Assessment and Administrative scenes. When creating the individual scenes, different components needed to be added to the hierarchy depending on the scene, both the Training and Assessment scene had virtually identical scenes but differed in the scripts and methods presented. The Administrative scene entailed a standard UI with labels hinged on the outcomes of the Assessment data. The least demanding scene to create was the Administrative scene as its main functionality involved employing a two sub-scenes, a login and a display scene. The login screen used dependant username and password variables with the text fields and the display scene presenting the student's score alongside game attempts. This method of using the PHP component and Unity WWWForms as a Webview was enabled to alleviate the over loading of the thesis with server connections.

Having this form of Webview enabled external data visualisation and could be easily displayed through the component panel as it was textual information. In order to create the Webview functionality a series of aspects needed to be linked to the Webview, these included a PHP script to display the data, a Unity script to get the data, and a database to store the data from the Unity thesis. The variables for the database included Student Name, Score, Attempts all of which were only accessed through a password portal for the lecturer with a standard generic username and password. The database was created through SQL and the dedicated variables were included awaiting server connection from the application.

The PHP script retrieved the data from the database and visualised the data in an appealing format, granting the lecturer to distinguish between multiple students in a grouping table displaying the database variables and their results.

The Unity script dedicated to retrieving the separate variable data was located within the hierarchy of the Assessment scene, as the script tallies the results and other details from the Assessment scene and sends it to the database.

The Webview brings all of these components together as it was able to visualise the PHP script server-side to view the database table remotely on the application.

The next scene created was the Training scene which incorporated many created models as part of the full thesis. The models were filed into the asset folder of the thesis and subsequently filed into the hierarchy list of the Training scene.

The training scene was sectioned into three different parts, the first being the already created informative mini games (Placenta Position etc.), the second being the video, 3D instructions and the last section comprised of the haptic input with prompts. As the former sections had been created and exported previously, the focus was mainly on the creation of prompt generating on positive interaction between the external simulation and the Unity thesis to convey a procedure accurately.

In order to process these sections and generate the application efficiently, the prototype of the end result needed to show at least just one procedure to present a working example. Other procedures could be processed after initial proof of concept.

To create the prototype procedural example training, one procedure was created, this procedure was a normal delivery. To create a learning process during training, markers needed to be generated to lead students through a delivery with a mapped path. A structured blueprint was created to anticipate several training scenarios, these scenarios were given dedicated markers and informative labels. The three delivery scenarios omitted in the training section were the delivery of the baby model in an OA (Occiput Anterior), OP (Occiput Posterior) and Transverse Lie Position.

The structure of the application design can be seen in Figure 51.

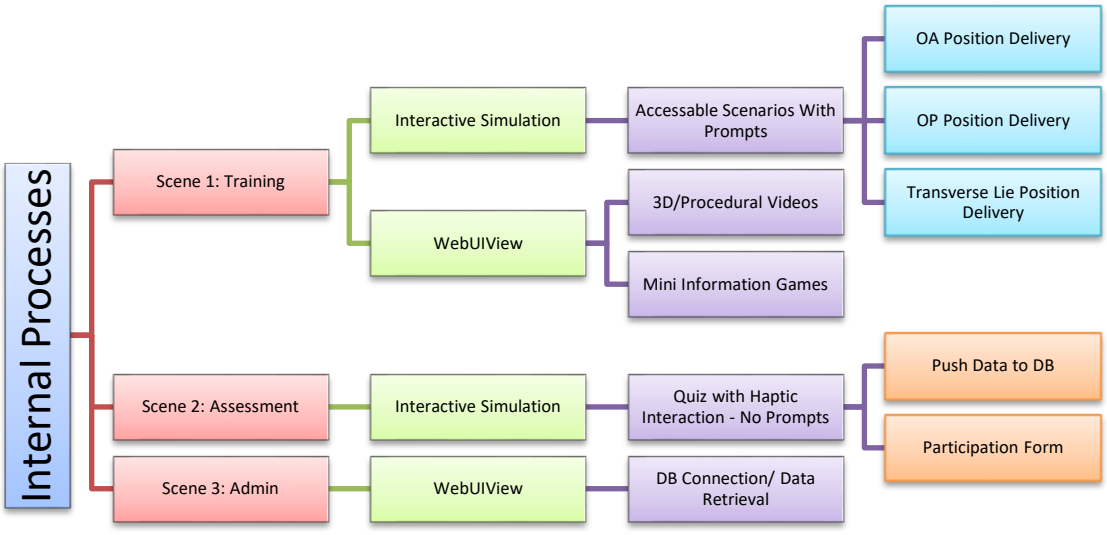



Figure 50: Application internal structure path.

As the intricacies of the Admin section had been formerly described through the use of Webview implementation and will later be described in the linear process pipeline, the focus was turned to the key factors of Training and Assessment.

Each section/scene had its own interactive simulation connection the functionality within each differed in so form but the fundamental models and design stayed the same. The scenes incorporated a baby model, the placenta and umbilical cord all wrapped within an amniotic sac object with low transparency. A physics component called “Rigidbody” was added to 3D baby model. Inserting a Rigidbody component into this 3D object gave control of the objects movement to Unity's physics engine.

The Rigidbody component added to the fetal object pulled the baby model downward by gravity and enabled it to react to collisions and with incoming objects like the amniotic sac or a Collider component.

To ensure the 3D baby model stayed within amniotic with the force of gravity pulling the object down, a Collider partition needed to be developed around the amniotic sac. There was multiple types of Collider components to choose from when it came to adding them to the scene, these included Box, Sphere and Mesh Colliders. When testing each Collider on the baby object, the object was present within each Collider, and the baby object would then get thrown from the object because the Rigidbody detected collision within the Colliders.

The most convenient Collider to use was the Mesh Collider as it mapped its collision border around the shape of the mesh (material and object) associated with that object. As it stood the Mesh Collider attached to the amniotic sac was causing the 3D baby object to take the form of a thesisile and eject from the amniotic sac when running the application (on build). To tackle this occurrence two options were considered to ensure that the baby stayed within the amniotic sac, these included creating a perimeter around the amniotic sac using a number of Box and Sphere Colliders and inversing the method of collision in the Mesh Collider attached.

This is so that the 3D baby is affected by the outside conditions of the amniotic sac mesh. The first method was approached but presented a more cumbersome design and structure. The perimeter of multiple Box Colliders prevented the baby from exiting the amniotic sac but the design had a lot of holes and gaps where the baby would eject into 3D space. This did not seem like a solid outlet to structure the Training and Assessment learning scenarios.

The other option of inversing the Collision needed to occur through reversing the normal of the mesh it associated with. To achieve this, script was written that enabled this switch of Collision function called *ReverseNormals.cs*, focusing on the inverting of the mesh filter.

The script was added to the mesh of the amniotic sac model which enabled the inverse change and prevented the model form exiting the amniotic sac.

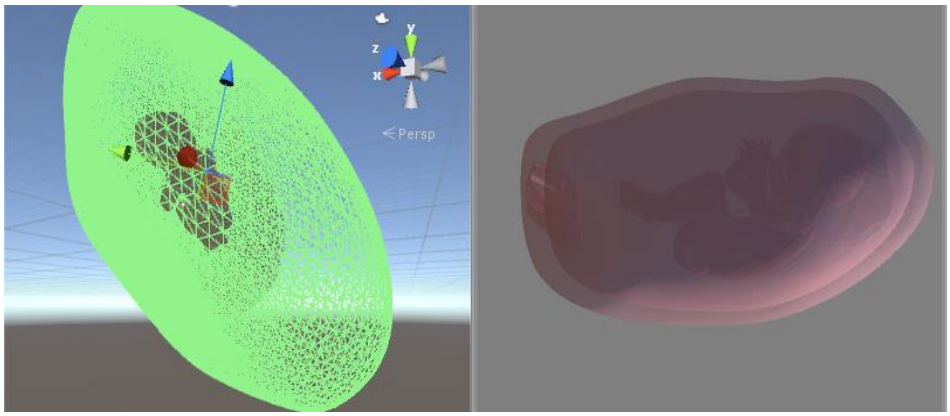



Figure 51: Mesh Collider in use with the Reverse Normal technique.

The next step was to enable the sensor tag to test the movement of the 3D baby within the bordered amniotic sac (on mobile application deployment). The model moved but only relative to the borders created by the Colliders. This meant that the focus was drifting towards creating the training modules of the application. To create ease of use, an option to move the 3D camera to another point within the 3D space was introduced. This change in camera orientation was achieved by attaching the camera to an empty GameObject and animating the blank object along a set circular track.

This circular mapped track was laid around the fetal model and associated models marked with key animation stop-points at main angles of focus referencing the focal object which was the 3D abdomen and all the models within.

Therefore, if the 3D babel model was to reach the cervix of the abdomen model or if the student interacted with the created camera components, the camera would swing around to the front of the model focusing on procedural segments like the crowning or the final delivery processes. To create the training process of OA, OP, Transverse Lie Delivery, some sort of prompt technique was needed to guide the student through delivery in steps. Even if the supplementary videos along with the mini serious games were provided the haptic interaction needed a form of instruction directive, from this need the information marker path was created.

The idea behind the IMP (information marker path) was to have a responsive path for which the model could track and successfully travel to the inevitable delivery outcome depending on the training process in session. To do this markers were created which had a distinct colour to distinguish them from the rest of the models in the environment.

These markers were spherical and placed in key points within the amniotic sac, the markers created a line at which the students would follow.

Code was then implemented to have function when the 3D baby model collided with the IMP markers. In the script generated for the IMP, a scoring variable was created which was initially left blank, a GameObject was also referenced which referred to the created IMP markers. Once there was a link between the IMP script and the IMP marker, a "destroy object" function was created to remove each IMP marker on collision by the 3D baby model. In addition to the "destroy on collision" function two other conditions were added to the IMP script code to add more functionality.

The first was the recording of score from destroying IMP markers, within the function of destroying the markers the variable for score was indicated for incrementing, meaning the score variable (which was original was set to 0) would increment by 1 every time an IMP marker was destroyed.

A simple HUD (heads up display) was created to show users their score in progress, viewing the numbers as they increase every time a marker is hit. The second implementation was a GUI (graphical user interface) label injection on entering a certain part of the amniotic sac.

For example the GUI label would appear after a certain point down the trail of the IMP, this point could be the point of crowning where a GUI label could be deployed with a label (like the HUD) appearing giving instruction on how to support the baby's head on delivery or the best practice in delivery of the head and shoulders. This was achieved through implementing empty GameObjects in the necessary segments of importance in the amniotic sac and adding an "onEnter" function to throw a UI label display on entering the GameObjects hit radius. An example of this can be seen in Figure 52, the abdomen and pelvic models were removed to show the amniotic sac more clearly.

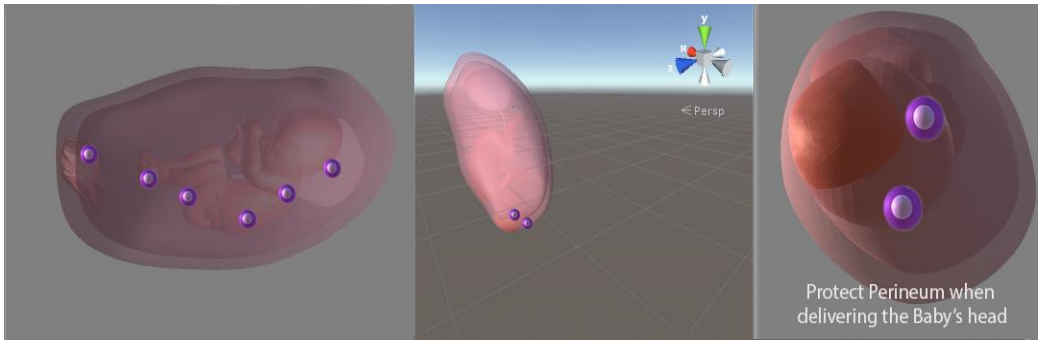



Figure 52: IMP Marker position and removal, label injection on entering empty GameObject.

These markers were changed on completion of a certain procedural scenario, the empty GameObjects and IMP markers orientation changed to adhere to the particular delivery process. Once having a basic training module setup the same simulated interactive response needed to be produced by the Assessment scene/section.

There were some similarities between the Assessment section and the Training section having the majority of the 3D environment duplicated across the Unity thesis. As a whole, the Assessment section was mainly focused on the sensor orientation input generating the testing aspects on the real-time input by the students. The IMP used in the Training section was again used for the Assessment section, however on this occasion the IMP markers were removed and replaced by empty GameObjects. These empty GameObjects were used so that the student users were not able to view the path to a successful delivery process. The objective of the assessment was to let students incorporate the manoeuvres they learned from training without prompts or hints assisting the student in the tests completion.

The score label and UI label injection were also removed, although the score variable was retained to keep calculating the hits generated from the empty GameObjects.

This score variable and its calculated results were then exported to a dedicated database table using a combination of C# and PHP using WWWForm. Once inserted into the "ObApp" database table, the data was kept there until being directly used by either the lecturers or author. This component was implemented on all sections including scene 1 (Training), scene 2 (Assessment) and scene 3 (Administration).

The use of the Webview on scene 1 was due to the Training sections access to informative material. The Webview component would display a webpage with a tabbed CMS (content management system) boasting the 3D and procedural videos creating in the previous chapters alongside the mini games created including but not limited to the fetal head examination.

In the Assessment section the Webview controller was used to house a form of potential questions submitted by lecturers to students before using the physical simulation. This Webview was a placeholder created to enable the lecturer to set test questions for the student using a CMS site generated by the author. In terms of its use on the Administration section, the Webview was connected to a PHP created site enforced by a single user login (one username and password given to the lecturers – subject to change over time).

Once connected through the login, the lecturers were greeted with a table of student's names, scores and potential answers to lecturer created questions. This landing point of the simulation grants the lecturer the freedom to review a student's progress and additionally implement new tasks with ease.

In addition to the created scenes and implemented functionality of the Unity platform and sensor integration, the application needed to have a functioning UI. The UI created for the final resource incorporated the fundamental preferences established by results from the obstetrics students in Chapter 3.

### 6.5.3 Physical Simulator and Sensor Setup

After creating the internal application, establishing its connection to a sensor and subsequently moving the sensor in cooperation, the resource needed to be connected to a physical HPS (human patient simulation) to finish the haptic interaction and aesthetic.

Initially, when in development of the simulation structure, a mock HPS (created using a store bought baby doll and an enclosed box) were used to represent the spatial constraints of the HPS and the fetal model pairing. Before obtaining access to the obstetric HPS in UCC, this mock simulation was used to test the sensor interactions with the Unity application within a confined space (like the inside of the HPS abdomen). The sensor was cut into the baby model to hide the sensor during the interaction. The boxes space enabled the restriction within the simulated womb presented in the HPS. This activity enabled multiple practice builds of the interaction and communication of the sensor driven HPS and the 3D aided simulation application.

After some practice and final granted access to incorporate the sensors to the HPS, the sensor was attached to the fetal model provided by the HPS and inserted into the abdomen of the simulation.

The application and HPS communication was tested with the new parameters and generated positive results as there was no loss in communication, also the restrictions of space were not as limited as the mock tests.

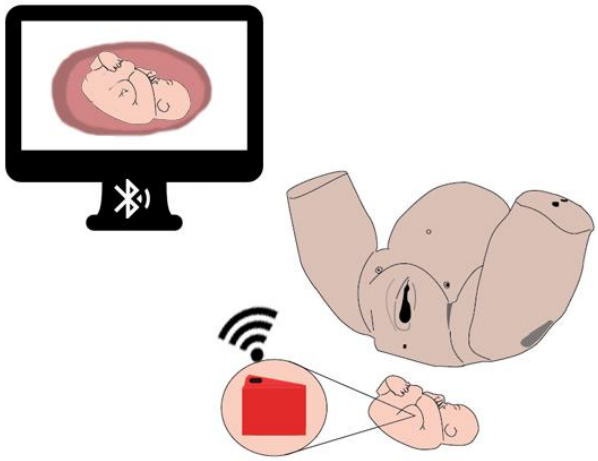


Figure 53: Final Physical simulator and sensor setup.

### 6.5.4 Performance testing

Performance testing was conducted on the finished resource to establish the notable high points or issues with the resource when in use. Like previously mentioned, the prototype was limited to a small number of actions and processes for the purpose of proving the concept of a full 3D / HPS hybrid system for teaching and learning.

The goal of the performance test was to prove that the resource could function and endure potential user interaction and pass as a usable prototype.

The test conditions to be similar to the expected actual use, having the devices and models in close proximity to each other and all connections established.

The performance test included stress testing, and isolation testing. Other performance tests were not considered due to the maximum user intake per resource session being one, and these tests would have not been applicable. The stress testing used involved an overload of user aided prompts and inputs to determine the resource's robustness, while the isolation testing involved repeating a test execution that resulted in a resource problem, isolating it then confirming the issue or fault. Performance testing was conducted instead of the typical usability test because ethical approval needed to be granted before having students test the resource and using the PROMPT simulator on students. The performance test granted an evaluation of aspects attributed to the full resource and outline notable progressions when observed.

To stress test the resource multiple application scenes were accessed at a rapid pace while also using the sensor. This was registering multiple data inputs externally and internally. The resource ceased to respond (froze) but managed to slowly recuperate from this while loading the data. This showed that even at with a large amount of user activity the application and subsequent resource failed to crash. The multiple inputs that caused the delay in operation were once again repeated and logged for the purposes of the isolation test. The results showed a decrement in the elapsed time during the display freezes before resuming functionality.

From booting the resources mobile device controlled application the freezing occurred between 10-20 seconds before resuming functionality when stress testing. After 5 minutes of resource use, the stress test caused 5-10 seconds of elapsed freezing or hanging time. When testing the assessment and training scenes within the resource, the reliability of the sensor was assessed by checking the sensors tracking distance of the sensor, the real-time performance of the sensor, dropping rate and latency.

As the sensor was contained within a fetal model which in turn was within an abdomen model, the degrees of freedom of the sensor were limited to the abdomens internal space. This was acceptable as the point of interest when conducting the experiments on the resource were the processes within the abdomen model. Some collisions off known colliders within the 3D space (amniotic sac) caused some disruption in orientation creating some inaccurate orientation readings.

The BLE compatibility on the mobile device enabled more than 100 metres of distance or range between it and the sensor, but it didn't need to be more than 1 metre. The rate at which the orientation data was transferred via Bluetooth was 1Mb/s noting that the orientation data was considerably lower than 1Mb.

Even with this quick data response time there was a noticeable delay in the matching of the 3D model and the sensor aided real-time actions. The latency of these sensor aided model to 3D model reactions was estimated at roughly 6ms. This delay was only a matter of milliseconds which did not disrupt or hinder the real-time experience. As the sensor used has a multitude of unused sensors this could be affect the data acquisitions. A sensor developed specifically for this resource would invoke a better response time and in turn a more coordinated 3D model reaction. The next step from these performance tests were usability tests which could be potentially be conducted as a research progression from this study.

## Summary

In this chapter the background of Simulation and its many forms (including physical and digital) were discussed in relation to Medicine and Education. From the examples shown, simulation has a significant role in creating a physical learn by doing platform to students and practitioners. Like the 3D examples in previous chapters, simulation in both in its physical or digital capacity can accurately portray procedural scenarios and allow students to fully engage themselves in a virtual environment and train with no risk of patient morbidity.

The importance “learn by doing” is a key aspect of the obstetrics student learning style results, this concept is combined with the students need for visual representation to create a hybrid 3D and HPS simulated learning experience through the acquisition of the obstetric students’ preferences and needs. During this chapter the creation of the system was quite taxing as shown from the many tested sensor types from which the thesis did not progress. Once the finalised sensor and approach was established, the hybrid simulator was created through the use of combining applications created as described in previous chapters, with the haptic centred real-time simulation training and assessment. These aspects were complemented by the integration of a review process page created for the lecturers to assess student progress and create their own assessment components. The creation and successful completion of the simulation hybrid enables the introduction of an interactive and immersive digital learning experience within an academic setting which is lacking in most fields of medicine and other disciplines.

# Chapter 7. Conclusion and Recommendations

The work described in previous chapters of this thesis contributes new knowledge to the area of hybrid computer aided learning in obstetrics and its alignment with student centred designs formed with student preference influence. In this body of work an array of distinct influential areas of learning technology, including online learning and learning styles design, 3D manipulation and integration, complex video interaction, simulation and an amalgam of all these areas were reviewed and scrutinised with reference to meeting and improving the educational needs of obstetric students. Having reviewed previous research on each of these areas of technological and computer aided learning, there was evidence of an overall positive response in terms of the acceptance of future emerging technologies in medical education and in the field of obstetrics. This finding supported the proposal that a merged-media simulated e-training resource would be beneficial to the students and would positively affect the learning outcomes of the obstetric students.

Findings from published literature largely supported a combination of multiple affiliated aspects of technology as are present in the final full learning resource.

On the merit of the reviewed literature, each element of the learning resource was assessed within the linear progression of this thesis and the positive and progressive aspects of each component is apparent in the final resource.

The steps taken and methodology throughout the process progression (e-learning, 3D etc.) as outlined in the previous chapters were informed by the recommendations of previous research on each component. The e-learning resources were created using responsive sites and online databases for learning style score and student preference in terms of UI and their overall learning process. A survey was conducted, acquiring these attributes to later be used in multiple constructive ways throughout the finalised thesis cycle. The e-learning aspect of this resource is significant as e-learning is already proven to be utilised and successful in medical education toady. These online courses and multi-media driven learning devices can prove to be as beneficial in teaching students a subject to a specific skill as a traditional course, but with the additional benefit of mobility and freedom on the part of the student and the tutor. This is supported by Hadley et al., (2010), who found that students achieved the same score when conducting tests within a traditional or digital environment.

In some cases, the more digitally inclined courses surpassed the traditional courses noting increases in knowledge procurement (Hassan et al., 2013). This also applies to simulation integration where digital tasks perform just as well if not better than the more traditional simulation teaching strategies. One of the objectives of this thesis as outlined in the e-learning chapter was the procurement of the learning preferences of student. Therefore, a learning styles model needed to be obtained, distributed and tested with the students. The model needed to be adaptable to changing opinion and contain a robust list of possible user/student learning styles (Adetunji et al., 2014). A number of models were subjected to scrutiny and one learning styles model in particular, the FSLSM (Felder-Silverman Learning Styles Model), had the potential prerequisites to fulfil the creation of a robust comprehensive examination of the typical learning preferences of a group of obstetric students. It was suggested by Cemal Nat et al., (2011) that the acquisition of the learning preference in order to create a suitable platform presents itself as a type of adaptive design, creating the application around the student preference.

Cemal Nat et al., (2011) suggested the use of the FSLSM within an application that was seeking to incorporate adaptive learning and to work with a robust amount of attribute laden results. The 3D, virtual reality and usage of 3D visualisation was important in the visualisation of the key aspects of obstetric procedural processes and actions. The visual representation of these internal processes granted students with an interactive and more detailed look at these processes to better understand them. From the research reviewed, 3D and VR was associated with beneficial ways of essential teaching, counselling and surgical skill attainment in obstetrics (Letterie, 2002). The 3D aspect was chosen for this thesis due to its ability to detail orientation in ways a 2D object could not. In addition, the interaction with 3D space grants more freedom for the student to interact with the components.

According to the literature, 3D is a viable alternative to 2D especially when referencing obstetric material (Beryl et al.,2005). Previous studies in other disciplines possessing similar concepts as the 3D environment aspects within the final resource in this thesis, have introduced VR into curricular study.

One study using VR in training of laparoscopy showed positive results and feedback from users after repetition of the given tasks (Aggarwal and Tully et al., 2006).

This showed the value of repetition in tasks however in medicine or obstetrics, the repetition of tasks cannot be easily done multiple times in real-life training scenarios but only observed and detailed. Research also suggests that the introduction of 3D provides a clinically relevant understanding of the obstetric processes (McCarthy et al., 2016). When set on video as its means of distribution, the medium offered a means by which the students could interact with a platform to which they would have already been accustomed (e.g. YouTube etc.). The amalgam of video and 3D, set a new bar for video interactivity holding the same accustomed interactions, with elevated 3D interactivity and diverse content and components.

Video has previously been used for preparatory and examination purposes within obstetric training, by having students review their task through video playback (Gibeau, 2008). In the literature, Video was found to create a good point of reflection for students to revise or visualise their methods of practise. Following the created synchronising of video and 3D information resource in this thesis, this point of reflection was apparent as the students could reflect and progress through new insightful methods of skill or knowledge acquisition. The idea adopted from the literature of skill validation (Bahl et al., 2010), presented a positive feature to the online cross video platform and the finished resource.

According to the literature, simulation has been a key area of obstetric training, used in both visual (Amitai et al., 2006) and physical (Amitai et al., 2007) representation, with an acceptance of both by the obstetric students involved. One key need identified by the students was of tailored content (Freeth et al., 2009). In the present thesis, results from students learning style survey, provided evidence of their need for haptic features and visual aids and a positive reception to all connected media. These results informed the creation of the finished learning resource which has content tailored to the obstetric students learning styles and needs. The final learning resource fused the students desired features and also introduced a way to visualise obstetric processes (such as normal birth), along with creating function between the physical and visual representations. The final resource is therefore a combination of all aspects of learning preference identified by the students, from tailored features to the hand-on visual inputs in a fully rounded obstetric training platform and learning experience. The hybrid aspects work in tandem providing the students with a multipurpose resource that can improve their procedural skills, educate through informative visuals and assess student learning with tutor feedback and input.

## Limitations

Through the course of the research and resource development there were a number of limitations. These are mainly due to delay or latency in processes to completion. There are a number of components within the final learning resource (e-learning, 3D, video, and simulation) that involved a long process and work that would be more readily completed within a team. The technology available to this thesis was limited in some instances, for example for rendering of 3D animations. The performance of rendering was very time consuming and this hindered the results presentable in terms of 3D. High performance computer systems or 'render farms' are available to companies like PIXAR or DISNEY with the sole purpose of CGI rendering on a large scale. The 3D animations of a few minutes duration needed for the learning resource took days to render using the technology available to this thesis.

These would be generated within a few seconds in render farms. The acquisition of sensors also proved difficult and there was a great deal of time devoted to trial and error testing of possible compatible sensors. Most industries were unwilling to provide sensors or when sensors were provided most proved unsuccessful. Nevertheless, a great deal of learning was achieved from this process.

The sample size for usability tasks within the research and testing platform aspects of the thesis was also limited to the students accessible to the department and due to some non-participation of students. A larger sample size for each activity would be a more generalizable outcome or result. However, the thesis resulted in a new hybrid learning resource. This is a new concept with a prototype developed that is based on student learning preferences and has undergone preliminary usability testing with students. Although a usability test of the video platform has been conducted a full scientific test of the final software developed with associated statistical analysis has not been completed due to time limitations. This test could be the basis of future work and further development in the area of medical educational enhancement.

## Recommendations from this research

The concept and prototype has potential to be developed further and applied to many other disciplines and fields. Additional research and development is therefore recommended to enhance its potential in the future.

- The learning resource should be tested with a larger sample to secure a more accurate reading of its usability and judge the resource accordingly.

In addition, the testing of this resource could be completed with a wider student demographic to encourage its use within more medical or scientific professionals.

- The final resource could be further tested on obstetric students to fully round the results and further match them to their learning styles. These tests could alter the functionality of the resource and possibly create more immersive experience for students.

- As the resource was created in situ with the learning style of the obstetrics students, future iterations of this resource could adopt more adaptive learning capabilities. These iterations may include changing resource components, aesthetic and content based on the learning preference an individual in real-time rather than that of a group. This aspect could have so much potential in expanding learning and training methods within third level education.

- The resource would also benefit from additional material. There is room for further 3D creation and procedures, as these were limited in the project due to technical restrictions. An increase in available technology would also increase productivity of the finished resource and enable the creation of new content or material for it. Access to technology such as render farms could enable the creation of animations more efficiently and on a reduced time.

- Pro software could eradicate restrictive aspects of certain software packages e.g. Unity Pro – erase splash banner). There is also a need to have a simulation dedicated to the resource instead of having to adapt simulations like the PROMPT simulator to create the finished resource.

- As the prototype creates the foundation for possible adaptation, elaboration of key assessment or training components could be integrated. These components could refer to changes in layout (presenting interface components for training and not for assessment), interactive methods of tutor feedback and adapting this information as the session progresses. This opens up the prototype to

incorporate a more responsive and robust assessment/feedback system for both the student and tutor. Multiple scenarios and procedures could also be adopted into a resource library accessed through training or assessment.

- Complicated labour cases such as shoulder dystocia could be taught using multiple sensors to teach the precise techniques of delivery and added to this resource library. In terms of further research and resource integration, student usability and their experiences with the adapted prototype could be logged and altered to suit the needs of student and tutor. This data could be matched to the student's live subject assessment in comparison to a control group to observe notable differences in skill acquirement, ease of process, competence and confidence.

- This learning resource application was also created for use on mobile devices but was limited in its functionality. This aspect of the resource could be further developed to create better mobile access and a more improved and flexible application for students and lecturers.

# References


Adetunji, A. and Ademola, A. (2014). A Proposed Architectural Model for an Automatic Adaptive E-Learning System Based on Users Learning Style. International Journal of Advanced Computer Science and Applications, 5(4).

Aggarwal, R., Tully, A., Grantcharov, T., Virtual reality simulation training can improve technical skills during laparoscopic salpingectomy for ectopic pregnancy. BJOG: An International Journal of Obstetrics & Gynaecology (113, 12). 2006, 1382-1387.

Amitai Ziv, Shaul Ben-David, & Margalit Ziv. (2007) Simulation Based Medical Education: an opportunity to learn from errors. Medical Teacher, Vol. 27, No. 3, pp. 193–199

Amitai, Ziv. (2006) Simulation-Based Medical Education: An Ethical Imperative. Academic Medicine. Pp. 783-88.

Arch Virtual. (2016). Medical Environments in Virtual Reality. [online] Available at: http://archvirtual.com/thesis/medical-virtual-reality/ [Accessed 16 May 2016].

Arias, T, Tran, A, Breaud, J, Fournier, J, Bongain, A, & Delotte, J, (2016) 'A prospective study into the benefits of simulation training in teaching obstetric vaginal examination'. 2016.

Autry, A, Knight, S, Lester, F, Dubowitz, G, Byamugisha, J, Nsubuga, Y, Muyingo, M, & Korn, A, 'Teaching Surgical Skills Using Video Internet Communication in a Resource-Limited Setting', Obstetrics & Gynecology, Academic Search Complete. 2013. 122, 1, pp. 127-131
Available at:
http://www.statista.com/statistics/272835/share-of-internet-users-who-watch-online-videos/ [Accessed 20 Mar. 2016].

Bahl, R, Murphy, D, & Strachan, B, 'Non-technical skills for obstetricians conducting forceps and vacuum deliveries: qualitative analysis by interviews and video recordings', European Journal Of Obstetrics & Gynecology & Reproductive Biology. 2010. 150, 2, pp. 147-151.

Barskar, N. and Patidar, C. (2016). A Survey on Cross Browser Inconsistencies in Web Application. International Journal of Computer Applications, 137(4), pp.37-41.

Bhatti, I., Jones, K., Richardson, L., Foreman, D., Lund, J. and Tierney, G. (2011). E-learning vs lecture: which is the best approach to surgical teaching?. Colorectal Disease, 13(4), pp.459-462.

Beryl R. Benacerraf, MD, Carol B. Benson, MD, Alfred Z. Abuhamad et al.,Three- and 4- Dimensional Ultrasound in Obstetrics and Gynecology Proceedings of the American Institute of Ultrasound in Medicine Consensus Conference. JUM December 1, 2005 vol. 24 no. 12 1587-1597.

Biggs, J., Kember, D. & Leung, D.Y. The revised two-factor Study Process Questionnaire: R- SPQ-2F. The British journal of educational psychology, 71(Pt 1) , 2001. pp.133 –149.

Blair-Early, A. and Zender, M. (2008). User Interface Design Principles for Interaction Design. Design Issues, 24(3), pp.85-107.

Botella, C., Baños, R., Villa, H., Perpiñá, C. and García-Palacios, A. (2000). Virtual reality in the treatment of claustrophobic fear: A controlled, multiple-baseline design. Behavior Therapy, 31(3), pp.583-595.

Brennan, A., Zhang, J., Deluzio, K. and Li, Q. (2011). Quantification of inertial sensor-based 3D joint angle measurement accuracy using an instrumented gimbal. Gait & Posture, 34(3), pp.320-323.

Cao, X., Liu, Y. and Dai, Q. (2009). A Flexible Client-Driven 3DTV System for Real-Time Acquisition, Transmission, and Display of Dynamic Scenes. EURASIP Journal on Advances in Signal Processing, (1), p.351452.

Carleton.edu. (2016). Carleton College: Virtual Campus Tour. [online] Available at: http://www.carleton.edu/campus/tour/ [Accessed 13 May 2016].

Caron, F., Duflos, E., Pomorski, D. and Vanheeghe, P. (2006). GPS/IMU data fusion using multisensor Kalman filtering: introduction of contextual aspects. Information Fusion, 7(2), pp.221-230.

Cemal Nat, M., Walker, S, Dastbaz M., Bacon L, (2011). Learning design approaches for personalised and non-personalized e-learning systems. Teaching English with Technology, IATEFL Poland Computer Special Interest Group & University of Nicosia, pp 176-187 11(1).

Chao, T, Wendel, G, McIntire, D, & Corton, M 'Effectiveness of an instructional DVD on third- and fourth-degree laceration repair for obstetrics and gynecology postgraduate trainees', International Journal Of Gynecology & Obstetrics. 2010. 109, 1, pp. 16-19.

Chen, P., Lambert, A. and Guidry, K. (2010). Engaging online learners: The impact of Web-based learning technology on college student engagement. Computers & Education, 54(4), pp.1222-1232.

Chudasama, Rajesh K.; Godara, Naresh K.; Srivastava, Ratan K. (2009), Assessing computer literacy and attitude towards e-learning among final year medical students". IJMI, Internet Journal of Medical Informatics,Vol. 5 Issue 1, p1.

Cisco, (2016). Cisco Visual Networking Index: Forecast and Methodology, 2015–2020. [online] Cisco. Available at: http://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking- index-vni/complete-white-paper-c11-481360.html [Accessed 6 Mar. 2016].

Coffey D., Tabirca S., Greene R.,(2014). Obstetrics eLearning: Through the use of video and other media to enhance learning styles in Obstetric students. The 10th International Scientific Conference eLearning and software for Education, At Bucharest, Volume: 1.

Coffey D., Tabirca S., O'Riordan M., Greene R., (2015). The use of 3D modelling to aid visualisation in Obstetrics E-Learning. The 11th International Scientific Conference eLearning and Software for Education, At Bucharest, Volume: 2.

Coffey D., Tabirca S., O'Riordan M., Greene R., (2016). Investigating and Assessing the Learning Styles of Obstetrics Students. The 12th International Scientific Conference eLearning and Software for Education Bucharest, 10.12753/2066-026X-16-090.

Coffey, D.P., Tabirca, S.M, Greene, R. (2014) Analysis of Obstetric E-Learning, IWOOTI 23rd International Scientific Conference Mittweida, At University of Applied Sciences , Mittweida, Germany, Volume: 1.

Coffey, D.P., Tabirca, S.M, Greene, R., (2016). A Framework for Versatile Sensors in Medical Simulation: Assessing current sensor technologies to further their advancement in third level education. International Conference on Mathematics and Computer Science, MACOS, 2nd Edition.

Coffey, D.P., Tabirca, S.M, Mehigan, T., (2016) Evaluating the Learning Styles of Computer Science Students. International Journal of Computer and Information Technology IJCIT (ISSN: 2279 – 0764) Volume 05 – Issue 02.

Conklin, G., Greenbaum, G., Lillevold, K., Lippman, A. and Reznik, Y. (2001). Video coding for streaming media delivery on the Internet. IEEE Trans. Circuits Syst. Video Technol., 11(3), pp.269-281.

Coolen. (Kim, Jason, and Jillian) (2015) "A Prospective Cohort Study Using E-Learning Modules As A Supplemental Teaching Resource For Obstetrics And Gynaecology Clerkship Students." Journal Of Obstetrics And Gynaecology Canada: (JOGC) Journal D'obstétrique Et Gynécologie Du Canada: JOGC 37.9:819-823.

Cooper, S., Cant, R., Porter, J., Bogossian, F., McKenna, L., Brady, S. and Fox-Young, S. (2012). Simulation based learning in midwifery education: A systematic review. Women and Birth, 25(2), pp.64-78.

Dayal, A, Fisher, N, Magrane, D, Goffman, D, Bernstein, P, & Katz, N, (2009) 'Simulation training improves medical students' learning experiences when performing real vaginal deliveries', Simulation In Healthcare: Journal Of The Society For Simulation In Healthcare. 4, 3, pp. 155-159.

Developer.android.com. (2016). SensorManager | Android Developers. [online] Available at: https://developer.android.com/index.html [Accessed 23 Mar. 2016].

Dunn, R. Honigsfeld, A. Doolan, L.S., Bostrom, L., Russo K., Schiering M.S., (2009) et al., Impact of learning-style instructional strategies on students' achievement and attitudes. The Clearing House: A Journal of Educational Strategies, Issues and Ideas, 82 (3)pp. 135–14.

Dweet.io. (2016). dweet.io - Share your thing- like it ain't no thang. [online] Available at: https://dweet.io/ [Accessed 25 May 2016].

Freeth, D, Ayida, G, Berridge, E, Mackintosh, N, Norris, B, Sadler, C, & Strachan, A, (2009) 'Multidisciplinary obstetric simulated emergency scenarios (MOSES): promoting patient safety in obstetrics with teamwork-focused interprofessional simulations', Journal of Continuing Education in the Health Professions. 29, 2, pp. 98-104 7p.

Gaba, D. (2007). The Future Vision of Simulation in Healthcare. Simulation in Healthcare: The Journal of the Society for Simulation in Healthcare, 2(2), pp.126-135.

Galitz, W. (2002). The Essential Guide to User Interface Design: An Introduction to GUI Design Principles and Techniques; Second Edition. John Wiley & Sons. Pp 19-23, 169-171.

Gambadauro, P, & Magos, (2008) A, 'NEST (network enhanced surgical training): A PC-based system for telementoring in gynaecological surgery', European Journal Of Obstetrics & Gynecology & Reproductive Biology. 139, 2, pp. 222-225.

Gardner, C. (2015). Medicine's uncanny valley: the problem of standardising empathy. The Lancet, 386(9998), pp.1032-1033.

Ghost Productions. (2016). Urology / Gynocology 3D Animation & Video. [online] Available at: http://ghostproductions.com/gynecology-urology/ [Accessed 16 Mar. 2016].

Giannopoulos, K., Chronopoulou, K., Mystakidis, S. and Kostopoulos, K. (2014). E-learning through Virtual Reality Applications. The International Journal of Technologies in Learning, 21(1), pp.57-68.

Gibeau, A, (2008) 'Pregnant women's experience viewing childbirth preparation videos: an interpretive ethnography', Pregnant Women's Experience Viewing Childbirth Preparation Videos, CINAHL Plus with Full Text. pp. 316 p-316 p 1p.

Gill, D. (2011). Effective Blended Learning Techniques. Journal of College Teaching & Learning (TLC), 6(2).

Gilliam M., Rosenberg D., Davis F., (2002), The likelihood of placenta previa with greater number of caesarean deliveries and higher parity Obstet Gynecol, 99 (6) pp. 976–980.

Goh, J., Clapham, M. et al., The Clinical Teacher. 'Attitude to e-learning among newly qualified doctors', Volume 11, Issue 1, pages 2023, February 2014.

Google, (2016). Patent US20130044258 - Method for presenting video content on a hand- held electronic device. [online] Google Books. Available at: https://www.google.com/patents/US20130044258 [Accessed 20 Jun. 2016].

Graf, S., Viola, S., Leo, T. and Kinshuk, (2007). In-Depth Analysis of the Felder-Silverman Learning Style Dimensions. Journal of Research on Technology in Education, 40(1), pp.79-93.

Hadley, J. et al.,( 2010) Effectiveness of an e-learning course in evidence-based medicine for foundation (internship) training. Journal of the Royal Society of Medicine. 103(7), pp.288–94.

Hagino, T. (2011). HTML5. Eizo Joho Media Gakkaishi, 65(4), pp.467-470.

Hai-Jew, S. (2010). Digital imagery and informational graphics in E-learning. Hershey, PA: Information Science Reference.

Hassan, A. Life Science Journal. 'Effect of E-Learning on Knowledge Retention and Student's Achievement in Obstetrical and Gynaecological Nursing Curriculum', 2013; Dec; pp. 10871092.

Hea.ie. (2016). National Strategy for Higher Education to 2030 | Higher Education Authority. [online] Available at: http://www.hea.ie/en/policy/national-strategy [Accessed 22 Jun. 2016].

Healthysimulation.com. (2016). HumanSim Provides Advanced Virtual Healthcare Training. [online] Available at: http://healthysimulation.com/4035/humansim-provides- advanced-virtual-healthcare-training/ [Accessed 11 Apr. 2016].

Heinrichs LW, Youngblood P, Harter PM, Dev P. (2008) Simulation for team training and assessment: case studies of online training with virtual worlds. World J Surg. Feb;32(2):161-70. doi: 10.1007/s00268-007-9354-2. PubMed PMID: 18188640.

Herrington, J., Reeves, T., Oliver, R. and Woo, Y. (2004). Designing authentic activities in web-based courses. J. Comput. High. Educ., 16(1), pp.3-29.

Hong, H. and Kinshuk, (2004). Adaptation to Student Learning Styles in Web Based Educational Systems. EDMEDIA, 21-26.

Hoy, M. (2011). HTML5: A New Standard for the Web. Medical Reference Services Quarterly, 30(1), pp.50-55. https://developer.android.com/reference/android/hardware/SensorManager.html [Accessed 28 Apr. 2016]. doi:10.7150/ijms.8.439. Available from http://www.medsci.org/v08p0439.htm.

Hughes, C; Anderson, G; Patterson, D; O'Prey, M. (2014). Introducing an obstetric emergency training strategy into a simulated environment. British Journal of Midwifery (BR J MIDWIFERY); 22(3): 201-207.

I Am A Type 1 Diabetic. (2013). Type 1 Diabetes Video Game — The Magi and The Sleeping Star. [online] Available at: https://iamatype1diabetic.com/2013/11/17/type- 1-diabetes-video-game-the-magi-and-the-sleeping-star/ [Accessed 12 May. 2016].

Instruments, T. (2016). Can i connect to Sensor Tag from Windows 8 ? - Bluetooth® low energy Forum - Bluetooth® low energy - TI E2E Community. [online] E2e.ti.com. Available at https://e2e.ti.com/support/wireless_connectivity/ bluetooth_low_energy/f/538/t/237042 [Accessed 15 May 2016].

Issa N, Schuller M, Santacaterina S, Shapiro M, Wang E, Mayer RE, DaRosa DA. Applying multimedia design principles enhances learning in medical education. Med Educ. 2011 Aug;45(8):818-26. doi: 10.1111/j.1365-2923.2011.03988.x. PubMed PMID: 21752078.

Issenberg, B., Gordon, M., Gordon, D., Safford, R. and Hart, I. (2001). Simulation and new learning technologies. Medical Teacher, 23(1), pp.16-23.

Jang DG, We JS, Shin JU, Choi YJ, Ko HS, Park IY, Shin JC. Maternal Outcomes According to Placental Position in Placental Previa. Int J Med Sci 2011; 8(5):439-444.

Johansson, R. et al., (2016). Sensor fusion and IMU 26 Department of Automatic Control, Lund University Education. [online] Play.google.com. Available at: https://play.google.com/store/apps/details?id=imu3.imu5.app&hl=en [Accessed 6 May. 2016].

Jude, D, Gilbert, G, & Magrane, D, (2006) 'Simulation training in the obstetrics and gynaecology clerkship', American Journal Of Obstetrics & Gynecology. 195, pp. 1489-1492 4p.

Khan, K. S, Coomarasamy, A. (2006). A hierarchy of effective teaching and learning to acquire competence in evidenced-based medicine. BMC Medical Education. BMC series.

Kirkko-Jaakkola, M., Collin, J. and Takala, J. (2012). Bias Prediction for MEMS Gyroscopes. IEEE Sensors J., 12(6), pp.2157-2163.

Klein, A. and Lehner, W. (2009). Representing Data Quality in Sensor Data Streaming Environments. Journal of Data and Information Quality, 1(2), pp.1-28.

Knowles, M., Holton, E. and Swanson, R. (2005). The adult learner. Amsterdam: Elsevier.

Laerdal.com. (2016). PROMPT Birthing Simulator. [online] Available at: http://www.laerdal.com/us/doc/224/PROMPT-Birthing-Simulator [Accessed 21 Apr. 2016].

Lapeer R., Chen M.S. and Villagrana. J. An Augmented Reality based Simulation of Obstetric Forceps Delivery. Proceedings of the Third IEEE and ACM International Symposium on Mixed and Augmented Reality. 2004. 0-7695-2191-6/04.

Lauesen, S. (2005). User interface design. Harlow, England: Pearson/Addison-Wesley. pp 9- 12, 81-83

Leape, L. and Berwick, D. (2005). Five Years After To Err Is Human. JAMA, 293(19), p.2384.

Learn.chm.msu.edu. (2016). Obstetrics and Gynecology eLearning Modules. [online] Available at: http://learn.chm.msu.edu/apgo/ [Accessed 10 Feb. 2016].

Leeds, E. and Maurer, R. (2009). Using Digital Video Technology to Reduce Communication Apprehension in Business Education. INFORMS Transactions on Education, 9(2), pp.84-92.

Lepage, J., Cosson, M., Mayeur, O., Brieu, M. and Rubod, C. (2016). Pedagogical childbirth simulators: utility in obstetrics. European Journal of Obstetrics & Gynecology and Reproductive Biology, 197, pp.41-47.

Letterie, Gerard S. How virtual reality may enhance training in obstetrics and gynecology American Journal of Obstetrics & Gynecology , 2002. Volume 187 , Issue 3 , S37 - S40.

Liu, A. et al., (2016). 3D Printing Surgical Implants at the clinic: A Experimental Study on Anterior Cruciate Ligament Reconstruction. Scientific Reports 6: 21704.

Marcy, V. (2001). Adult Learning Styles: How the VARK© Learning Style Inventory Can Be Used to Improve Student Learning. The Journal of Physician Assistant Education, 12(2), pp.117-120.

McCarthy, R, Orsi, N, Treanor, D, Moran, O, Vernooij, M, Magee, D, Roberts, N, Stahlschmidt, J, & Simpson, N, 'Three-dimensional digital reconstruction of human placental villus architecture in normal and complicated pregnancies',

European Journal Of Obstetrics & Gynecology & Reproductive Biology, Academic Search Complete. 2016. 197, pp. 130-135.

McGaghie, W., Issenberg, S., Petrusa, E. and Scalese, R. (2010). A critical review of simulation-based medical education research: 2003-2009. Medical Education, 44(1), pp.50-63.

Medicalvideos, (2016). Medical Videos - Free Online Medical Videos, Health, Images, Audios-. [online] Medicalvideos.us. Available at: http://www.medicalvideos.us/ [Accessed 20 Jun. 2016].

MedTube, M. (2016). Medical Videos, Surgery and Procedures Videos, MEDtube.net. [online] MEDtube.net. Available at: https://medtube.net [Accessed 6 Mar. 2016].

Michahelles, F. and Schiele, B. (2005). Sensing and Monitoring Professional Skiers. IEEE Pervasive Comput., 4(3), pp.40-46

Microsoft.com. (2016). Internet Explorer End of Support. [online] Available at: https://www.microsoft.com/en-us/WindowsForBusiness/End-of-IE-support [Accessed 4 Feb. 2016].

Mioduser, D., Nachmias, R., Lahav, O. and Oren, A. (2000). Web-Based Learning Environments. Journal of Research on Computing in Education, 33(1), pp.55-76.

Montana.edu. (2016). Understanding the Global Positioning System. [online] Available at: http://www.montana.edu/gps/understd.html [Accessed 28 Apr 2016].

Moore, J., Dickson-Deane, C. and Galyen, K. (2011). e-Learning, online learning, and distance learning environments: Are they the same?. The Internet and Higher Education, 14(2), pp.129-135.

MotionNode. (2016). MotionNode Bus Specification. [online] Available at: http://www.motionnode.com/MotionNode_Bus_Specification.pdf [Accessed 28 Apr. 2016].

Moule, P. (2006), E-learning for healthcare students: developing the communities of practice framework. Journal of Advanced Nursing, 54: 370–380. doi: 10.1111/j.1365-2648.2006.03813.x.

Moulton, S. and Kosslyn, S. (2009). Imagining predictions: mental imagery as mental emulation. Philosophical Transactions of the Royal Society B: Biological Sciences, 364(1521), pp.1273-1280.

Myftiu, J. (2015). Individual Differences Considering Students' Learning Styles. MJSS.

Nilsson C, Lund, B., Jette, S., Srensen J. 'Comparing hands-on and video training for post-partum hemorrhage management'. Acta Obstetriciaet Gynecologica Scandinavica. 2014. pp. 5-9.

Noraxon USA. (2016). IMU Technology. [online] Available at: http://www.noraxon.com/learn-about-biomechanics-technology/wireless-inertial-measurement-technology/ [Accessed 29 Apr. 2016].

Nucleusmedicalmedia.com. (2016). Nucleus Medical Media - Home. [online] Available at: http://www.nucleusmedicalmedia.com/nmm1_7 [Accessed 16 May 2016].

Obando C, Maurer J, Plantegenest G, Dokter C. The Use of E-learning Modules to Improve Student Knowledge in Obstetrics and Gynecology. MedEdPORTAL Publications; 2014.

Obgyn-101.org. (2016). OBGYN-101 | Introductory Obstetrics & Gynecology. [online] Available at: http://obgyn-101.org/ [Accessed 10 Feb. 2016].

Oravcova, J., (2009). Learning styles of university students in relation to educational methods. The New Educational Review,19(34), 72-82.

Ortner, C, Richebé, P, Bollag, L, Ross, B, & Landau, R, (2014) 'Repeated simulation- based training for performing general anesthesia for emergency cesarean delivery: long-term retention and recurring mistakes', International Journal Of Obstetric Anesthesia. 23, 4, pp. 341-347.

Ott, K. (2013). Simulation in the Learning Environment. The International Journal of Technologies in Learning, 19(4), pp.49-53.

Parilo, D, & Parsh, B, (2014) 'Case Study: Student Perceptions of Video Streaming Nursing Class Sessions', Journal Of Nursing Education. 53, 3, pp. 161-163.

Paschold M, Schröder M, Kauff DW, Gorbauch T, Herzer M, Lang H, Kneist W. (2011) Virtual reality laparoscopy: which potential trainee starts with a higher proficiency level? Int J Comput Assist Radiol Surg.Sep;6(5):653-62. doi: 10.1007/s11548-010-0542- 4. Epub 2011. PubMed PMID: 21246302.

Pashler, H., McDaniel, M., Rohrer, D. and Bjork, R. (2009). Learning Styles: Concepts and Evidence. Psychological Science in the Public Interest, 9(3), pp.105-119.

Pattanasith, S., Rampai, N. and Kanperm, J. (2015). The Development Model of Learning though Virtual Learning Environments (VLEs) for Graduated Students, Department of Educational Technology, Faculty of Education, Kasetsart University. Procedia - Social and Behavioral Sciences, 176, pp.60-64.

Perception Neuron. (2016). Perception Neuron by Noitom. [online] Available at: https://neuronmocap.com/ [Accessed 29 Apr. 2016].

Persuasive Games. (2016). Persuasive Games - Fatworld. [online] Available at: http://persuasivegames.com/games/game.aspx?game=fatworld [Accessed 12 May 2016].

Póljanowicz, W., Latosiewicz, R., Slawomir, Terlikowski, J., (2012). The results of teching of subject "Obstetrics, gynecology and gynecological and obstetric nursing" with the use of e-learning platform at the Faculty of Health Science, Medical University of Bialystok in 2009 - 2012, 26(3), 191

.

Pun, C., Zhu, H. and Feng, W. (2011). Real-Time Hand Gesture Recognition using Motion Tracking. International Journal of Computational Intelligence Systems, 4(2), p.277.

Purnamasari, H. and Syifana, N. Prima D. (2014). Clickable and interactive video system using HTML5. The International Conference on Information Networking 2014 (ICOIN2014).

Re-mission2.org. (2016). Re-Mission 2: Fight cancer and WIN! Games for cancer support based on scientific research.. [online] Available at: http://www.re-mission2.org/ [Accessed 12 May 2016].

Remondino, F., Menna, F., Koutsoudis, A., Chamzas, C. and El-Hakim, S., (2013), October. Design and implement a reality-based 3D digitisation and modelling thesis. In Proc. IEEE Conference Digital Heritage (Vol. 1, pp. 137- 144).

Rhoads Kinder S, Cherepski A, Freeman K. E-Learning in Obstetrics and HIV: Utilizing Online Interactive Scenarios to Replicate Critical Decision Making Moments. JOGNN: Journal Of Obstetric, Gynecologic & Neonatal Nursing. June 2, 2014;43.

Rodríguez-Díez, M, Díez-Goñi, N, Beunza-Nuin, J, Auba-Guedea, M, Olartecoechea-Linaje, B, Ruiz-Zambrana, A, & Alcázar-Zambrano, J, (2013) .'[Confidence assessment among medical students trained with an obstetric simulator]', Anales Del Sistema Sanitario De Navarra. 36, 2, pp. 275-280.

Rose, N, & Eller, A, (2014). 'The impact of noninvasive fetal evaluation: its effect on education, training, and the maintenance of clinical competence in prenatal diagnosis', Current Opinion In Obstetrics & Gynecology. 26, 2, pp. 117-123 7p.

Roszak, M., Kołodziejczak, B., Półjanowicz, W., Bręborowicz, A., Ren-Kurc, A., Kowalewski, W. (2015). E-learning Portal Tools for Medical Education. Studies in Logic, Grammar and Rhetoric. Volume 43, Issue 1.

Russell GA. (2013) Vesalius and the emergence of veridical representation in Renaissance anatomy. Prog Brain Res.;203:3-32. doi: 10.1016/B978-0-444- 62730- 8.00001-3. PubMed PMID: 24041275.

Sabourin, J, Van Thournout, R, Jain, V, Demianczuk, N, & Flood, C, (2014) 'Confidence in performing normal vaginal delivery in the obstetrics clerkship: a randomized trial of two simulators', Journal Of Obstetrics And Gynaecology Canada: JOGC = Journal D'obstétrique Et Gynécologie Du Canada: JOGC. 36, `7, pp. 620-627.

Schopp, P., Klingbeil, L., Peters, C., Buhmann, A. and Manoli, Y. (2009). Sensor Fusion Algorithm and Calibration for a Gyroscope-free IMU. Procedia Chemistry, 1(1), pp.1323-1326.

Semeraro, F., Bergamasco, M., Frisoli, A., Holtzer, M. and Cerchiari, E. (2008). Virtual reality prototype in healthcare simulation training. Resuscitation, 77, pp.S60-S61.

Severi, F, Prattichizzo, D, Casarosa, E, Barbagli, F, Ferretti, C, Altomare, A, Vicino, A, & Petraglia, F, (2005) 'Virtual fetal touch through a haptic interface decreases maternal anxiety and salivary cortisol', Journal Of The Society For Gynecologic Investigation, Academic Search Complete. 12, 1, pp. 37-40.

Shoaib, M., Bosch, S., Incel, O., Scholten, H. and Havinga, P. (2014). Fusion of Smartphone Motion Sensors for Physical Activity Recognition. Sensors, 14(6), pp.10146-10176.

Sivasubramanian, K. and Pramanik, M. (2016). High frame rate photoacoustic imaging at 7000 frames per second using clinical ultrasound system. Biomedical Optics Express, 7(2), p.312.

Sørensen J, van der Vleuten, C., Rosthøj, S., Østergaard, D., LeBlanc, M., Johansen, M., Ekelund, K., Starkopf3, L., Lindschou, J., (2015) Simulation-based multiprofessional obstetric anaesthesia training conducted in situ versus off-site leads to similar individual and team outcomes: a randomised educational trial. BMJ Open. pp-5.

Sørensen, T., Therkildsen, S., Makowski, P., Knudsen, J. and Pedersen, E. (2001). A new virtual reality approach for planning of cardiac interventions. Artificial Intelligence in Medicine, 22(3), pp.193-214.

Statista, (2016). Percentage of internet users who watch online video content on any device in 2014, Online video penetration in selected countries 2014 | Statistic. [online] Statista.

Stratog.rcog.org.uk. (2016). StratOG Home Page. [online] Available at: https://stratog.rcog.org.uk/ [Accessed 10 Feb. 2016].

Sun, P., Finger, G. and Liu, Z. (2014). Mapping the Evolution of eLearning from 1977–2005.

Support.google.com. (2016). Supported browsers - Google Apps Administrator Help. [online]Availableat: https://support.google.com/a/answer/33864?hl=en [Accessed 4 Feb. 2016].

Svirko, E. & Mellanby, J., Attitudes to e-learning, learning style and achievement in learning neuroanatomy by medical students. Medical teacher, 30(9-10), 2008. pp.e219–e227.

Technologies, U. (2016). Unity - Scripting API: Vector3.operator - [online] Docs.unity3d.com. Available at: https://docs.unity3d.com/ScriptReference/Vector3-operator_subtract.html [Accessed 27 Apr. 2016].

Thalmann, S. Adaptation criteria for the personalised delivery of learning materials: A multi-stage empirical investigation. Australasian Journal of Educational Technology. (2014). pp.30 to Inform Understandings of eLearning Historical Trends. Education Sciences, 4(1), pp.155-171.

Todd, M., Manz, J., Hawkins, K., Parsons, M. and Hercinger, M. (2008). The Development of a Quantitative Evaluation Tool for Simulations in Nursing Education. International Journal of Nursing Education Scholarship, 5(1), pp.1- 17.

Tyndall Institute. (2016). Inertial Sensing Systems Movement tracking & orientation estimation. [online] Available at: https://www.tyndall.ie/content/inertial-sensing-systems [Accessed 27 Apr. 2016].

Ucc.ie. (2016). Ethical Approval| | School of Medicine UCC. [online] Available at: https://www.ucc.ie/en/medical/currstud/aboutprog/procedures/ethical/ [Accessed 5 Feb. 2016].

Ushikubo, T. (2002). Why Do Movie Films Run at 24 Frames Per Second. The Journal of the Institute of Image Information and Television Engineers, 56(4), pp.558-559.

Valaitis, Ruta K.; Sword, Wendy A.; Jones, Bob; Hodges, Andrea. Problem-Based Learning Online: Perceptions of Health Science Students. Advances in Health Sciences Education, 2005. 22 pp. v10 n3 p231-252.

van Lonkhuijzen L, Groenewout M, Schreuder A, Scherpbier A, Aukes L, van den Berg P. Perceptions of women, nurses, midwives and doctors about the use of video during birth to improve quality of care: focus group discussions. British Journal of Obstetrics & Gynaecology (BJOG). 2011; Il8: 1262-67.

Vieille, P, Mousty, E, Letouzey, V, Mares, P, & de Tayrac, R, (2015).'[Assessment of gynecology obstetric interns training on birth simulator]', Journal De Gynécologie, Obstétrique Et Biologie De La Reproduction. 44, 5, pp. 471-478.

Vorbrich, K. (2011). Analysis of some low- and high-dynamics errors of Low-Cost IMU. Geodesy and Cartography, 60(1).

Vysor.io. (2016). Vysor. [online] Available at: https://www.vysor.io/ [Accessed 25 May. 2016].

Weideman, Y.L. and. Culleiton, A.L.(2014) A Virtual Pregnancy for Pre-Licensure Nursing Students: Nine Months Up and Close. Nursing Education Perspectives: 2014, Vol. 35, No. 6, pp. 410-413.

Who.int., World Health Organization. (2016). World Health Organization. [online] Available at: http://who.int/en/ [Accessed 23 Apr. 2016].

York, S, Maizels, M, Cohen, E, Stoltz, R, Jamil, A, Mcgaghie, W, & Gossett, D, (2014) 'Development and evaluation of caesarean section surgical training using computer-enhanced visual learning*', Medical Teacher. 36, 11, pp. 958-964.

Youssef, A., Salsi, G., Ragusa A., Ghi, T., Pacella, G., Rizzo N., Pilu, G (2015). Caregiver's satisfaction with a video tutorial for shoulder dystocia management algorithm. Journal of Obstetrics and Gynaecology. Vol. 35, Iss. 5.

Zambelli, A. (2016). Smooth Streaming Technical Overview : The Official Microsoft IIS Site. [online] Iis.net. Available at: http://www.iis.net/learn/media/on- demand-smooth-streaming/smooth-streaming-technical-overview [Accessed 8 Jun. 2016].

Zhang, Q., Lee, L., Gruppen, L. and Ba, D. (2013). Medical education: Changes and perspectives. Med Teach, 35(8), pp.621-627.

# Appendices

## Appendix A

Letter to the National Perinatal
Epidemiology Centre and Professor
of Clinical Obstetrics
XXXX Ireland
12/12/12

Director of The National
Perinatal Epidemiology Centre and
Professor of Clinical Obstetrics
XXXX Hospital
XXXX

**Re: Enhance the practice of Obstetrics Training/Education through 3D simulation and Mobile technology**

Dear ……..

I am currently undertaking a PhD in Computer Science and Obstetrics in University College Cork (UCC). As part of my study I am required to complete research on an area of interest within my professional scope. The research I have chosen is 3D simulation for Obstetrics. I wish to conduct this study using the expertise of both departments of Obstetrics and Computer Science to development an intuitive application and fully establish the need for ICT development in Obstetrics. I am writing to you to seek your permission to invite Obstetrics students in you department to participate in my study. Permission is sought to complete this study and to further establish the type of learning styles students possess to develop an intuitive application.

The aim of my research is to examine the current computer aided interaction in Obstetrics and use this information to enhance the practice of Obstetrics Training/Education through 3D simulation and Mobile technology. It is hoped that through exploring these issues that greater understanding of the impact technology has on the Obstetrics students and practitioners, through their knowledge and attitude.

Part of my research involves the completion of an online questionnaire package. It involves a list of questions determining the students individual learning styles using the felder-soloman learning style index. This study helps the development of an intuitive applications user interface and establishes the student's reactions to computer aided learning. All completed questionnaires will be collected using online database retrieval. A letter of invitation will be issued to all potential participants. All participants maintain the right to withdraw from the study at any time. Enclosed you will also find a copy of my research proposal.

All ethical issues will be considered and addressed during and after the study. Anonymity and confidentiality will be protected at all times. Approval will be obtained from the Clinical research Ethics Committee of the Cork Teaching Hospital for UCC and the Mid-Western Regional Hospital Complex Scientific Research Ethics Committee which covers approval for Mid-West region of Ireland.

Thank you for taking the time to read this letter. I would be grateful for your permission to carry out this study to have access to student in your department. Should you have any queries please feel free to contact me at XXXX or email XXXX at any stage.

I look forward to hearing from you.
Yours sincerely

_____

Donnchadh Coffey MSc., BA.

# Appendix B

**Letter to the Ward Managers**

XXXX
Ireland
12/12/12

XXXX
XXXXXXX
XXXXX
XXXXXXXXXX

**Re: Enhance the practice of Obstetrics Training/Education through 3D simulation and Mobile technology**

Dear ……..

I am currently undertaking a PhD in Computer Science and Obstetrics in University College Cork (UCC). As part of my study I am required to complete research on an area of interest within my professional scope. The research I have chosen is 3D simulation for Obstetrics. I wish to conduct this study using the expertise of both departments of Obstetrics and Computer Science to development an intuitive application and fully establish the need for ICT development in Obstetrics. I am writing to you to seek your permission to invite Obstetrics students in you department to participate in my study. Permission is sought to complete this study and to further establish the type of learning styles students possess to develop an intuitive application.

The aim of my research is to examine the current computer aided interaction in Obstetrics and use this information to enhance the practice of Obstetrics Training/Education through 3D simulation and Mobile technology. It is hoped that through exploring these issues that greater understanding of the impact technology has on the Obstetrics students and practitioners, through their knowledge and attitude.

Part of my research involves the completion of an online questionnaire package. It involves a list of questions determining the students individual learning styles using

the felder-soloman learning style index. This study helps the development of an intuitive applications user interface and establishes the student's reactions to computer aided learning. All completed questionnaires will be collected using online database retrieval. A letter of invitation will be issued to all potential participants. All participants maintain the right to withdraw from the study at any time. Enclosed you will also find a copy of my research proposal.

All ethical issues will be considered and addressed during and after the study. Anonymity and confidentiality will be protected at all times. Approval will be obtained from the Clinical research Ethics Committee of the Cork Teaching Hospital for UCC and the Mid-Western Regional Hospital Complex Scientific Research Ethics Committee which covers approval for Mid-West region of Ireland.

Thank you for taking the time to read this letter. I would be grateful for your permission to carry out this study to have access to student in your department. Should you have any queries please feel free to contact me at XXXX or email XXXX at any stage.

I look forward to hearing from you.

Yours sincerely

_____

Donnchadh Coffey MSc., BA.

# Appendix C

**Learning styles survey Leaflet**

**My name is Donnchadh Coffey. I am a student in computer science and I have a great interest in this area and wish to complete a study, investigating the practice of Obstetrics Training/Education through 3D simulation and Mobile technology.**

Dear Obstetric students,

You are being invited to take part in a research study carried out to further develop an educational tool for Obstetrics. Before you decide whether or not to take part, you should read the information provided below carefully. Take time to read the questions – do not feel rushed or under pressure to make a quick decision.

You should clearly understand the pros and cons of taking part in this study so that you can make a decision that is right for you. This process is called "Informed Consent".

You do not have to take part in this study and a decision not to take part will not affect you.

You can change your mind about taking part in the study at any time. Even if the study has started, you can still opt out of it. You do not have to give a reason.

Here are some questions and answers that may help you in being informed.

**Why is this study being done?**

The purpose/aim of the research is to investigate and enhance Obstetrics education/training with the use of computer aided tools. It is hoped that greater understanding and more in-dept information, both locally and nationally will be obtained and therefore links and trends will be identified and made tangible to draw conclusion within the research.

**Who can take part in the study?**

All Obstetrics students can take part in the study, working, part time or full time.

**How will the study be carried out?**

The study will take place September 2014 and will involve the completion of an online questionnaire package. A list of questions categorising the learning styles of students to develop an intuitive user interface applied to an educational application. The learning styles questions are based on the felder soloman index. All consenting Obstetric are welcome to participate in the study.

**What will happen to me if I agree to take part?**

It involves the completion of the questionnaire package which will take approximately 5- 10 minutes to complete in total. The student will be asked to register and sign in to complete the questionnaire. Students will receive feedback of results and an option to print. Please complete the questionnaire at a time that is convenient to you.

**What should I do with the completed Questionnaires?**

Please complete ALL SECTIONS and then view your results. All data will be remotely retrieved. Make sure to log out when completed.

**What are the benefits?**

There is an array of benefits introduced in this study including the accumulating of the learning styles displayed by student in the field of Obstetrics. The outcomes of the study would help with minimum requirement for students/lecturers to be present for most patient childbirth procedures (can be unnerving for patients). The study also introduces new technologies to a hospital environment enabling development with technical equipment practice. This study can be applied to all medical fields and aspects can be scrutinized to further develop ICT's role in medicine with regard to the research community and wider society including other courses involved in 3D simulation in education.

**What are the risks?**

There are no directly related risks attached to this study but the online questionnaire will demand 5 - 10 minutes of your time.

**Is the study confidential?**

Any information gathered during this study will remain fully confidential and anonymous and this will be maintained throughout the study. Names will not be entered or obtain or linked to any individual, All participants have the right not to take part or to withdraw from the study at any stage without penalty. The information gathered and kept will not identify you. Anyone who completes the questionnaires is giving their consent to participate in the study. The collected questionnaire package will be held by the co-investigator in UCC for 7 years and then will be disposed on in a secure manner.

**What happens to the information gathered?**

All information will be analysed, and feedback will be given on the researched results at the end of the study. All data will be collected and stored securely for one year after the completed research and will then be destroyed. Confidentially will be strictly maintained and adhered to throughout the research. The study and results may be published at a future date.

**Do you have any queries/questions?**

If you have any further questions about the study or if you want to opt out of the study please be assured it will not affect you in the future. If you would like to ask me now or any time in the future please contact me on XXXX or email XXXX. This phone number is only answered during office hours.

Thanking you in advance

Donnchadh Coffey MSc., BA.

Appendix D

**PLEASE COMPLETE ALL SECTIONS**

Please complete this questionnaire by ticking one box for each question unless otherwise indicated.

1. I understand something better after I
   - ○ **(a)** try it out.
   - ○ **(b)** think it through.
2. I would rather be considered
   - ○ **(a)** realistic.
   - ○ **(b)** innovative.
3. When I think about what I did yesterday, I am most likely to get
   - ○ **(a)** a picture.
   - ○ **(b)** words.
4. I tend to
   - ○ **(a)** understand details of a subject but may be fuzzy about its overall structure.
   - ○ **(b)** understand the overall structure but may be fuzzy about details.
5. When I am learning something new, it helps me to
   - ○ **(a)** talk about it.
   - ○ **(b)** think about it.
6. If I were a teacher, I would rather teach a course
   - ○ **(a)** that deals with facts and real life situations.
   - ○ **(b)** that deals with ideas and theories.

7. I prefer to get new information in

   ○ **(a)** pictures, diagrams, graphs, or maps.

   ○ **(b)** written directions or verbal information.

8. Once I understand

   ○ **(a)** all the parts, I understand the whole thing.

   ○ **(b)** the whole thing, I see how the parts fit.

9. In a study group working on difficult material, I am more likely to

   ○ **(a)** jump in and contribute ideas.

   ○ **(b)** sit back and listen.

10. I find it easier

    ○ **(a)** to learn facts.

    ○ **(b)** to learn concepts.

11. In a book with lots of pictures and charts, I am likely to

    ○ **(a)** look over the pictures and charts carefully.

    ○ **(b)** focus on the written text.

12. When I solve math problems

    ○ **(a)** I usually work my way to the solutions one step at a time.

    ○ **(b)** I often just see the solutions but then have to struggle to figure out the steps to get to them.

13. In classes I have taken

    ○ **(a)** I have usually gotten to know many of the students.

    ○ **(b)** I have rarely gotten to know many of the students.

14. In reading nonfiction, I prefer

    ○ **(a)** something that teaches me new facts or tells me how to do something.

    ○ **(b)** something that gives me new ideas to think about.

15. I like teachers

- **(a)** who put a lot of diagrams on the board.
- **(b)** who spend a lot of time explaining.

16. When I'm analyzing a story or a novel

- **(a)** I think of the incidents and try to put them together to figure out the themes.
- **(b)** I just know what the themes are when I finish reading and then I have to go back and find the incidents that demonstrate them.

17. When I start a homework problem, I am more likely to

- **(a)** start working on the solution immediately.
- **(b)** try to fully understand the problem first.

18. I prefer the idea of

- **(a)** certainty.
- **(b)** theory.

19. I remember best

- **(a)** what I see.
- **(b)** what I hear.

20. It is more important to me that an instructor

- **(a)** lay out the material in clear sequential steps.
- **(b)** give me an overall picture and relate the material to other subjects.

21. I prefer to study

- **(a)** in a study group.
- **(b)** alone.

22. I am more likely to be considered

- **(a)** careful about the details of my work.
- **(b)** creative about how to do my work.

23. When I get directions to a new place, I prefer

- **(a)** a map.
- **(b)** written instructions.

24. I learn

- **(a)** at a fairly regular pace. If I study hard, I'll "get it."
- **(b)** in fits and starts. I'll be totally confused and then suddenly it all "clicks."

25. I would rather first

- **(a)** try things out.
- **(b)** think about how I'm going to do it.

26. When I am reading for enjoyment, I like writers to

- **(a)** clearly say what they mean.
- **(b)** say things in creative, interesting ways.

27. When I see a diagram or sketch in class, I am most likely to remember

- **(a)** the picture.
- **(b)** what the instructor said about it.

28. When considering a body of information, I am more likely to

- **(a)** focus on details and miss the big picture.
- **(b)** try to understand the big picture before getting into the details.

29. I more easily remember

- **(a)** something I have done.
- **(b)** something I have thought a lot about.

30. When I have to perform a task, I prefer to

- **(a)** master one way of doing it.
- **(b)** come up with new ways of doing it.

31. When someone is showing me data, I prefer

- **(a)** charts or graphs.
- **(b)** text summarizing the results.

32. When writing a paper, I am more likely to

- **(a)** work on (think about or write) the beginning of the paper and progress forward.
- **(b)** work on (think about or write) different parts of the paper and then order them.

33. When I have to work on a group thesis, I first want to

- **(a)** have "group brainstorming" where everyone contributes ideas.
- **(b)** brainstorm individually and then come together as a group to compare ideas.

34. I consider it higher praise to call someone

- **(a)** sensible.
- **(b)** imaginative.

35. When I meet people at a party, I am more likely to remember

- **(a)** what they looked like.
- **(b)** what they said about themselves.

36. When I am learning a new subject, I prefer to

- **(a)** stay focused on that subject, learning as much about it as I can.
- **(b)** try to make connections between that subject and related subjects.

37. I am more likely to be considered

- **(a)** outgoing.
- **(b)** reserved.

38. I prefer courses that emphasize

- **(a)** concrete material (facts, data).
- **(b)** abstract material (concepts, theories).

39. For entertainment, I would rather

- **(a)** watch television.
- **(b)** read a book.

40. Some teachers start their lectures with an outline of what they will cover. Such outlines are

- **(a)** somewhat helpful to me.
- **(b)** very helpful to me.

41. The idea of doing homework in groups, with one grade for the entire group,

- **(a)** appeals to me.
- **(b)** does not appeal to me.

42. When I am doing long calculations,

- **(a)** I tend to repeat all my steps and check my work carefully.
- **(b)** I find checking my work tiresome and have to force myself to do it.

43. I tend to picture places I have been

- **(a)** easily and fairly accurately.
- **(b)** with difficulty and without much detail.

44. When solving problems in a group, I would be more likely to

- **(a)** think of the steps in the solution process.
- **(b)** think of possible consequences or applications of the solution in a wide range of areas.

45. How would you rate your computer skill level?

- (a) Never used a computer
- (b) Beginner (c) Competent

46. How confident are you with computers?

- (a) Not confident at all
- (b) It depends on the task (c) Confident

47. Do you own a computer?

- (a) Yes
- (b) No

48. How often do you use computers?

- (a) Never
- (b) Monthly (c) Weekly (d) Daily

49. Can you find and start a program on a computer?

- (a) Yes
- (b) No

50. Can you navigate between programs and websites?

- (a) Yes
- (b)No

51. Can you exit or quit an application?

(a) Yes

(b) No

52. Do you own a Smartphone or Tablet Device?

(a) Yes

(b) No

53. Do you understand what a browser does?

**(a)** Yes

**(b)** No

54. Can you download and save files, such as graphics, documents, or PDFs, from the Internet?

(a) Yes

(b) No

55. Can you read, compose and send email messages?

(a) Yes

(b) No

56. Does the colour and theme of an application have an effect on your work?

(a) Yes

(b) No

57. In your opinion, which tone would best suit a mobile and pc application User Interface

(a) Light

(b) Dark

58. In terms of the User Interface (UI) of a PC application, which layout better suits you?

(a)A minimalistic layout, very few buttons. Mostly graphics, content is hidden but can be revealed.

(b) Plenty of text, all available widgets and content are presented on screen

59. Please choose your preferred layout from the selection below?

(a) UI on the right

(b) UI on the left

(c) UI on the top

(d) UI on the bottom

# Appendix E

***Sensor Email – sent to multiple companies***

Dear XXXX.,

Let me begin by saying how amazing your products are and how dynamic/ ergonomic your sensors are, in particular your XXXX.

Allow me to introduce myself, my name is Donnchadh Coffey, I am a PhD student studying computer science (in University College Cork) with an insight into developing sensor driven material for a chosen medical field. As part of my research I have to move 3D designed medical apparatus by using a sensor input mapping out the objects orientation and rotation. When coming to grips with my first interactions with sensors I used Bluetooth enabled sensors and also allowed my cellular device to mask as an active imu to move the object. The use of these methods however had latency issues and had no foresight into a more permanent solid solution. I came across your site and subsequent sensors when researching the particular specifications of the sensors needed to accurately achieve the desired outcome of my thesis. I came across your XXXX which is so elegantly presented schematically and visually on your site. All the features are perfect for thesis integration.

I wanted to correspond with you and ask you to aid me in my thesis progression. All I need is one example of your sensor XXXX even a beta version to test alongside my 3D environment. My thesis has potential beyond the scope of my PhD to be applied to an array of multiple medical and interdisciplinary fields. Apart from notable references to your assistance within my research, if you can help me progress there could be promising future developments with the end product. Please consider my request.

Thank you for time and please contact me if you have any questions.

Kind regards

Donnchadh Coffey, PhD student