The Application of Innovative Virtual World Technologies to Enhance Healthcare Education

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PhD Thesis
Abstract
The World Wide Web has evolved leading to the development of three-dimensional virtual worlds. These are online, accessible environments through which a user may engage, communicate and interact via their digital self, known as their avatar. These virtual worlds offer the opportunity for further content to be generated in order to provide new environments and simulations. This research work explores the potential of virtual worlds in providing an educational platform for healthcare professionals. In order to establish this, the effectiveness of a virtual world environment was determined through the use of a custom-built virtual world operating theatre, which was utilised to train operating theatre novices in preparation for the real-life environment.

Following the application of a virtual world environment, this research explored the development of a virtual patient scenario for training healthcare professionals. The virtual patient scenario focused on the management of adverse events associated with medical infusion devices with a nurse user group assessing the simulation face validity. The next step was to devise a methodology to develop a series of immersive virtual patients. This involved the use of allied web technologies to produce a robust, reproducible method of 3D virtual patient generation. Three virtual patients were constructed, with distinct surgical pathologies at three levels of increasing complexity. Subsequently the face, content and construct validity of the virtual patients was established to differentiate surgeons of different training grades. Finally the virtual patients were utilised to emulate real clinical situations, in which handoff of patient information occurred. The virtual patients were used to
establish if the quality of handoff impacted on the subsequent patient management in a simulated setting. Overall this research has demonstrated the efficacy of virtual world environments and simulations in providing an alternative educational platform for healthcare professionals.
Acknowledgements
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LIST OF ABBREVIATIONS

ABG  Arterial Blood Gas
ACGME Accreditation Council for Graduate Medical Education
ARPANET Advanced Research Projects Agency Network
ALS  Advanced Life Support
ATLS Advanced Trauma Life Support
CPR  Cardiopulmonary Resuscitation
COPD Chronic Obstructive Pulmonary Disease
CEX  Clinical Evaluation Exercise
CSV  Comma Separated Value
C   Control
CT1 Core Trainee 1
CRP  C-reactive Protein
ED  Emergency Department Junior Resident
XML Extensible Markup Language
FY1 Foundation Year 1
HUD Head-Up Display
ISBAR Identity, Situation, Background, Assessment and Recommendation
IT  Information Technology
IPPI Integrated Procedure Performance Instrument
I   Intern
iVAS International Virtual Association of Surgeons
IQR Inter-Quartile Range
IV  Intravenous
JPEG Joint Photographic Experts Group
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>JR</td>
<td>Junior Resident</td>
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<tr>
<td>L</td>
<td>Lecture</td>
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<tr>
<td>MRCS</td>
<td>Membership of the Royal College of Surgeons</td>
</tr>
<tr>
<td>MUD</td>
<td>Multi-User Dungeon</td>
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<tr>
<td>NHS</td>
<td>National Health Service</td>
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<tr>
<td>NPSA</td>
<td>National Patient Safety Agency</td>
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<tr>
<td>OSCE</td>
<td>Objective Structured Clinical Examination</td>
</tr>
<tr>
<td>OLIVE</td>
<td>Online Interactive Virtual Environment</td>
</tr>
<tr>
<td>SL</td>
<td>Second Life Virtual Operating Theatre</td>
</tr>
<tr>
<td>SR</td>
<td>Senior Resident</td>
</tr>
<tr>
<td>SOS</td>
<td>Simulated Operating Suite</td>
</tr>
<tr>
<td>STeLI</td>
<td>Simulation and Technology-enhanced Learning Initiative</td>
</tr>
<tr>
<td>ST3</td>
<td>Specialist Trainee 3</td>
</tr>
<tr>
<td>SUMMIT</td>
<td>Stanford University Medical Media and Information Technology</td>
</tr>
<tr>
<td>JR1</td>
<td>Surgery Junior Resident</td>
</tr>
<tr>
<td>TIC</td>
<td>Theatre Induction Curriculum</td>
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<tr>
<td>3D</td>
<td>Three-Dimensional</td>
</tr>
<tr>
<td>T-NOTECHS</td>
<td>Trauma Non-Technical Skills Scale</td>
</tr>
<tr>
<td>US</td>
<td>United States</td>
</tr>
<tr>
<td>USMLE</td>
<td>United States Medical Licensing Examination</td>
</tr>
<tr>
<td>Vs</td>
<td>Versus</td>
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<tr>
<td>VUE</td>
<td>Visual Understanding Environment</td>
</tr>
<tr>
<td>VOIP</td>
<td>Voice Over Internet Protocol</td>
</tr>
<tr>
<td>WCC</td>
<td>White Cell Count</td>
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Declaration
Except where acknowledged in the acknowledgements and text, I declare that this dissertation is my own work and is based on research that was undertaken by me in the Department of Surgery and Cancer, Imperial College from 1\textsuperscript{st} July 2008 to 30\textsuperscript{th} June 2011.

Vishal Patel Date: 14\textsuperscript{th} April 2015

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PEER REVIEW PUBLICATIONS AND PRESENTATIONS

Publications


Presentations

Patel V, Lee H, Aggarwal R, Darzi A. *Virtual Worlds are an Innovative Tool for Medical Device Training in a Simulated Environment*

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Chapter 1

Literature Review
1.1 Introduction

Technology advancement has been synonymous with the progression of the continuing art of practising medicine. Previous advancements, such as the development of the stethoscope by Rene Laennec (1816) (Roguin, 2006) have been incorporated as integral components of day-to-day medical practice. The most profound advancement in recent global technology has been the advent of the World Wide Web and the process through which it is accessible, the Internet. The emergence of the World Wide Web has completely revolutionised modes of communication; it has had an exponential growth in social, business and health environments within the last 15 years. This has resulted in a hyper-production and hyper-distribution of information, which has overwhelmed the capacity to utilise it. (Eysenbach and Jadad, 2001)

The original vision of the World Wide Web incorporated an expansive network where all consumers could interact regardless of time or place. This vision involved a platform where the consumers of content were also the producers and there was no obvious hierarchy regarding content production and management. This original vision was unable to develop according to this plan due to the breadth of technology management required at this stage; the available technology was not amenable to widespread distribution and
access. This produced a limited group of providers who had initial control of
the web and disseminated content to the consumers.

The turning point arose in 2001, when the dot.com bubble burst. (O’Reilly, 2005) This heralded an evolution in the method of content transfer across the
web: content delivery altered from a one-way distribution of information to a
more interactive approach where information and knowledge was transferred
laterally between consumers. This progression marked the gradual
introduction of the concept known as Web 2.0.

The term Web 2.0 does not have a distinct definition and can be considered a
difficult term to define. (Giustini, 2006) It can be loosely described as a group
of inter-related networks, which engage the user in content creation and
consumption, whilst employing further interactive social networking between
various communities. The content that Web 2.0 encompasses does not
remain static but continues to evolve, with increasing user interest and
participation. This web progression has ensured that users are more involved
and more immersed in their online activities.

The shift of Web 2.0 towards a more user-centric focus has resulted in more
Internet flexibility, with consumers able to demonstrate greater participation
within the social web and being able to act as both information providers and
consumers. This has been aided by the significant growth of computer
ownership and Internet use worldwide. (Internet_World_Statistics, 2009) This
has resulted in greater collaboration in knowledge transfer, with new networks
forming in order to create and distribute this information. There has been an emergence of various technologies such as Wikis, Blogs and Podcasts within this new dynamic web, which has enhanced the ability of the consumer to establish further social contacts and easily communicate with them, to access knowledge from a variety of sources and to obtain audio and video formatted files. The Web 2.0 has also evolved to incorporate new environments such as three-dimensional (3D) virtual worlds, which is the subject of this body of work.

As technology has advanced, so has its implementation into medical education. This has been a necessity, in part, given the various challenges that have faced healthcare education, especially in more recent times. As part of a strategy change away from traditional methods of healthcare education, there has been a progression in educational theories, which have formed the backdrop for the implementation of these innovative tools. It is therefore imperative to comprehend the development of educational theories in order to ascertain how virtual world technologies could be used for educational purposes.
1.2 Initial Theories in Adult Education

The traditional method of education delivery was frequently the dissemination of knowledge from teacher to learner through the active delivery of information, with the learner being the passive recipient. This has some merit as a method for the transmission of knowledge, but is lacking in that frequently the knowledge imparted is abstract, with no context described, and holds no meaning for the learner. Consequently, different approaches to learning have been proposed.

Dewey (1938) was an early advocate for the importance of previous experiences and previous knowledge in developing new understanding. He described the traditional techniques of learning as providing a strict authoritarian approach, which was more concerned with the delivery of pre-ordained knowledge and not focused on the actual art of learning. He stipulated that the challenge of education was to provide learners with quality experiences that would result in the growth of their knowledge and creativity, which could be developed for future experiences. Dewey proposed that experiences in education should encompass ordinary life experiences rather than simply factual learning. It was his opinion that it was the educator’s responsibility to ensure that the educational problem was significant enough and interesting enough to motivate learners to seek more information in order to stimulate the production of new ideas.

In relation to this previous work, Knowles (1984) introduced the concept of andragogy, which can be described as 'the art and science of teaching adults
to learn’. (Knowles, Holton and Swanson). This principally describes key components related to motivation in adult learning. These are:

- Adults need to be aware of the reason for learning something (need to know)
- Previous life experiences (including past errors) are a rich basis for learning activities and may enhance new learning (foundation)
- Adults need to be responsible for their decisions on educational involvement and in the planning and evaluation of their instruction (self concept)
- The most interest in adult learning is visible when the content is relevant to the learner’s work and/or personal life (readiness)
- Learning is problem- rather than content-orientated (orientation)
- Adult learners respond better to internal rather than external motivation i.e. they would much rather satisfy personal goals than seek rewards from external incentives (motivation)
1.2.1 Experiential Learning

Following the concept of andragogy and Dewey’s theory, Kolb (1984) described experiential learning. This focuses on the principle that a person would learn primarily through experiences and the discoveries made from these experiences. This can be highlighted through Kolb’s cycle, which proposes four stages of experiential learning (Figure 1a).

The first part of the cycle, described as concrete experience, is the process of an individual, team or organisation performing a task. The key principle for learning within this phase is active involvement. Kolb asserts that learning can only be performed effectively by doing and being proactive, rather than watching or reading about how to perform a task. The ‘reflective observation’ phase involves taking time away from the experience in order to review what has been performed and experienced. If this is performed within a team, then the communication channels can be opened between the members of the team; it is deemed important in this situation to discuss the experience with others in order to further facilitate learning.
Figure 1a: Kolb’s cycle
The next stage of the cycle is the notion of abstract conceptualisation, which involves the process of making sense of what happened during the experience. This centres on interpreting the events that have occurred and understanding the relationships between them. At this stage the learner makes comparisons between what they have done and reflects on their prior knowledge. They may even draw upon theoretical knowledge, generate ideas from colleagues, rely on previous observations in order to frame and explain events. This phase is finally followed by active experimentation, which is when the learner considers how they are going to apply the lessons from their experience and implement them into practice. In order for this learning to be useful, it is essential for the learner to contextualise the experience so that it is subsequently relevant for future practice.

A similar concept to the idea of effective learning being generated through experiences is constructivism. This stipulates that learning is generated through the interaction between ideas and experiences and that learning is derived from real life experiences, which construct and condition knowledge. Piaget (1950) postulated a theory on constructivist learning, which focuses on the process of assimilation and accommodation through which individuals generate new knowledge based on experience. The concept of assimilation describes how human adults perceive and adapt to new information. It involves the process of fitting new information into pre-existing schema. This occurs when individuals are faced with new or unfamiliar information and they refer to previously learned information in order to make sense of it. The process of accommodation subsequently follows, whereby the learner
absorbs new information from previous experience and alters their pre-existing schema in order to accommodate in the new information. It is only through assimilation that accommodation can be achieved and the two processes cannot function independently.

The above concepts all relate to the learner generating knowledge from their experiences. However effective learning can also be facilitated by the educator or by the use of an assistant. Vygotsky (1962) influenced the constructivism theory by describing the concept of a ‘zone of proximal development’. This suggests that learners are able to demonstrate the capacity to problem-solve with assistance from an expert even if they are not able to perform the task independently. A child can exemplify this, initially learning to solve a jigsaw puzzle with the assistance of an adult; this then develops the skills necessary to perform the task effectively and independently in the future. Vygotsky viewed the interaction with more expert peers in learning as an effective modality of developing skills. However, it is acknowledged that each learner has their own zone of proximal development, which is variable, and that the educator has to adjust their assistance accordingly to accommodate this variation and facilitate effective learning.

Bruner (1967) subsequently progressed Vygotsky’s theory through the idea of ‘scaffolding’. This suggests that learning is more effective in the presence of interactional frameworks, which enable stepwise progression. This allows a learner to progressively move forward in their own zone of proximal development by progressing through routines with increasing expectations.
from their educator with each repeated task, with the end goal being the independent performance of the task.

Applebee (Applebee and Langer, 1983) used the notion of scaffolding as a method to describe essential components of formal instruction. In their opinion, learning is a gradual process of internalisation of routines and procedures from the social and cultural context in which learning occurs. This results in a learner’s competence increasing, with the scaffolding decreasing, until the learner is able to function autonomously in their task performance. Applebee stipulated five criteria that are essential for effective scaffolding

- The learner should take ownership of the learning event. This requires the instructional task to enable learners to make their own contribution to the activity.
- The instructional task should be appropriate. This suggests that the task should build upon knowledge and skills that the learner already possesses.
- There should be a structured learning environment. This will present learners with useful strategies and approaches to the task at hand.
- Responsibility should be shared between the learner and the educator. This ensures that the role of the educator is more collaborative than evaluative.
Transfer of control should occur. This enables learners to take more responsibility for controlling the progress of the task as their performance improves.

The scaffolding technique enables stepwise progression to ensure that, with repeated deliberate task practice, a learner’s performance will improve. Dreyfus and Dreyfus (1988), characterise the steps that a learner undertakes in order to develop expertise, describing how individuals progress through various levels in the acquisition of skills and incorporate ideas with regard to learning. They propose that a learner progresses through five levels in skill acquisition, from ‘novice’ to ‘expert’, with the stages of ‘advanced beginner’, ‘competent’ and ‘proficient’ between.

At the novice stage, an individual follows rules that are context-free and does not undertake any responsibility for anything other than following the rules. Competence subsequently develops after having considerable experience, with proficiency demonstrated in individuals who use intuition in decision-making and develop their own rules to formulate plans. Expertise is then characterised by a fluid performance that occurs automatically and is no longer dependent on expert knowledge. Therefore, the progression is a gradual transition from rigid adherence to taught rules and procedures through to an intuitive mode of operation that is reliant on deep, implicit knowledge. Ultimately, the introduction of new technologies in medical education attempts to facilitate this development of expertise with progressive progression through the different stages of knowledge and skill acquisition.
The different theories underpinning the methods that can be used to deliver education to the learner, with progression to expertise, have been described. It is important for these to be acknowledged, as alternative theories to the more traditional ones are required to deliver education in the context of an evolving healthcare service. This is also against the background of increasing challenges being encountered in the delivery of education to healthcare professionals, particularly hospital-based clinicians.
1.3 Challenges to Healthcare Education

Healthcare education is currently in a state of transition. This is because the medical profession has traditionally relied upon learning from the accumulation of vast experience, with knowledge, skills and decision-making abilities developed over a long period during which trainees treated a vast number of patients. (Reznick and MacRae, 2006) However, in recent times there have been a number of reasons why training opportunities have been lost, resulting in a vast reduction of the experience that could be obtained from treating large volumes of patients.

The primary reason for this experience reduction has been pressure to reduce the length of medical training required to reach the consultant grade. This is particularly evident in the United Kingdom, where it is no longer sustainable for a period of 12-14 years to be taken to reach Consultant status. (Traynor, 2011). Coupled with the implementation of the European Working Time Directive, in which there is a maximum limit of 48 hours in the working week, this has resulted in a major loss of time spent acquiring the clinical experience and skills necessary to become a Consultant. The predicted result is that a medical trainee, particularly a surgeon, will have a training time equivalent to a fifth of the time spent training their counterparts from a previous era. (Chikwe et al., 2004) This working hours reduction has also resulted in a transition towards a shift-working pattern, with the effect of less time being spent within the normal clinical team. The main result of this is a potential breakdown of the relationship between the trainee and their trainer, who may act as their mentor in the traditional apprenticeship model that has hitherto been
paramount in medical training. These reasons are resulting in an increasing opinion that it is becoming more challenging to provide sufficient training opportunities within the normal workplace. (Weigelt, 2003)

A further and increasingly frequent pressure affecting training opportunities is the reporting of patient outcomes from Consultant-led care. With the publication of patient outcomes and Consultant-led care becoming more specialised there are limits to the tasks trainees are permitted to perform. There is also an increase in patient demand for treatment to be delivered by a Consultant rather than a trainee (Dowie and Langman, 1999). This is coupled with the acknowledgement of the increasing cost of healthcare error and an increasing requirement for patient safety. (Windsor, 2009) Whilst this can only serve the patient better, at present it results in decreasing training opportunities and, more alarmingly, it jeopardises the quality of training, which is becoming an increasing necessity in order for a trainee to become an independent practising consultant.

Whilst the above factors are obvious reasons why training opportunities have been lost, there are more understated factors that demonstrate high variability depending on where a trainee works. There is increasing pressure from hospital managements for various hospital quality assurance targets to be met, resulting in more service provision for the trainee and less focused training time. (Aggarwal and Darzi, 2006) Within the United Kingdom, NHS trusts are under increasing pressure to reduce waiting list times; therefore
Consultants are typically stretched for time and may not offer the educational training that would benefit their more junior colleagues (Smith et al., 2009)

Finally, as well as the reasons discussed, medical technology has seen an explosion of new tools that can be implemented to maximise patient benefit. Firstly, the advancement of imaging techniques has resulted in increased diagnostic accuracy, which has reduced the need for exploratory surgery that was often non-therapeutic (Lewis and Klingensmith, 2012). Also, the advent of laparoscopic and robotic surgery in addition to advanced endoscopic and interventional radiology techniques have resulted in further re-training being required at a more advanced stage of a medical practitioner’s career. Due to the learning curve required to obtain expertise in these more advanced procedures, consultants or senior trainees are performing these procedures as opposed to their more junior counterparts, resulting in diminished opportunities for learning at an earlier stage of a trainee’s career. There is a now a need to fill this ever-increasing training void and compensate for this increasing problem. Fortunately, there is a potential solution in the form of medical simulation. Whilst this has existed for many years, there are a number of ways in which simulated techniques have more recently been exploited to provide the appropriate training means that are becoming an increasing necessity.
1.4 Simulation

Clinical simulation is used in healthcare education to mirror a clinical setting in order to learn both the technical skills and the competency required for healthcare. (Akaike et al., 2012, Bradley, 2006, McGaghie et al., 2010) Gaba (2004) has defined simulation as a technique (not a tool or technology) to replace, augment or amplify reality with guided experiences, frequently immersive in nature, that evoke or replicate substantial aspects of the real world in an interactive fashion. However, simulation encompasses a broad spectrum of different techniques, applied using different tools and technologies, which can demonstrate variable fidelity.

Fidelity is a term that has been used in tandem with simulation to represent the extent to which a simulation represents reality (Weller et al., 2012). It also refers to the immersive nature of the educational intervention and the accuracy of the clinical environment being represented (Beaubien and Baker, 2004). However, it has been stipulated that simulation as an exercise is not so much dependent on the level of fidelity but on how both the trainee and the trainer use the simulation (Aggarwal et al., 2010). Despite the vast variation in fidelity that can be found in different simulation models, the principle of simulation techniques does provide many benefits in the education of healthcare professionals.

Kneebone (2003) has previously described the potential advantages that simulated techniques may offer in healthcare education. This includes the fact that training can be tailored to suit the needs of the learner and is not
dependent on patient-related factors, which principally underpin clinical practice. This ensures that a learner can focus on a whole procedure, part of a procedure or even the knowledge that is relevant to the procedure, and thus apply their learning needs as they see fit. Simulation can also provide an environment in which learners are allowed to fail with no consequence to patient care: in such a controlled environment, it is then feasible for the learner to learn from such errors and therefore improve subsequent performance. Such a technique can therefore facilitate deliberate practice (Ericsson, 2004), as learners can rehearse their clinical skills within a structured framework in a focused and repetitive manner, thereby refining their skills until their performance becomes fluent and instinctive (Weller et al., 2012).

Other advantages described by Kneebone (2003) relate to the use of simulator tools themselves, in that they can provide real-time objective evidence of performance, which is able to provide both formative and summative assessment. This holds particular relevance, as formative assessments can deliver information about how a learner is progressing in task performance and summative assessments can delineate whether a learner is able to meet criteria in order to progress to a further level. The strength of many different simulation techniques is that the feedback that they provide is immediate and thus can be implemented directly into a learner’s training.
McGaghie and colleagues (2010) have described a series of features and best practices of simulation-based education that medical educators could incorporate into their simulation technique. These include the use of feedback, educational and professional context, simulation fidelity and the use of outcome measurements. An outcome measure/assessment of performance that delivers reliable data is essential to the medical educator. The outcome measurement enables inferences to be made about training performance and provides meaningful data regarding the potential for transfer to real-life practice. It also offers an insight into the context of the training and whether the knowledge, skills or attitudes obtained will be maintained post-training. However, in order to incorporate assessment into simulation the assessment measurements should possess certain attributes, such as validity and reliability.
1.5 Quality of Assessment

Assessment of performance is integral towards determining the benefit that a simulation technique may offer. In order to provide data that is meaningful, an assessment tool should be both valid and reliable. The validity of an assessment refers to the degree to which an assessment tool measures what it is supposed to determine. It can be described in several different categories (Aggarwal et al., 2007):

- Face validity refers to the extent to which an assessment tool reflects a real-life situation.

- Content validity is a reflection of whether the components of the assessment tool are relevant to the situation.

- Construct validity is the extent to which an assessment tool measures what it proposes to measure, i.e. is it able to discriminate between different performance levels that are relevant to real life? This has previously been shown as the ability to discriminate between novice and expert performance within a simulation.

- Concurrent validity determines the level of agreement between the assessment tool and other appropriate measures of performance for the same task.
Predictive validity is the ability of an assessment tool to predict future performance on a different but related task or in a real-life similar situation.

The reliability of an assessment refers to the consistency or precision of measurement. This can be assessed according to the following domains:

- Retest reliability refers to the reproducibility of the results if the assessment were repeated at multiple episodes.

- Inter-rater reliability refers to the level of agreement on individual or group performance from two or more independent assessors.

- Internal consistency describes the correlation between scores in the sub-categories of an assessment tool. It essentially refers to whether these individual scores are related and are measuring the same domain.

It is also noteworthy that as well as an assessment tool demonstrating validity and reliability, it should also be practical and cost-effective to implement, thus displaying feasibility. Whilst it is important to ensure that there is a rigorous approach to assessment, it is also relevant to determine the effect that a simulation-based educational intervention has. The principle of assessment of performance can underpin this, but it is appropriate to evaluate the impact of the simulated technique. This can be determined according to Kirkpatrick’s
framework for assessing a training program, which is categorised into four levels:

**Level 1-Reaction.** This refers to the participant’s reaction to a training intervention. This principally is a reflection of how valuable the participant found the training intervention.

**Level 2-Learning.** This measures what a participant within a training intervention has learnt from their educational intervention and whether this has resulted in a subsequent change in their knowledge, skills and attitudes relevant to their training.

**Level 3-Behaviour.** This evaluates how far a participant has changed their behaviour as a result of the training they have received; therefore, it specifically focuses on how the participant applies the information in real-life practice following the information they have acquired.

**Level 4-Results.** This determines the effect that a training intervention has had in resulting in an overall process change; however it has been acknowledged there is a lack of studies demonstrating Level 4 change in simulation-based medical education (Weller et al., 2012).

Whilst it is imperative to acknowledge the different methods of assessing the relevance and the impact of a simulation-based educational intervention, it is important to review the simulation techniques that have been, and are
currently being, used and determine the effectiveness of these techniques as well as the challenges that they have encountered. The next section offers a review of some of the simulation techniques that are currently in use.
1.6 Simulation Techniques

1.6.1 Standardised Patients

Standardised or simulated patients are individuals that have been carefully recruited and trained to portray patients for teaching and for the evaluation of clinical skills of a healthcare provider. Standardised patients were first conceived and developed by Dr Howard Barrows in 1964 (Barrows and Abrahamson, 1964) and were used as a tool for clinical skill instruction and assessment for the Neurology and Psychiatry examinations in the US. Since their initial use for instructional purposes, they have become much more widespread, with 96% of US medical colleges reported to have used different standardised patients for student assessment (Du et al., 2011).

The use of standardised patients has become more common since the advent of the Objective Structured Clinical Examination (OSCE). The OSCE was first described by Harden and Gleeson as, ‘a timed examination in which medical students interact with a series of standardised patients in stations that may involve history-taking, physical examination, counselling or patient management’ (Harden and Gleeson, 1979) As OSCEs have been shown to be feasible and have good reliability and validity, their use has become widespread as the standard for performance-based assessment, particularly in undergraduate examinations (Hodges et al., 1996).

Standardised patients have also been integrated with other forms of simulation to form a hybrid simulation, which enhances the authenticity of the simulation experience and increases the opportunity for the teaching and
assessment of additional competencies. Kneebone et al. (2006) had previously developed the Integrated Procedure Performance Instrument (IPPI), which combines technical skills training using part-task trainers with communication challenges in a variety of clinical contexts using standardised patients. Each scenario has a bench-top model procedural skill, e.g. a wound closure, associated with a standardised patient. Therefore the participant has to assess and communicate with the standardised patient prior to undertaking the closure of the patient’s wound. These scenarios therefore facilitate the participant to develop the skills to deal with difficult situations such as the anxious or confused patient who requires an assessment and intervention.

Whilst the implementation of standardised patients within the context of hybrid simulations and the Objective Structured Clinical Examination has been successful, there are still challenges associated with the use of standardised patients. The main challenge is that these simulated patients require training to fulfil the designated role and will also require further training for any role that they undertake; this involves the cost of training the standardised patient as well as the use of the trainer’s time. Simulated patients do offer the advantage of protecting real patients from repeat exposure to the novice skills of the trainee, but it is difficult to replicate all the signs and symptoms of the real patient. However, despite these challenges it is becoming obvious that standardised patients will become more integrated into both undergraduate and graduate training curricula, along with other techniques such as the use of mannequins.
1.6.2 Mannequin Simulators

The origin of the mannequin for simulation can be traced back to the 1960s. Asmund Laerdal (Cooper and Taqueti, 2008), a Norwegian toy manufacturer, designed the original mannequin, Resusci-Anne, for training in mouth-to-mouth ventilation. This initial model, which allowed the airway to be obstructed and hyperextension of the neck to be performed, enabled the use of mannequins for resuscitation training. The mannequins have subsequently evolved with various models to the current generation, which can demonstrate accurate physiological responses to interventions from the clinician. The iSTAN mannequin, initially developed by Medical Education Technologies Inc. (CAE Healthcare, Canada) has attained near-human likeness in both texture and feel and has progressed to a level where the mannequin simulators are computer-controlled.

This ability to control the mannequins has resulted in the facility to alter physiological data in order to facilitate better medical training for the user. The simulators can be operator-driven and the instructor can enable the alteration of the mannequins’ physiological state (Levine et al., 2013). The alternative is the autonomous mannequin, where the initiation of management decisions from the user will result in automated changes in the physiological data of the mannequin, therefore providing a more immersive experience.

The successful implementation of mannequins within medical simulation has been highlighted in a systematic review performed by Mundell et al. (2013). Their review demonstrated that simulation-based training of resuscitation
skills was effective, regardless of the assessed outcome, level of learner or the specific task trained. They also found that in the studies assessed (n=182), simulation-based training improved knowledge and process skill. However, their review did acknowledge that few studies assessed whether the skills acquired transferred to real patient outcomes (predictive validity) and therefore more evidence would be required to demonstrate this.

The systematic review demonstrated the obvious benefits of implementing this form of simulation into training. However there are challenges that need to be overcome before its use becomes more common. Primarily, the use of mannequins is fixed to specific locations due to their lack of portability (Levine et al., 2013). The solution to this, though, is the use of part-task trainers, in which the structure of the mannequin will only be part of the body, i.e. for resuscitation purposes the mannequin will only consist of the head, neck and torso. This smaller format will increase portability and has already integrated itself into popular training courses such as the Advanced Life Support (ALS) training course.

The other challenge remains the cost of mannequins. With increasingly complex and more immersive mannequins, the associated costs of their use increases, not only the initial purchase cost but also the costs of maintenance and operator. New features for the mannequins may also require more cost and result in associated training for the instructors. In fact, due to the instructor training requirements it may be a necessity for training centres to have full-time staff members who are solely responsible for mannequin
training and therefore the cost not only encompasses the mannequin itself but also the associated training of faculty. The use of mannequins, in medical simulation, is somewhat dependent on the presence of training faculty. However this is not a necessity in other forms of simulation, which can function independently without trainers being present. One such example is virtual reality simulation.
1.6.3 Virtual Reality Simulation

Virtual reality simulation refers to a computer-generated representation of an environment that allows sensory interaction and therefore gives the user the impression of actually being present and performing a task within the environment (Coleman et al., 1994). The modern-day virtual reality simulators used in surgery have a physical interface, which when moved by the user is tracked in the virtual field appearing on the screen as precise movements by a surgical instrument.

Since their initial inception, virtual reality simulators have progressed from simple task performance as seen in the MIST-VR® (Mentice, Gothenberg, Sweden) to full procedure with force feedback, seen in the LapMentor™ (Simbionix, Cleveland, Ohio, USA) (Aggarwal et al., 2004a). This has been feasible through the advances in computer graphic development, which have resulted in increasingly realistic virtual reality simulators (Fried et al., 2004). The current virtual reality surgical simulators allow the user to practise standardised laparoscopic tasks repeatedly, with instant objective feedback of performance. This feedback enables the user to obtain information on their stepwise progression in performing surgical tasks and permits comparison with their counterparts.

Nagendran et al. (2013) demonstrated in a systematic review including 8 trials covering 109 surgical trainees with limited laparoscopic experience, that virtual reality training shortens the operative time (3 trials; 49 participants; MD -11.76 minutes; 95% CI -15.23 to -8.30) and results in significantly better
operative performance using a fixed effects model (2 trials; 33 participants; SMD 1.65; 95% CI 0.72 to 2.58) than trainees with no supplementary training. In addition, virtual reality simulation training resulted in improved operative performance (1 trial; 19 participants; SMD 1.46; 95% CI 0.42 to 2.50) than training using laparoscopic box trainers.

Dawe et al. (2014) performed a systematic review to establish whether simulation-based training acquired skills from either simulated laparoscopic cholecystectomy or endoscopy resulted in a transfer to operative performance. They concluded from the laparoscopic cholecystectomy studies (n=10) and endoscopy studies (n=10) that participants who reached skills proficiency in the simulators performed with higher global assessment scores and fewer errors in the operating room than those who did not have simulated training. It was also noted that the studies addressing laparoscopic cholecystectomy included seven different virtual reality simulators, therefore this global improvement in operative performance occurred irrespective of the virtual reality simulator used.

Despite the advantages of virtual reality simulation training that have been described, there still remain some challenges with their use. Seymour and Rotnes (2006) have described the challenges that exist in the development of the simulation hardware and software. These include the further development of the simulation of objects within the visual field and their interaction; coupled with the further development of the interaction between the surgical instrumentation and the simulated tissue; however, with progressive
technology development, improvements in the realism of the simulators will occur.

These improvements will occur at a cost, with only a handful of companies working in simulation technology and therefore ensuring a high expense in order to purchase a simulator. In order to drastically advance the concept of simulation, it is necessary for additional funding to be obtained to provide for further research and development for the use of these virtual reality simulators (Aggarwal et al., 2010). Until this occurs, virtual reality simulation is potentially limited to the few centres that have access to funds to purchase the simulators. It is therefore imperative that simulation-based medical education can be disseminated to a greater population rather than restricted to a few select centres. A potential solution to combat this problem of disseminating simulation-based education is through the increasing use of e-learning.
1.6.4 E-learning

The concept of e-learning has emerged, in which internet technologies are utilised to deliver solutions for enhancing knowledge and improving performance (Ruiz et al., 2006). There are several advantages to the use of e-learning in healthcare education, such as good accessibility of the educational information at the users’ own convenience and allowing educators the ability to revise material easily. Coupled with the fact that learners have control of content and their learning sequence and can proceed to learn at their own pace (Department_of_Health, 2011), these factors demonstrate that e-learning has much to offer as healthcare education progresses.

Cook et al. (2008) performed a meta-analysis to determine the benefits of internet-based learning in the health professions. Across 201 studies, despite heterogeneity of results, they demonstrated multiple beneficial effects of internet-based interventions in acquisition of knowledge (n=126 studies: pooled effect size =1, 95% confidence interval, 0.9-1.10; p<0.01) compared with no intervention. There were also benefits demonstrated in skills outcomes (n=16 studies: pooled effect size =0.85, 95% confidence interval 0.49-1.2; p<0.01). In contrast, with non-internet based interventions there was little benefit for skills (n=12 studies: pooled effect size =0.09, 95% confidence interval = -0.26 to 0.44, p=0.61). They concluded that internet-based interventions had a positive effect compared with no intervention although they found the results inconsistent compared with other interventions. Therefore the benefits of e-learning in healthcare education remain to be conclusively proved.
There are still many questions to be answered regarding the effectiveness of e-learning. These primarily involve the cost-effectiveness of the implementation of online learning programs, as this may incorporate a large cost outlay initially, although it may prove to be cost-effective in the long term. Also there is no clear information on how much time is required for the development of e-learning programs and whether e-learning can globally enhance healthcare education. Whilst these points remain to be answered, it is becoming evident that educators are more interested in incorporating e-learning into their curricula (Cook et al., 2010). E-learning can facilitate teaching techniques that are not feasible using traditional methods, providing learning to a vast audience; and with the increasing use of the World Wide Web exciting new opportunities are emerging, specifically with the advent of virtual worlds technologies.
1.7 Virtual Worlds

1.7.1 History

The ancestry of virtual worlds can be traced back to an era prior to the exponential growth of the World Wide Web. Essex University is responsible for the introduction of the first Multi-User Dungeon (MUD), the precursor to virtual worlds, in the early 1980s (Bartle, 2003). Traditionally, MUDs were text-based immersive environments, which followed a similar series of rules to the popular dice-playing game Dungeons and Dragons (Tactical Studies Rules Inc., Wisconsin, USA). However, it is a myth that the origins of the two are related. The original scripting language used for the first MUD was Multi-User Dungeon Definition Language. The initial popularity of Multi-User Dungeons was restricted predominantly to university departments, as these could access them through the Advanced Research Projects Agency Network (ARPANET), the predecessor to the Internet. (Bartle, 2003)

The progression from text-based environments towards a more animated graphic user interface was through LucasFilm’s Habitat (Lucasfilm Ltd, California, USA). This represented a multi-user environment in which the user’s input was relayed to the host through the Commodore 64 (Commodore International, Pennsylvania, USA). The host would then continually enforce updates within the virtual community, which would be transferred back towards the user’s machine (Morningstar, 2008). Whilst this was available for a short period only it possessed certain attributes, which would become apparent in the current virtual worlds. It introduced the concept of the avatar
and the ability for the avatar to inhabit and communicate within a similar environment.

Habitat represented what was potentially feasible in producing virtual communities; however, with the increasing use of personalised computers it was the game Sims (Electronic Arts Inc., California, USA), which demonstrated the potential popularity of both the ability to create content and to inhabit a virtual environment. Within two years of introduction it had become the highest selling PC game in history. Its initial use was limited to one’s desktop and not shared through online networks, but with an obvious market becoming apparent, major corporations identified the potential opportunity and created their own specific virtual worlds.

In 1999 Sony Online Entertainment launched Everquest (Sony Corporation, Tokyo, Japan). Using a subscription basis, this online game rapidly became popular, predominantly through word of mouth. It was able to attract and retain new users and demonstrated commercially what could be achieved through multi-player online games. Specific features such as the ability to navigate through a multitude of zones, participate within a group and have specified targeted activities ensured that the popularity of these games would grow and a new era of online role-playing would retain interest.
1.7.2 Definition

There is no consistent definition of a virtual world; rather, many definitions have emerged. Bainbridge defined a virtual world as ‘an electronic environment which visually mimics complex physical spaces, where people can interact with each other and with virtual objects and where people are represented by animated characters’ (Bainbridge, 2007). Bell was more concise in his definition, combining the elements from prior definitions to produce ‘A synchronous, persistent network of people, represented as avatars, facilitated by networked computers’ (Bell, 2008). Sivan added that a true virtual world constitutes a 3D environment with organised and managed communities, the immediate capability to create objects and services and the presence of a virtual commerce (Sivan, 2008). However, Defreitas highlighted the fact that virtual worlds are often, but not always, 3D. (Defreitas, 2008)
1.7.3 Virtual World Features

Kumar et al. (2008) describe a series of integral features that are prerequisites for a virtual world to support its clients. These include a diversity of interface designs, which are capable of supporting a broad range of user activity; this would include the ability to support a variety of hardware such as a joystick, keyboards and the mouse. Other features that are integral are the ability to support clients using different machines with different processing speeds. This would require that a baseline specification is present, which computer processing units must meet in order to access the virtual world.

A virtual world’s servers must be capable of ensuring that a persistent virtual world exists: that is, that the virtual world continually visually renders environment alterations, regardless of whether a user is logged on at that present time. In order for this to occur, a virtual world must contain highly scalable servers; these servers must be able to ensure that there is limited network latency, so that updates are transferred at a quick rate towards the client and their avatar.

Within the software, the virtual world must employ a specific physics engine to ensure that objects and avatars are able to evolve over time and, where feasible, real life activity is modelled, e.g. gravity. There is also a requirement for artificial intelligence technology, so that non-avatar characters are able to be responsive to promote game-like capabilities. Finally, a virtual world must ensure that security and privacy are maintained for the avatar and its corresponding client.
1.7.4 Avatar

The word ‘avatar’ is derived from the Sanskrit word meaning ‘deity’ or ‘incarnation’ (Galanxhi and Nah, 2007). An avatar may be defined as a user-created digital representation that symbolises the user’s representation within a virtual world (Bailenson et al., 2005), serving as an intermediary between the individual and the community (Taylor, 2003). Depending on the virtual world, avatars may possess human-like actions such as the ability to walk or run as well as additional capabilities such as flying. Avatar communication can occur through a variety of modalities including text-based chat, instant messaging or, more recently, voice-over Internet protocol (VOIP). Avatars may take various shapes or forms ranging from simple forms, such as the Nintendo Wii avatar, to more realistic avatars as seen in Second Life (Figure 1b). An avatar does not necessarily have to resemble his or her physical self (Nowak, 2004); in terms of users having the ability to create their own unique avatar to their own personal preferences, this only serves to increase the popularity of virtual worlds.
Figure 1b: A Second Life avatar and Nintendo Wii avatars
1.7.5 Popularity of Virtual Worlds

Virtual worlds have experienced an exponential growth in registered users, with the majority of users being in the under 15 age group (Figure 1c). Reasons for this increase in popularity are increasing awareness of virtual world technology and also increasing numbers of virtual worlds (Figure 1d). However, success in the current Web 2.0 arena does not guarantee success in the virtual world market; this was exemplified by the Google-hosted virtual world ‘Lively’, which terminated after 4 ½ months in service (Google, 2008). Predictions in 2007 suggested that by the end of 2011 80% of Internet users would have a virtual presence within any named virtual world. (Gartner, 2007)
Figure 1c: The number of virtual world registered users in 2011 by age category

<table>
<thead>
<tr>
<th>Age Range</th>
<th>2009 Q1</th>
<th>2009 Q2</th>
<th>2009 Q3</th>
<th>2009 Q4</th>
<th>2010 Q1</th>
<th>2010 Q2</th>
<th>2010 Q3</th>
<th>2010 Q4</th>
<th>2011 Q1</th>
<th>2011 Q2</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 to 10</td>
<td>77m</td>
<td>114m</td>
<td>152m</td>
<td>179m</td>
<td>190m</td>
<td>211m</td>
<td>219m</td>
<td>235m</td>
<td>272m</td>
<td>320m</td>
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<tr>
<td>10 to 15</td>
<td>246m</td>
<td>334m</td>
<td>367m</td>
<td>392m</td>
<td>413m</td>
<td>444m</td>
<td>468m</td>
<td>511m</td>
<td>561m</td>
<td>652m</td>
</tr>
<tr>
<td>15 to 25</td>
<td>73m</td>
<td>99m</td>
<td>117m</td>
<td>193m</td>
<td>237m</td>
<td>273m</td>
<td>288m</td>
<td>299m</td>
<td>313m</td>
<td>385m</td>
</tr>
<tr>
<td>25+</td>
<td>18m</td>
<td>21m</td>
<td>23m</td>
<td>25m</td>
<td>27m</td>
<td>30m</td>
<td>34m</td>
<td>36m</td>
<td>39m</td>
<td>42m</td>
</tr>
<tr>
<td>Total</td>
<td>414m</td>
<td>568m</td>
<td>659m</td>
<td>789m</td>
<td>867m</td>
<td>958m</td>
<td>1,009m</td>
<td>1,081m</td>
<td>1,185m</td>
<td>1,399m</td>
</tr>
</tbody>
</table>
Figure 1d: The increase in numbers of virtual worlds.
1.7.6 Virtual World Categories

Virtual worlds can be broadly categorised into game-orientated worlds or open culture worlds such as Second Life (Franceschi et al., 2008). Game-orientated virtual worlds are principally characterised by having a storyline that defines activities within the virtual world. The most popular game-orientated virtual world is Blizzard’s Entertainment World of Warcraft, which has previously cited a subscription of 11.5 million users worldwide (Blizzard Entertainment, 2008). This consists of a multi-player game, where the user, via their avatar, is able to explore their surroundings, fight monsters and complete various targets in order to progress.

Defreitas (2008) described an alternative list of categories for virtual worlds (Table 1a). This contrasts with the classification of Messinger et al., (2009), which describes five classes of virtual world: education-focused, theme-based, community-specific, children-focused and self-determined. This classification specifically excludes World of Warcraft as a virtual world and considers it as a game instead. However, Messinger et al. did acknowledge the potential for education and learning within virtual worlds, as have other authors (Messinger et al., 2008; Antonacci and Modress, 2008; Belloti et al., 2008; Kluge, 2008)
<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>EXAMPLE</th>
<th>KEY FEATURES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Role-Playing</td>
<td>World of Warcraft</td>
<td>Game-orientated virtual world. Avatar able to explore surroundings, interact with other avatars, encounter various challenges to fulfil goals.</td>
</tr>
<tr>
<td>Social Worlds</td>
<td>Second Life</td>
<td>No specific aim. Avatars interact with each other and environment to form communities. Possess ability to generate own content.</td>
</tr>
<tr>
<td>Working Worlds</td>
<td>Project Wonderland</td>
<td>Enable collaboration in education, business and government. Environments may be developed to facilitate high fidelity communication and sharing of desktop applications.</td>
</tr>
<tr>
<td>Training Worlds</td>
<td>OLIVE (Online Learning Interactive Virtual Environment)</td>
<td>Training environment with focus on team-based learning. Extensive use by the military with early use in healthcare</td>
</tr>
<tr>
<td>Mirror Worlds</td>
<td>Google Earth</td>
<td>Reflection of the real world. Possesses opportunity for interoperability with other applications through mash up of content.</td>
</tr>
</tbody>
</table>

Table 1a: Virtual World Categories and Examples
1.7.8 Healthcare Education

The Stanford University Medical Media and Information Technologies (SUMMIT) group have been early adopters in applying this unique platform to medical education. In a collaborative study with the Karolinska Institute, Sweden, they designed, developed and assessed a virtual platform to train high school students to conduct cardiopulmonary resuscitation (CPR) (Youngblood et al., 2007). The scenario revolved around students interacting with one another in groups of four to practise the steps they would undertake to rescue a person who had had a cardiac arrest. This scenario was created and conducted in Forterra System Inc.’s (San Mateo, California) On-Line Interactive Virtual Environment (OLIVE) game development platform.

Twenty-four students participated in the project, with evaluation of the simulation through Likert scale-based questionnaires regarding the ease of use, the extent of immersion and also the resulting confidence in approaching a real-life cardiac arrest. The students were grouped according to the school where the study was conducted, i.e. either the US school (RHS) or the Swedish school (HG). The results demonstrated that on a Likert scale of 1-5 (low to high) the mean scores for the RHS and HG groups were 3.97 and 4.00 for the ease of use and 3.83 and 4.00 for the extent of immersion within the simulation. The RHS group also reported an increase in confidence in reaction to a cardiac arrest pre- and post- training from a mean of 3.97 to 4.46.
Further studies performed by the SUMMIT group demonstrated the ability to use the virtual world as a platform for training medical staff in team training for the trauma patient (LeRoy Heinrichs et al., 2008). The group developed a series of trauma patients within a virtual world and assessed whether this would improve training in trauma leadership. Sixteen participants, including final year medical students and year 1 residents, participated in the virtual world simulation; post-training analysis demonstrated a significant improvement (p=0.01) in performance in test cases designed for assessment. These test cases included trauma scenarios in which the participant played the role of a trauma team leader. Comparison was made with the human patient performance simulator (a mannequin simulator) and there was no significant difference between this form of simulation and the virtual world group in post-test analysis.

The SUMMIT group was also able to replicate a mass casualty scenario with the creation of 20 virtual patients that had supposedly been exposed either to a radioactive bomb (n=10) or nerve toxin (n=10). Volunteers from Stanford’s Emergency department (n=7 physicians and n=6 nurses) were able to work in teams to assess and triage these patients arriving in the virtual emergency department. Their findings showed that 62% of the participants had not received any prior training in responding to a mass casualty. Their post-session findings showed that participants had increased confidence if exposed to such real-life situations, with a subjective rating increase from a mean of 2 to 3.08 on a 5-point Likert scale. However, there was no objective measure of improvement post training within this particular study.
Whilst the above examples demonstrate the benefits of utilising virtual worlds and gaming technologies, there has been restricted access to these virtual worlds. Development costs have also proved a hindrance towards more disseminated adoptions of such technologies. However, a potential solution to this is the virtual world of Second Life, which is both widely accessible and free to use.
1.8 Second Life-An overview

Linden Laboratories (Linden_Laboratories) first launched Second Life in 2003. It is currently the most popular online virtual world, with a total number of over 19 million residents in 2010, of whom 1 million had logged in during the preceding 60 days (Second_Life_Statistics, 2010). This is a more important figure, as it demonstrates repeated use of Second Life. The majority of users are European in origin – 54% – with the United States of America accountable for 31% of residents (Second_Life_News_Centre, 2007). The average age of users is 33, with a slight male predominance.

Residents of Second Life are able to form part of the general community through the use of their avatar. The avatar is able to walk, run or fly as well as communicate with others through the use of text, local chat or other Web 2.0 communication tools such as instant messaging or voice-over Internet protocol (VOIP). The voice function enables users to be heard by all avatars within 20 metres from the listening position, with the volume having a distance fall-off for spatial effect (Second_Life_Voice, 2010). Alternatively, text messages may be heard up to 20 metres from the speaker location, with the exception of when the user shouts and can be heard from 96 metres. Features such as these increase the sense of community amongst the inhabitants.

Second Life is unique in that it possesses a currency for residents to exchange for services, information or objects. The Linden dollar has a real-life exchange value with the US dollar and previously the value was 267 Linden $
to the US $ (Linden_Dollar, 2010). Whilst Second Life is free to access, the purchasing power associated with the currency has ensured that wealth can be accumulated. This has resulted in one of the residents, Anshe Chung, becoming the first real-life millionaire through activities within Second Life (Bloomberg_Business, 2006). Her wealth was accumulated through the acquisition of land within the Second Life virtual world.

Second Life consists of islands, which represent pieces of independent land of 256 x 256 m. (Varvello et al., 2008) Each island has a maximum of 4 adjacent regions within a specified space. These regions may be private or public, with private islands being purchased and maintained by the owning individual or organisation. The appearance of each region is a reflection of the objects that it contains. An object is a variety of different geometric shapes, which may be scripted in Linden Scripting Language, Second Life’s unique scripting code. (Vilela et al., 2010), The object is persistent in nature, therefore it will be present continuously regardless of whether a user is logged in or not.

There are an increasing number of educationalists who have realised the potential of these environments for transmitting information to learners (Carr, 2008; Edirisingha et al., 2009; Inman et al., 2010; Jones, 2009; Foss, 2009). The most profound insight is that Second Life can aid students into understanding concepts as well as learning to perform specific tasks (Haycock and Kemp, 2008). Second Life education is considered to be an active source of learning in which the student may interpret, analyse, discover
and initiate action in order to solve the problem presented (Antonacci and Modress, 2008). This learning methodology is viewed as a form of constructivist learning in which the acquisition of knowledge is generated through the meaning of experiences (Jonassen and Land, 2000).

Jennings et al. (Jennings and Collins, 2007) demonstrated that in 2007 there were 170 educational institutions that had a presence on Second Life. These included accredited colleges, universities and schools, which were either identified through location on Linden Laboratory’s official website or found through Second Life’s unique search tool. Of the 170 institutions, the majority – 120 institutions (70.6%) – had a group in Second Life, while 71 institutions (41.8%) occupied land in Second Life. Of these institutions that occupied land, 48 (67.6%) were located in North America and 12 (16.9%) in North Europe. The United Kingdom only accounted for 8 land-based institutions. However, there are now an increasing number of institutions that are attempting to explore the potential benefits of utilising Second Life and virtual worlds under the umbrella of a non-profit organisation, the New Media Consortium (New_Media_Consortium, 2010). Of these, some are primarily healthcare affiliated entities focused on enhancing healthcare education.
1.8.1 Healthcare Spaces

A growing consortium of healthcare and academic medical institutions have been using the domain of Second Life to interact with residents for the purpose of enhancing medical education. Second Life offers the opportunity to educate a variety of differing healthcare groups, patients as well as professionals (National Library of Medicine, 2010). Beard et al. (2009) utilised various search strategies to identify areas of Second Life that were focused on healthcare. They established a total of 68 health areas, with 34 primarily focused on education and awareness and 11 specifically focused on training. Interestingly they found that Second Life’s search engine only retrieved 13 of the relevant healthcare areas, with the others being found through Google (Google Inc., California), Google Scholar (Google Inc., California) and Pubmed (United States National Library of Medicine). Of the areas found, the majority were focused on the dissemination of healthcare information.
1.8.2 Healthcare Professional Education

The emergence of web technologies has resulted in medical educators attempting to create desktop simulations and problem-based learning cases to enhance education. Huang et al. (2007) reported that in 2005, 26 different US and Canadian medical schools had developed a series of online virtual patients for their students to assess, diagnose and appropriately manage, with virtual patients being cited as potentially offering the opportunity to improve the accuracy and speed of cognitive, behavioural and psychomotor tasks (Zielke et al., 2010).

Conradi et al. (2009) have demonstrated that it is feasible to create such virtual patients within Second Life for training. Conradi and her team at St Georges University developed and evaluated scenarios within the virtual world for paramedic students to utilise for training. These scenarios all followed a similar extensible markup language (XML) standard for case development, the Medbiquitous standard (Medbiquitous_Consortium, 2010). This standard is intended for use by anyone who wants to create or implement interoperable tools for virtual patient development, so that a data structure is created to represent virtual patient activity in a standard way. The purpose of this is to reduce the dependence of virtual patient development on expert clinicians, therefore reducing the time and cost involved.

The aim of the scenarios developed in this study was to focus on paramedic students collaborating to form a consensus for decision-making in managing their virtual patients. Of the 20 subjects who took part in the user testing of
this simulation, there was a general positive response towards this new form of training. In the evaluation questionnaire, the subjects either ‘agreed’ (n=15) or ‘strongly agreed’ (n=5) that Second Life was a relevant resource for clinical work preparation. The majority of the students (n=15) also ‘agreed’ or ‘strongly agreed’ that Second Life was a valuable source for revision for practical examinations. This study, though, does not identify individual paramedics’ performance in the management of these virtual patients, which would be essential if such a training tool could be incorporated into medical education programmes. Further information is required on whether this form of training may also be used for assessment and whether the training received could result in improved real-life clinical management.

The ability to collaborate in decision-making in patient management has also been addressed by the University of Auckland. Diener et al. (2009) describe how they have developed a University Medical Centre in Second Life, which can be used for team training. The Centre contains an emergency room with a resuscitation bay in which the university instructor may take the role of the patient with the students acting as the attending physicians. All student decisions can be made through a head-up display (HUD) in which they can select options such as cardiac or bowel sound auscultation, the rate and administration of intravenous fluids and other choices. Patient vital signs are displayed above the patient’s bed and can be altered by the instructor through a separate HUD. The ability to alter patient variables during a virtual patient scenario is advantageous, as this offers the opportunity for instructors to introduce patient deterioration after inappropriate management decisions or
stress-invoking scenarios at the outset. It has been acknowledged that in
Second Life it is feasible to script for complex scenarios and observe the
assessment of individual responses in a simulated environment (Windsor,
2009). Whilst this is an innovative method of team training, further data is
awaited following user trials. Second Life has also appealed as an
environment for collaborative learning for medical conferences.
1.8.3 Medical Conferences

Medical conferences have long been established as an essential method of disseminating relevant research and establishing different and improved methods of clinical practice. In order to present research, obtain recent clinical information on novel practice or network with associated specialists at conferences, it is often essential to travel to a variety of worldwide locations (Green, 2008). The feasibility of attending several conferences is limited due to time constraints and often it is necessary to select which is the most appropriate conference to attend.

The feasibility of hosting and attending a Second Life conference was demonstrated through the International Virtual Association of Surgeons (iVAS) Conference (Figure 1e) held on the 22nd April 2008 (Leong et al., 2008). This consisted of 47 delegates from 5 different countries, congregating in the same virtual space to attend a conference discussing surgical robotics and emerging surgical technologies. The invited speakers were able to deliver their presentation through their avatar using VOIP and slides on Microsoft PowerPoint, (Microsoft Corporation, Redmond, Washington), which were displayed to the audience. A post hoc questionnaire revealed that 96% of attending delegates’ agreed’ or ‘strongly agreed’ that the experience was highly rated, with all delegates agreeing to attend another meeting in the same setting. Second Life has been further used for conferencing as an adjunct to real-life conferences, thus having both a real and a virtual audience (Society_of_Laparoendoscopic_Surgeons, 2010; NHS_Confederation, 2009).
It would be interesting to determine how much organisation and cost is required to set up a large-scale virtual conference in comparison to a real-life conference. However, one of the major issues with using virtual worlds to support synchronous meetings lies in the imposed limits of physical world time zones (Schmell et al., 2013); this possibly explains why there has not been more use of this unique method of virtual conferencing.
Figure 1e: The inaugural iVAS conference
Huang et al. (2008) describe how it may be feasible in the future to integrate poster sessions for virtual conferences with Second Life. They cite the many advantages of having conferences within Second Life, such as negating the need for travel and locating accommodation. They also describe how modifying virtual rooms and customising specific objects, as well as presenters having the ability to add or edit content depending on the feedback they receive, could enhance the conference. There are also benefits to conference organisers in that they are able to informally invite attendees as well as promote the conference outside the specialist field to other delegates.

Wiecha et al. (2010) have demonstrated how such group seminars could be utilised to enhance medical education. In this study, 14 primary care physicians received a lecture (training intervention) in Second Life regarding insulin therapy for diabetic patients. The study followed a pre-post test design with 10 primary care physicians asked to manage a mock diabetic scenario, hosted within Second Life, before and after the lecture. Their results showed that the percentage of participants providing correct insulin initiation increased from 60 to 80% (p=0.2) pre-post and the percentage of participants providing correct initiation of mealtime insulin increased from 40 to 90% (p=0.09). Whilst these results were not statistically significant, there was a significant increase in the subjective rating of participants’ confidence in their ability to select the appropriate insulin for type 2 diabetes - mean 4.9 to 6.5 (p=0.002) on a 7-point Likert scale. There was also a significant increase in participants’ confidence in their ability to initiate insulin therapy for type 2 diabetics - mean 5 to 6.2 (p=0.02). This is the first study performed in Second Life that
attempted to assess how training within this environment may impact on future behaviours. Whilst this should be commended, it would have been beneficial to have more participants in the sample and then more information could have been retrieved on how effective Second Life is as a learning environment. It would have been interesting to note whether these primary care practitioners did provide the correct insulin initiation for their patients in their real practice and whether they provided the correct mealtime insulin initiation. However, this is one of the primary studies, which potentially demonstrates the benefit of using Second Life as an environment for enhancing healthcare education.
1.9 Conclusion

Second Life and the virtual world are in the primary stage of dissemination into the broader community. This early stage of adoption of such a technology is similar to the initial advent of the World Wide Web: this widespread technology has seen an unparalleled growth, which has transcended all boundaries through its continued enhancement. The potential exists for virtual worlds to follow a similar pattern of growth with the possibility of implementing them into everyday use. It has been acknowledged that new technologies are needed to enhance training within current healthcare service restrictions (Aggarwal et al., 2008).

Early healthcare research has been established within the virtual world, more specifically in Second Life. Whilst it is commendable that early innovators have experimented with this new form of media, more extensive research is required to establish the efficacy of such developments and its applicability to healthcare education and training. However, the initial step has been undertaken to evaluate whether the use of virtual worlds can be integrated into medical education; it does offer a potential solution to the challenges that are affecting current educational programmes, as well as proposing a different form of simulation to those in current use. Only through more experimental research will it be established whether Second Life has the potential to be an educational platform for healthcare professional training.
1.10 Hypothesis of Thesis

Virtual world simulations can enhance healthcare education.

1.11 Aims of Thesis

This thesis seeks to explore whether Second Life is a feasible environment for healthcare professional training. This will be established through a series of experimental studies, which will focus on educating different healthcare professionals, namely medical students, nursing staff, postgraduate surgeons and emergency doctors. The thesis aims to:

Investigate whether a Second Life virtual environment can be used as an orientation for a real clinical environment.

Determine whether a virtual patient can be created in Second Life and be subsequently used for healthcare training.

Progress the virtual patient design in order to create a reproducible method for virtual patient development.

Establish whether the developed virtual patients can be used as an assessment tool for training surgeons.

Ascertain whether the virtual patients can be used to simulate the emergency care pathway in order to determine the impact of handoff referrals.
Chapter 2

Operating Theatre Introduction for the Novice
Aim

To establish whether a custom-built virtual world operating theatre in Second Life could be used to train operating theatre novices in preparation for the real operating theatre.
2.1 Chapter Overview

This chapter seeks to establish whether a Second Life developed environment is a feasible setting for training a group of healthcare professionals. This investigation was performed by training operating theatre novices in a virtual operating theatre. The training content was developed through information derived from an operating theatre training curriculum for novice medical students. The training within the virtual world operating theatre was compared to other training techniques, namely a Simulated Operating Suite (SOS) and a didactic lecture, to establish how the virtual world operating theatre compares with other training modalities in educating the pre-trained novice in preparation for the real operating theatre.

2.2 Introduction

The operating theatre is considered to be a high-pressure and dynamic environment with multiple medical specialties collaborating towards the sole purpose of enhancing the patient’s outcome (Undre et al., 2007). With no defined role, a novice’s first exposure may be both intimidating and unproductive, with students frequently learning through humiliation (Lyon, 2003). This can potentially be detrimental to a student’s initial learning curve, with a possible impact on their future career decision (Stark, 2003); a decline in interest in general surgery has been evident (Antiel et al., 2012).

The operating theatre is unique, in that it provides an opportunity for students to enhance their knowledge regarding patient management, and potentially to
improve their basic skills such as gowning and gloving and simple suturing, within the same setting. However, there has been an emphasis on alternative learning environments, such as the clinical ward and the outpatient department, as the optimal sources of student education (Lyon, 2003), which neglects the use of the operating theatre as a potentially rich source of learning for the student. This then poses the question of how an operating theatre can be effectively utilised to train medical students.

Lyon has postulated that students need to manage learning across three domains within the operating theatre environment (Lyon, 2003): managing the demands of the working environment; the educational tasks; and the learning and social relations of the operating theatre. Students able to successfully manage these have an enhanced experience within the operating theatre. It is also important to establish that a student has sufficient preparation prior to undertaking any new action, especially in an environment such as the operating theatre.

The lack of a structured introduction towards the operating theatre may not only be detrimental to the novice, but may also compromise patient safety. Fernando et al. (2007) have previously concluded, from their qualitative study of factors contributing to operating theatre learning, that theatre-based learning could be improved with the provision of a well-timetabled preparatory session for the operating theatre.
The aims of this study were primarily to investigate whether a virtual world operating theatre, developed within Second Life, could be used as an introductory technique for novice students in preparation for the real-life operating theatre. The educational content for this training was derived from a theatre induction curriculum (TIC), developed following an exploratory study identifying what both surgical trainers and trainee students deemed important for initial attendance in the operating theatre. The secondary aims were to determine which training method: a didactic lecture, a virtual world operating theatre or a simulated operating suite, provided the most benefit for the novice in training for the operating theatre environment.
2.3 Methods

2.3.1 Development of the Theatre Induction Curriculum

Prior to this work, another study (Vadhwana et al., 2009) had been performed, establishing both trainers and student trainees’ expectations of a student’s initial attendances within the operating theatre. This study involved a qualitative semi-structured interview of both trainers (n=8 General Surgery senior registrars and consultants) and trainees (n=9, 3rd and 4th year Imperial College medical students with at least 1 year’s experience of attending the operating theatre) to achieve an in-depth comprehension of the main issues surrounding the current initial medical student operating theatre training and how the experience could be enhanced.

The results focused on the components of a good and bad operating theatre experience; factors impeding the ability to train; the trainer’s expected knowledge prior to entering the operating theatre; preparation for attending the operating theatre; and what students should gain from the operating theatre. A recurring theme that emerged from the study was that students were unprepared for attending the operating theatre, stating a lack of knowledge of what and how to prepare for the operating theatre experience. The results from this study demonstrated various attributes, in the form of knowledge, skills and attitudes, which were deemed important for the initial operating theatre attendances. It is these items deemed important that formulated the structure of the theatre induction curriculum (Appendix 1) that was used extensively in this study.
2.3.2 Development Team

I formed a group with a Clinical Lecturer in Surgery and a Senior Lecturer in Experimental Psychology, both of whom were instrumental in the study described above. This group assumed responsibility for the development of the outcome measures. In addition, a 4th year Imperial College medical student was employed to perform assessments in the operating theatre.

2.3.3 Personal Role

My personal role was to be responsible for the study design and the subsequent presentation of the study for ethical approval, as well as the development of the outcome measures. I was also responsible for the recruitment of the subjects and their allocation to respective operating theatre cases. In addition, I organised the timetabling of all structured assessments for all of the participants. Finally, I delivered all the training interventions to the relevant groups in the study.

2.3.4 Timescale

The study design totalled 3 months with another 5 months for data collection. However, the data collection did not occur consecutively due to the conflicting schedules of the medical students. Therefore an initial 3 months of data collection was performed, followed by a 2-month hiatus and then resumption of the data collection for another 2 months.
2.3.5 Development of the Outcome Measures

The research group was convened and it was agreed that the attributes that we wanted to assess from the student performance was their knowledge, skills and attitudes, pre-, post- and intra-operatively. It was established that the optimal method for assessing this was through an observation rating scale (Appendix 2). I developed this, following a content review of the theatre induction curriculum, with a number of iterative revisions made following group discussion. The scale included a number of themes, which were rated according to a 6-point Likert scale.

In conjunction with the observation scale, a self-report rating scale (Appendix 3) was developed for the students to self-rate following operating theatre attendance; this would encapsulate how they felt they performed in terms of their knowledge, skills and attitudes during the pre-, intra- and post-operative phases of their operating theatre attendances. Again this self-report scale was based on the content from the theatre induction curriculum and was developed through a similar process as the observation scale, with revisions of the scale being progressively made.

Additionally the decision was made to further assess the knowledge of the students through a multiple-choice questionnaire (Appendix 4). This consisted of fifty multiple-choice questions, which I developed following a review of the theatre induction curriculum. All questions included information that was considered important for them to know for initial operating theatre attendance. These multiple-choice questions underwent iterative revisions, following a
similar process to both the observation and self-report scales. The group decided that the students should be assessed prior to operating theatre entry with the multiple-choice questionnaire, with the observation scale immediately pre-, during and immediately post-operating theatre attendance. Finally the students would self-rate their performance following their operating theatre attendance.

In order to observe the students, according to the observation rating scale, a 4th year medical student was recruited, to evaluate all operating theatre attendances by the students. This student was prepared for the task of observing the students at a group briefing, where the members described what knowledge, skills and attitudes displayed would constitute a poor, satisfactory and good performance for each item of the rating scale. Following this briefing, the student observer attended a series of ten operating theatre sessions with medical students present before commencement of the study. The observer proceeded to rate the students’ performance, with a debriefing with myself after the session in order for me to evaluate her ratings so that we were both taking a consistent approach to the rating. As the student observer proceeded to attend more operative theatre sessions she required less input into her ability to rate the student performance, with minimal input required on the final three operating theatre sessions.
2.3.6 Subjects

Before beginning the study or recruiting the student observer, Regional Ethical Approval (Brent Research Ethics Committee), reference number 09/H0717/10, was obtained. The study recruited 60 participants. All participants were first year medical students from Imperial College, London. First year medical students were selected because this is the only year group who would not have had any exposure to the operating theatre, as clinical attachments with surgical teams may commence from the second year onwards. All students were recruited through an email invitation to participate, which I distributed to every medical student in the first year of Imperial College. The email contained an attached poster (Appendix 5), which I had developed in order to facilitate recruitment of participants. The invitation detailed the specific exclusion criteria for the study, which excluded those who had previously attended an operating theatre. The students recruited were randomised into four groups using the closed envelope technique. The four groups were: C-control, L-lecture, SL- Second Life Virtual Operating Theatre, SOS-Simulated Operating Suite. I delivered the details of each student’s group to the students, through the closed envelope technique, prior to their first entry into the operating theatre.

2.3.7 Setting

The study predominantly took place in the Day Surgery Unit of St Mary’s Hospital, Imperial College NHS trust, London. The training interventions occurred in the Department of Surgery, St Mary’s Campus, Imperial College, London, in three specific areas depending on the training intervention: the
Simulated Operating Theatre training occurred in the Simulated Operating Suite located in the Department of Surgery; the lecture took place in a specific seminar room in the Department of Surgery; and the Second Life virtual operating theatre training occurred in the student computer room on the St Mary’s Campus of Imperial College. Prior to the use of this room for the study, arrangements were made so that the only occupants of this room would be study participants; this was to ensure that none of the students would be distracted during the training intervention.

2.3.8 Study Design

A pre- and post-test design was employed in this study (Figure 2a). All participants, either in pairs or independently, attended an operating theatre case performed in the Day Surgery Unit of St Mary’s Hospital. All cases attended were performed under general anaesthesia and a variety of procedures were observed, within the general surgery, gynaecology and otolaryngology specialties. All consultant surgeons and anaesthetists were informed about the presence of the students and the observer in the operating theatre.

On the evening before their day surgery attendance, I notified the medical student participants by email of the operative procedure being performed and the location of the procedure. Before going into the operating theatre, the students completed the demographic questionnaire and the knowledge-based multiple-choice questionnaire. They then attended the operating theatre and
observed the procedure. Following the completion of the operative case, the participants completed the self-report questionnaire.

The student participants then received their training intervention according to their designated group, aside from the control group. The control group did not receive any training, to represent current clinical practice. Participants who were exposed to a training intervention completed a Likert scale questionnaire to evaluate the training they received (Appendix 6). Following the training interventions, the students re-attended the operating theatre to observe an operative case under the same guidelines as previously employed and completed the same assessment criteria. Both operating theatre attendances and the training intervention were performed within a 7-day period for each participant.
Figure 2a: Pre- and post-intervention study design
2.3.9 Training Intervention

2.3.9.1 Didactic Lecture (L)

Prior to commencement of the study, I prepared a one-hour lecture in Microsoft® PowerPoint 2008. It consisted of information deemed essential from the theatre induction curriculum; the expert group reviewed the lecture contents and suggested appropriate amendments. This lecture included instructional videos regarding the process of gowning and gloving, which were obtained via Imperial College undergraduate teaching intranet (Imperial College, London, UK).

During the training I delivered the lecture to five students per session. The number of five students was in order to keep the numbers receiving training consistent for each training group: if the number was larger, then both the virtual operating theatre and the Simulated Operating Suite might have been too crowded for the student participants. Following the delivery of the lecture, students were granted the opportunity to ask questions to clarify any points they did not comprehend.
2.3.9.2 Second Life Virtual Operating Theatre (SL)

The Second Life Virtual Operating Theatre session occurred in a computer laboratory at Imperial College. Each participant accessed the virtual world of Second Life through a desktop computer. The Virtual Operating Theatre session primarily consisted of a half-hour introductory session to the Second Life environment prior to the tour of the operating theatre. This occurred within the Second Life orientation island (Second_Life_Virtual_Hospital), which had been purpose-developed to orientate new Second Life users for Imperial College’s developments.

A set of five avatars had previously been created in Second Life so that the students could automatically login with these specific avatars, as opposed to going through the laborious method of selecting and enhancing their own personalised avatars. The orientation consisted of subjects familiarising themselves with their avatars. Through their avatars, the participants were able to mobilise and communicate with each other and with myself within the virtual world. The avatars were able to listen and talk to other avatars through the use of a headset.

Following the orientation, the subjects participated in training in the Second Life Operating Theatre (Second_Life_Medical_School). This is a 3D representation of St Mary’s Hospital operating theatre (St Mary’s Hospital, Paddington, London). In the training, I directed the participants around the virtual world operating theatre and gave them information about it (Figure 2b). The content of the training was similar to the training delivered in the lecture
and was all based on content from the theatre induction curriculum. However, the major difference with this training modality was that the students were able to view different operating theatre objects and in some instances obtain further information by clicking on an object. For example, clicking with the mouse on the operating theatre lights would display a video showing how the lights could be moved in a sterile manner. This was further supported by an explanation to the students of how a scrubbed surgeon could move the operating theatre lights as opposed to how non-sterile theatre personnel could move them.

Before commencing the training, all avatars were instructed to wear virtual surgical scrubs. This session incorporated the same videos as the lecture regarding gowning and gloving, but these were embedded within the scrub room of the virtual operating theatre. Initiating these videos required the student to click on the operating theatre sink in the scrub room. The wearing of surgical scrubs and being taught how to gown and glove was a prelude to the content delivery within the virtual operating theatre. I conducted the training, through voice chat, in groups of five participants per session, with each operating theatre tour lasting approximately one hour to match the content delivery of the other groups.
Figure 2b: The Second Life Operating Theatre
2.3.9.3 Simulated Operating Suite (SOS)

This training session consisted of the students participating in a theatre induction curriculum-based instructional session in the Simulated Operating Suite at Imperial College. The SOS consists of a replicated operating theatre with an adjacent control room (Figure 2c). Within this replicated theatre is an operating table, a laparoscopic stack system, diathermy and trolleys containing equipment such as suture material, dressings etc. (Aggarwal et al., 2004b). Before going into the SOS, all the participants were instructed to dress in surgical scrubs. The training consisted of an instruction-led session, which was interactive and conducted by myself.

The content delivered in this training session was similar to the content delivered in both of the other training modalities, and consisted of a similar approach to the virtual operating theatre in that I was able to explain the purpose and use of various operating theatre equipment as well as demonstrating how the equipment was used. The main difference in this training session was that I demonstrated the practice of gowning and gloving myself and the participants were subsequently encouraged to perform this task themselves. However, in order not to give this group an advantage over the other groups, I refrained from giving them feedback on how well they performed in their gowning and gloving technique, although if any of the students displayed obvious difficulty in the placement of their surgical gown or gloves I would offer advice to assist them. The training intervention lasted approximately one hour to remain consistent with the other training modalities.
Figure 2c: The Simulated Operating Suite
2.3.10 Statistical Analysis

The data regarding knowledge, skills and attitudes, obtained from the observation scale, the self-report scale and the knowledge multiple choice questions, was analysed using SPSS version 16 for Mac (SPSS Inc., Chicago, USA). The internal reliability of the knowledge, skills and attitudes items on the observation and self-report scales was assessed using the Cronbach’s alpha coefficient. In view of the non-parametric nature of the data, the Wilcoxon Signed Rank Test was performed to assess for any difference between pre- and post- intervention outcomes. The Kruskal Wallis test was used to assess for any difference between all four groups for all pre- and post-intervention outcomes. Further group comparative analysis was performed using the Mann Whitney U Test to detect where the outcome difference was between the specific groups.
2.4 Results

The internal consistency for the knowledge, attitude and skills items was high for the observation scale ($\alpha \geq 0.72$) and for the self-report scale ($\alpha \geq 0.881$) (Table 2a), demonstrating a high reliability for the scales. 32 female and 28 male subjects participated in the study. The age range of all participants was 18-21 years. Of those who received a training intervention, there was no significant difference between their evaluations of the training they received ($p=0.36$).

The pre-intervention exposure to the operating theatre revealed no differences between the groups for knowledge assessment ($p=0.477$), observation score ($p=0.212$) and self-report scores ($p=0.099$). The L, SL and SOS groups all demonstrated significant improvement in the outcome measures post-training (Table 2b and Figure 2d for observation score improvement). The C group did not display any significant improvements. Post-intervention, there was a significant difference between the groups for all of the outcome measures ($p<0.001$).
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Table 2a: Internal reliability for Knowledge, Skills and Attitudes items in the Observation and the Self-report scale
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<td>Self-Report Scale</td>
<td>93</td>
</tr>
</tbody>
</table>

* Denotes statistical significance

Table 2b: Statistical Analysis for difference between pre-and post-intervention in participant performance
Figure 2d: Pre-and post-intervention observation scores for each group
Further analysis showed that the L, SL and SOS groups had significantly higher knowledge, observation and self-report scores compared to the C group. The SOS group demonstrated significantly higher knowledge (median 43 versus median 39, p<0.001), observation (median 132 versus 115, p=0.008) and self-report (median 142 versus median 118, p<0.001) scores than the SL group. The SOS group also displayed higher observation (median 132 versus 107, p<0.001) and self-report (median 142 versus 121, p<0.001) scores than the L group. The L group had a significantly higher knowledge score (median 42 versus median 39, p<0.001) than the SL group.
2.4.1 Observation Scale – Knowledge, Skills and Attitudes

Further analyses of the observation and self-report scores were performed in the subsections knowledge, skills and attitudes. There was no significant difference between all the groups for knowledge, skills and attitudes in the observation assessment pre-intervention. The L, SL and SOS groups all demonstrated significant improvement in the knowledge, skills and attitudes (Table 2c, Figure 2e for knowledge improvement). The C group displayed a significant improvement in the skills assessment only (p=0.013).

Post-intervention, the L, SL and SOS groups all achieved a significantly higher knowledge, skills and attitude score than the C group (p<0.001). The SOS group demonstrated higher knowledge (median 39.5 versus 34, p=0.033), skills (median 44.5 versus median 38, p=0.001) and attitudes scores (median 45 versus median 40, p=0.015) than the SL group. The SOS group also displayed a higher knowledge score (median 39.5 versus median 35, p=0.026) and a higher skills score (median 44.5 versus median 31, p<0.001) than the L group. The L group had a higher attitude score (median 43 versus median 40, p=0.009) than the SL group, with the SL group displaying a higher skills score (median 38 versus median 31, p=0.001) than the L group.
<table>
<thead>
<tr>
<th>ASSESSMENT</th>
<th>GROUPS</th>
<th>Control (n=15)</th>
<th>Lecture (n=15)</th>
<th>Second Life Theatre (n=15)</th>
<th>Operating (n=15)</th>
<th>Simulated Operating Suite (n=15)</th>
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<tr>
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<td>Post-</td>
<td>Pre-</td>
<td>Post-</td>
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<td>Skills</td>
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<td>20 (21-35)</td>
<td>18 (15-24)</td>
<td>31 (27-42)</td>
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* Denotes statistical significance

Table 2c: Statistical Analysis for pre-and post-intervention difference in knowledge, attitudes and skills in the observation scale
Figure 2e: Pre-and post-intervention knowledge score (from the observation scale) for each group.
2.4.2 Self-Report Scale – Knowledge, Skills and Attitudes

There was a significant difference between the groups, pre-intervention, for knowledge \( (p=0.026) \) and attitude \( (p=0.05) \) but not for skills \( (p=0.217) \). There was a similar improvement in the knowledge, skills and attitudes for the self-report scale for the groups as displayed in the observation score (Table 2d, Figure 2f for skills improvement). Due to the significant differences in knowledge and skills pre-intervention, both parameters were excluded from post-intervention analysis.

Post-intervention, the L, SL and SOS group reported a significantly higher skills score than the C group. The SOS group reported a significantly higher skills score (median 38 versus median 33, \( p<0.001 \)) than the SL group and the L group (median 38 versus 32, \( p=0.001 \)).
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* Denotes statistical significance

Table 2d: Statistical Analysis for pre-and post- intervention difference in knowledge, attitudes and skills in the self-report scale
Figure 2f: Pre-and post-intervention skills score (from the self-report scale) for each group
2.5 Discussion

This study was innovative in that it was the first study that has attempted to improve operating theatre education from the first operating theatre attendance. This is becoming increasingly important, as there are increasing reports suggesting a decline in interest in general surgery as a career choice (Cockerham et al., 2004; Cofer and Burns, 2008; Kahn et al., 2006). It is thus imperative to provide an extensive, formative insight into a career in general surgery as early as possible. There is a need, though, to ensure that those not entering a career in surgery also receive an extensive early exposure to surgery and its affiliated pathologies and are well taught through a well-structured format (Lewis et al., 2009).

This study attempted to enhance the education of those at a novice stage in surgical/operating theatre exposure through the use of a virtual world operating theatre. In this context, the use of this training environment successfully demonstrated an improvement in knowledge, in observed behaviour and in students’ self-reporting of their perceived performance in the operating theatre. In essence, the introduction of a theatre induction curriculum demonstrated a significant improvement in novice performance regardless of the methodology used to instruct the subjects. However, according to the data obtained, the virtual world operating theatre only resulted in a similar improvement in the outcome measures to the lecture group, but both were inferior to the results from the use of the Simulated Operating Suite.
The context of the findings of this study, however, must take into account some of the limitations of the study design. Firstly, a power calculation was not performed to ascertain the minimal sample size required to establish a difference between the groups. The reason for this was that this was a unique study with no previous studies to draw comparisons from. The study was restricted to 60 students in total, as the uptake by the first year cohort was limited. Despite the email invitation with the attached poster, a second email invite had to be sent in order to gain further recruits. In order to increase the number of participants, the study could have been extended to second year students who had no previous exposure in the operating theatre, but this would potentially have provided other difficulties.

In order to conduct the study it was necessary to perform all components of the study, i.e. the operating theatre attendance and the training intervention, outside the scheduled timetable of the first year students so as to not conflict with their scheduled lectures. This provided challenges, in that there were periods in the weekly timetable when some students would have no scheduled activity but others would have. Therefore it was difficult to coordinate the study to make full use of this potential time due to the five participants in each group. The addition of another year group would have provided a greater challenge in terms of scheduling the study components. In order to feasibly conduct the study, it became necessary to perform the study within the students’ holiday period if they were available. Due to all these
constraints, it was difficult to attain higher numbers and potentially perform a pilot study, which would have contributed to a power calculation for the study.

Another study limitation was the use of only a single rater in assessing the performance of the students through the observation scale and therefore not addressing the inter-rater reliability of the observation scale. Ideally there would have been two raters. The results could be questioned, in that without the use of a second rater the observation of the participants' behaviour was susceptible to rater bias. Although I initially briefed the rater, this did not formalise the reliability of the rating. In retrospect the optimal scenario would have been for me to observe a number of novice students in the operating theatre simultaneously with the student observer outside the remit of this study. The inter-rater reliability of the rating scale could then have been calculated prior to any observation of the student performance within this study. For further work in this field it would be sensible to proceed with the above plan or to use two raters throughout.

The other outcome measure included the use of multiple-choice questions to assess the student participants' knowledge. The use of multiple-choice questions for the knowledge assessment was limited, due to two reasons. Participants obtained high scores initially even before attending the operating theatre, which suggests that the questions were too simple and did not actually require attendance in the operating theatre. Also, with the multiple-choice questions it would have been feasible for the students to guess the correct response to the question even if they did not possess the appropriate
knowledge. In such a case the student would have a 50% chance of obtaining the correct answer. With both of the above reasons this study could have benefitted from an alternative method of measuring knowledge or alternatively, not measured knowledge at all, as the primary focus was to determine whether behaviour altered and knowledge does not necessarily translate to behaviour.

In retrospect perhaps an improved method of assessing knowledge would have been the development and use of single best answer questions in order to determine knowledge regarding the operating theatre environment. This would have removed the element of the students having a 50% chance of correctly selecting an answer and would have ensured that students possessed the appropriate knowledge in order to answer each question. However, the multiple-choice questions were initially selected as it was deemed easier to develop these questions, especially in the context of my lack of prior experience in developing such assessments. However, these questions should have been piloted and the construct validity established prior to their use in this study. This could have resulted in more appropriate revisions of the questions in order to provide more of a challenge for the students undertaking the assessment.

Another method by which this study could have been improved would have been to have all the students present for the same operating case performed by the same surgeon for both the pre- and post-theatre attendance. This would have ensured that the operating theatre was as uniform as possible for
all students, as it was obvious that some operating theatre team members engaged students more than others, therefore potentially causing variation in the results. However due to the time constraints within this study, particularly for the student observer, it was not feasible to conduct the study using the same cases, although without these constraints this could have been a possibility.

This study attempted to establish whether different training modalities resulted in improved training for the operating theatre experience at a novice stage. It used both innovative – the virtual world operating theatre and the Simulated Operating Suite – and traditional methods to educate the participants. This study could have been improved, though, by performing a qualitative analysis through a semi-structured interview of the participants in order to establish their views on the training modalities. This would have led to a more detailed analysis of what constituted a good training experience in the different methods. This would have also led to further insight into the positive aspects of the virtual world training experience and how this could have been improved, which would have been particularly beneficial for further developments.

The findings generated from this study have been unanimous in demonstrating the Simulated Operating Suite as the optimal environment to train the students. However the use of a Simulated Operating Suite has practical implications for novice training towards operating theatre exposure. The primary reason is the limited number of such training facilities available.
An alternative is using a real operating theatre to train novices; however, this would require that both instructor and students partake in such training out of regular hours. An interesting alternative, though, that could be used is the distributed simulation model as described by Kassab et al. (2011): this represents a versatile simulated environment that uses an inflatable enclosure to provide the illusion of an operating theatre environment in any limited space. This model could provide a high fidelity simulated environment akin to the Simulated Operating Suite. However, in order to assess its efficacy for training the novice in preparation for the operating theatre this study would have to be repeated with one of the intervention groups consisting of the distributed simulation model.

This study has shown that use of the virtual world operating theatre resulted in an improvement in all outcomes measured. However, it is disappointing that the results displayed are similar to the results from delivery of a lecture, which represents the current most common method of education delivery to students. The reasons why the virtual world operating theatre did not deliver better results are not obvious, although an explanation could be the fact that this was completely new software for the students, which they were being asked to use for the first time in order to receive educational information. In the other two training modalities, the students were only given the task of receiving and assimilating the information, whereas the virtual world operating theatre group had to familiarise themselves with the software as well as process the information that they were receiving. It is feasible that in the context of adapting to this environment some of the information that was
being received was not being fully processed. However, this explanation represents speculation only.

The virtual world operating theatre would have benefited from higher fidelity objects or simulations: for example, a virtual operation occurring within the operating theatre. This would have involved a virtual patient on the operating table surrounded by a virtual surgeon, virtual assistant etc. The incorporation of such an item into the environment could have resulted in a much higher fidelity and therefore been more immersive for the student participants. It would have then been interesting to determine if this would have resulted in further improvements in the outcome measures on a similar standard to the Simulated Operating Suite group.

The use of a didactic lecture displayed similar results to the virtual world operating theatre group and could easily be integrated into a training curriculum as a standardised lecture. There would be a requirement to deliver this several times during the calendar year to reflect different students being exposed to the operating theatre at varying times in the undergraduate curriculum. The alternative would be for the lecture to be delivered at the beginning of the training year with the lecture slides being uploaded onto the student intranet so that they are accessible at any given time.

Despite the favourable results demonstrated from a training intervention, it is not apparent how long the benefit from an intervention would last. There are potential implications that those who receive a structured initial orientation
gain more benefit from their progressive attendances within an operating theatre. A possible further study would be to progressively monitor the novices as they attend several subsequent operating theatre cases, to establish if there is a long-term benefit following an initial orientation. Another alternative is also to address if regular repeated training sessions with the methods employed in this study result in a sustained improvement in the observed behaviour within the operating theatre.

This study has demonstrated that a short period of training can increase novices’ knowledge, skills and attitudes towards the operating theatre. If such a curriculum were utilised as an adjunct to the World Health Organisation (WHO) curriculum for undergraduates on patient safety (World_Health_Organisation, 2010) this could potentially enhance the quality of care from an early stage of training. Training environments such as the virtual world operating theatre and the Simulated Operating Suite can provide a high level of immersion and realism, thus providing novices with the most profound positive effect. It is acknowledged, though, that further work must be undertaken, particularly regarding the virtual world operating theatre to enhance its fidelity and hence immersion as a training environment for the novice in exposure to the real operating theatre.
2.6 Conclusions

This study has demonstrated that the introduction of an operating theatre induction curriculum using a virtual world operating theatre is of benefit to novice medical students. However, as a training environment this has demonstrated inferior results to the Simulated Operating Suite, which displayed the most beneficial results. It is therefore essential to attempt to improve the fidelity of the virtual environment by providing simulations to determine if this may further enhance the training of different healthcare professional groups and thus demonstrate the efficacy of the use of virtual world simulations.
Chapter 3

The Development and Feasibility of a Virtual World Clinical Scenario
Aim

To develop a focused Second Life clinical scenario and then to assess its face validity for nurses.
3.1 Chapter Overview

This chapter describes the development of a focused virtual world clinical scenario. This scenario involved adverse clinical events associated with a medical infusion device. The development involved the creation of a paper-based storyboard of the scenario and subsequent transfer of this conceptual design into a three-dimensional simulated experience in Second Life. Post-development, a user group of forty clinical nurses were recruited to take part in this online simulated exercise and to deliver specific feedback on its use, relevance and potential future application.

3.2 Introduction

The previous study demonstrated the feasibility of utilising a virtual environment in Second Life to train a group of healthcare professionals. This was a static environment, though, in which engagement was predominantly passive with information being delivered to a group of students through the use of avatars. This next study sought to establish a method of developing a single virtual patient in an engaging clinical scenario. A single patient was selected so as to optimise the development methodology before proceeding to develop a multitude of reproducible virtual patients.

The virtual patient was developed for a clinical scenario, in which the user participant was to manage a patient affected by adverse events associated with a medical infusion device. This scenario may represent a single patient but could further guide future development by displaying the integration of
multiple events afflicting a patient, which could prove useful in further development of multiple patients. The reason for selection of a scenario focusing on an infusion device was that multiple events could affect the infusion device and therefore the virtual patient, resulting in a single scenario with multiple events.

Another reason is that medical devices are utilised in all aspects of modern healthcare, being integral to a vast array of clinical treatments. They are often complex and varied in design; providing inherent risks as well as benefits to patient safety (Hall et al., 2008). Unfamiliarity with such medical devices is associated with an increased risk of medical error (Senders, 1995) with medical device-associated errors contributing to a major source of patient morbidity (Kohn et al., 2000) with at least 700 unsafe infusion device-related incidents reported per year (NPSA, 2004, Agency, 2004).

One of the commonest medical devices widely employed is the intravenous (IV) infusion pump. IV pumps are integral to the safe delivery of appropriate medications in a range of hospital, outpatient and home environments. However, high error rates have been demonstrated with intravenous medication administration, with one or more errors cited in approximately half of all intravenous drug preparations (Taxis and Barber, 2003). The Medical Devices Agency has previously stipulated that there is an obligation for National Health Service (NHS) trusts to provide infusion device training, with resources allocated to ensure patient safety and minimise adverse events as well as report any adverse events.
This exploratory study investigated the preliminary development of a clinical scenario focusing on a single virtual patient in Second Life, with the further aim of guiding future multiple virtual patient developments. Following the production of this virtual patient, we sought to obtain opinion from a user group of nursing faculty in order to appreciate the value of undertaking future virtual patient design and development.
3.3 Methods

3.3.1 Outline

The methodology of the virtual patient design followed a specific path (Figure 3a). The preliminary design involved the storyboard of the case. This was produced after the case details had been discussed and formulated by a multidisciplinary expert group. This storyboard was then implemented into a virtual patient in Second Life. The virtual patient was integrated into a virtual ward, which was specifically created.

3.3.2 Development Team

The development group consisted of a subset of individuals with specific sets of skills required to guide scenario development. These included:

- A project manager with expertise in managing virtual world and software development projects;
- A 3D designer with specific expertise in Second Life development;
- Myself, with a background in general surgery, employed for case design, development and guidance for development of clinical environments;
- An undergraduate medical student who reviewed instructional sessions regarding infusion device training in order to guide storyboard design;
- A multidisciplinary expert group consisting of:
  - A consultant anaesthetist
  - A Clinical Reader in Surgical Education
  - An infusion pump training specialist
• A 3-D graphic designer
• A senior bioengineer with expertise in medical device training
• A Senior Research Associate
• 2 ITU (Intensive Therapy Unit) nursing specialists.

3.3.3 Personal Role

My personal role during the development involved convening the expert group and chairing the meetings. This subsequently led to the development of the storyboard of the case, which I undertook myself. I then informed and guided the 3D graphic designer on scenario development through regular virtual meetings in Second Life. I also recruited the nurses to participate in the study.

3.3.4 Timescale

The total time for the production of this virtual patient was 10 weeks. This included 5 weeks of preliminary meetings and storyboarding the case. A further 5 weeks was required for the scenario development within Second Life. A further 12 weeks was required for recruiting and testing the nurses.
Figure 3a: The process of scenario development

1. Review of resources
   - NHS Courses
   - E-learning modules

2. Multidisciplinary Expert Focus Group

3. Decision on main case components

4. Storyboard of case

5. Focus group review of case

6. Development of Scenario in Second Life

7. Expert Group approval of Scenario
3.3.5 Preliminary Investigation

The undergraduate medical student enrolled in a range of instructional sessions regarding medical infusion device training. This included attending NHS Trust-based courses and commercial industry representative-led sessions, as well as reviewing e-learning modules. In consultation with device training experts following these sessions, safe practice guidelines were collated and these formed the outline of the main features of the training scenario. This initial background research identified a formal training deficiency in the management of adverse events associated with medical device use in clinical environments. The scenario development focused on providing training in this obvious deficit.

3.3.6 Scenario Design

Following this preliminary investigation, the multidisciplinary expert panel was convened to guide scenario development. This, coupled with the presentation of online National Patient Safety Agency (NPSA) records, identified the principal components of medical infusion device practice that are often implicated in adverse events. The expert panel devised principal themes to be incorporated into the clinical scenario, which were both common and would provide the end users with a potential educational benefit.

I subsequently produced a clinical scenario through a storyboard format in a Microsoft Word document (Microsoft_Word, 2010) (Appendix 7). This incorporated hazardous events associated with infusion devices that were a potential source of patient morbidity.
These included:

1. Incorrect patient handoff- the participating nurse was informed that the patient was receiving a morphine infusion, when they were actually receiving an insulin sliding scale.

2. Intravenous occlusion alarm- the virtual patient rolled over, thus occluding their infusion tubing.

3. Inappropriate infusion device setting- the sliding scale was set at a low level of Actrapid Insulin (Norvo Nordisk Ltd, Bagsvaerd, Denmark) infusion whilst the glucose level was high.

4. Reduced device battery output- the infusion device was in reserve battery mode.

The clinical scenario was designed to ensure that a warning was issued either through a device alarm or through a presenting complaint of the virtual patient, thus alerting the participant that further action was required in order to effectively manage the situation. The participant would then attempt to solve the clinical problem and establish an improved patient outcome. The clinical scenario was structured so that adverse events occurred in the particular sequence listed above; however, in order to reflect the fact that infusion devices may be used in complex clinical situations, the adverse events were designed to occur simultaneously, ensuring that the participant had to prioritise their subsequent interventions. The storyboard was assessed and approved following a subsequent presentation to the expert panel and following minor amendments was initiated for virtual world development.
3.3.7 Virtual World Development

A central component of the virtual world scenario was the appearance of the infusion device. The nurse educators who were consulted for the study expressed a requirement for a unique device as opposed to a recognisable brand and model. This was to establish the focus on the management of the patient rather than on specific details of the function of the infusion device. A unique infusion device was also designed to avoid any infringement of the copyright of established medical device manufacturers. In order to design a unique virtual infusion device, a review of the NPSA and the Royal College of Art’s guide to infusion devices was undertaken by the medical student (NPSA, 2010). This document detailed recommended characteristics that an infusion device should possess in order to improve usability and enhance patient safety. The principal details regarding the aesthetic layout of the device were duly noted and implemented into the infusion device development. This prototype of the infusion device was presented, by the 3D developer, to the expert panel and following approval was integrated into the virtual ward for further development.

The 3D graphic designer, who had specific expertise in Second Life social and medical environment design, developed the infusion device (Figure 3b) and clinical environment (Figure 3c). This was performed with regular consultation, twice weekly, with myself for the storyboard design of the case. Four distinct areas were created within the virtual learning hospital of Imperial College: a reception area for Second Life familiarisation and scenario orientation, a changing room, a nurses’ office and a hospital ward. These
were all developed with Second Life’s unique internal building tools. Further equipment development required the same building tools for specified objects, such as a patient’s bed or a curtain. These pieces of equipment represented 3D graphics, which could be visualised but were not amenable for interaction. The development of equipment that required interaction, such as the infusion device or the mains output plug, required the object to respond to a user’s intervention. This was developed by coding information to the object using Second Life’s unique Linden scripting language.

The Second Life developer was able to depict which objects required interaction and what the designated output should be from precise instructions derived from the storyboard. I supported this by continually appraising the development and suggesting amendments if required. The virtual world development was subsequently showcased to the research group prior to commencement of the research study.
Fig 3b: A unique virtual infusion device
Fig 3c: The virtual patient within a virtual ward
3.3.8 Scoring System

An initial automated scoring system was integrated into the design phase. This delivered a score of +1 for a correct decision that was made regarding the patient management. This scoring system was outlined between the 3D graphic designer and myself, for development. Upon development this scoring system was implemented into the virtual patient.

During the development phase, it became evident that the integration of the score was more complex than previously thought. The primary reason for this was that the total score obtainable outnumbered the score integrated into the design, i.e. from the design the total score was 10 but within the software the total possible score was 16. Neither the 3-D designer nor myself were able to determine how these additional 6 points could be achieved, although on initial piloting of the cases repeated similar management steps resulted in different scores. The scoring system was therefore abandoned, on the premise that it did not demonstrate valid results for the performance of the participants.

3.3.9 Evaluation Questionnaire

An evaluation questionnaire (Appendix 8) was developed following a series of focus group discussions between myself and two other researchers with expertise in simulation scenario development and evaluation. This evaluation entailed questions regarding previous computing use, previous medical device training and evaluation of the scenario. Following principal
development of the scenario, the evaluation questionnaire was demonstrated and approved by the expert focus group.

### 3.3.10 Clinical Application

Forty nurses were recruited to participate in the validation of this training scenario. This number of nurses was selected as this was primarily an exploratory study and the expert group felt that this number would be sufficient to provide an opinion on the value of this unique training method. The sample size did not undergo a power calculation, as this was a completely innovative study so there was no previous data to interpret. The total of forty nurses was chosen as, in the Surgical wards at Imperial College NHS Trust, there are eight nurses present during a typical shift. Therefore the total of forty represents the nurses that would be present during a typical day on the General Surgery, Cardiothoracic, Vascular, Orthopaedic and Neurosurgery wards. They were recruited from an NHS London Academic Health Science Centre as well as a London-based private hospital. They were principally invited by email invitation through a nurse instructor. Upon agreement to participate, I further contacted them to take part in the study. Initial recruitment within the Academic Health Centre was insufficient; therefore further participants were recruited from another hospital.

The participating nurses undertook a variety of steps (Figure 3d), which commenced with an orientation. This involved basic navigation of the avatar, in which they were instructed on how to mobilise the avatar and use functions, such as a zoom function to view objects close up. The participants then
engaged in a mock scenario where they were able to interact with a virtual patient and their surrounding objects including the infusion device and medical charts. The purpose of this was to familiarise them with the virtual patients prior to proceeding to the virtual patient scenario. The participants next entered a changing room to change into appropriate uniform; they were then instructed to attend the virtual ward to begin the scenario. I was present with the participants at all times during the study, to ensure that the nurse participants were able to appropriately proceed through the orientation and simulation. All participants progressed through the scenario and, upon completing it, completed the evaluation questionnaire.
Figure 3d: The scenario flow

1. Nurse logs in as avatar
2. Second Life orientation
3. Complete orientation
4. Change into uniform
5. Receive handoff
6. Management of Virtual Patient with adverse events associated with medical infusion device
7. Complete scenario
8. Complete questionnaire
3.3.11 Statistical Analysis

In view of the non-parametric nature of this data, the median and inter quartile range (IQR) was described, and the Spearman’s rank correlation was used to compare variables.
3.4 Results

3.4.1 Demographics and computing experience

The 40 nurses in the sample population were aged between 20 and 59 years with a median age of 33 years (IQR 28-38 years). Thirty-five were female and five were male. The majority of participants (n=28, 70%) were band 5 nurses (nurses with little or no additional management responsibility), nine nurses were band 6 level (senior nurses, some management responsibility) and three participants were band 7 (ward manager or equivalent). The specialty backgrounds of participants were varied and are given in Table 3a. The previous computer experience of the participants is shown in Table 3b.

In addition to this information, the post-scenario questionnaire revealed that 18 participants (45%) owned a headset and 34 participants (85%) had access to a computer less than three years old. Only five participants (12.5%) did not have regular access to broadband Internet. The three participants who had used Second Life before had all used it less than five times.
3.4.2 Previous medical device training

Three participants stated that they had had no previous medical device training at all. Half of all the participants (n=20) had attended a formal course for medical infusion device training, and the majority of these courses were run by the hospital in which the participant worked. Nineteen participants (47.5%) had attended dedicated ward-based infusion device teaching and a total of 25 (62.5%) had previously received informal teaching from a mentor on medical infusion devices.
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<td>Paediatric ICU</td>
<td>2</td>
</tr>
<tr>
<td>Paediatric Accident &amp; Emergency Surgery</td>
<td>5</td>
</tr>
<tr>
<td>Surgery</td>
<td>20</td>
</tr>
</tbody>
</table>

Table 3a: Nursing specialty background of participants
## Previous computing experience

<table>
<thead>
<tr>
<th>Level</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic</td>
<td>4 (10)</td>
</tr>
<tr>
<td>Only for limited tasks and may need help</td>
<td></td>
</tr>
<tr>
<td>Competent</td>
<td>35 (87.5)</td>
</tr>
<tr>
<td>Word processing, email &amp; Internet browsing</td>
<td></td>
</tr>
<tr>
<td>Intermediate</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Specialist packages, e.g. statistics or video editing</td>
<td></td>
</tr>
<tr>
<td>Advanced</td>
<td>1 (2.5)</td>
</tr>
<tr>
<td>Programming experience</td>
<td></td>
</tr>
</tbody>
</table>

## Previous Computer game experience

<table>
<thead>
<tr>
<th>Experience</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Never used computer games before</td>
<td>5 (12.5)</td>
</tr>
<tr>
<td>Tried computer games but don’t play regularly</td>
<td>35 (87.5)</td>
</tr>
<tr>
<td>Regularly play computer games (&gt; weekly)</td>
<td>0 (0)</td>
</tr>
</tbody>
</table>

## Have you used Second Life before?

<table>
<thead>
<tr>
<th>Yes</th>
<th>3 (7.5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>37 (92.5)</td>
</tr>
</tbody>
</table>

Table 3b: Past computer experience of participants
3.4.3 Scenario evaluation

The orientation was reported to be sufficient to proceed to the simulation by 27 (67.5%) participants, with 12 (30%) not offering a definite opinion as to the adequacy of the orientation. Two participants disagreed with the statement that the orientation was adequate.

The majority of participants felt that the scenario was realistic and that the virtual tasks were representative of real-life tasks (Figure 3e). Four participants were neutral as to whether the virtual infusion device responded appropriately to interventions. Overall there was strongly positive feedback and only one participant disagreed with the scenario being useful for familiarising staff with the infusion device (Figure 3f). There were more neutral responses to proposals that the scenario should be used for technical training of infusion devices (n=6, 15%) or refresher training in infusion devices (n=5, 12.5%).

The time taken to complete both the orientation and the virtual training scenario were measured for each participant, and these are shown in Figure 3g. The orientation took less than 15 minutes for 95% of participants (n=38) and less than 20 minutes for everyone. For the scenario itself, 70% (n=28) of participants completed the training in less than 20 minutes, with only 2 participants (5%) taking between 25-29 minutes.

The time taken to complete the scenario broken down by age of participant is shown in Figure 3h. There was no statistically significant correlation between
increasing age and the time taken to complete the scenario (p=0.335), as shown in Figure 3i.
Figure 3e: Participants’ appraisal of the validity of the training scenario
Figure 3f: Participants’ overall appraisal of the virtual training scenario
Figure 3g: Time taken to complete Second Life orientation and virtual training scenario

![Bar graph showing time taken to complete orientation and scenario]
Figure 3h: Time taken to complete scenario by age range
Figure 3i: Relationship between participant age and time taken to complete scenario

Spearman's rho = 0.156 (p = 0.335)
3.4 Discussion

The aims of this study were to design and to develop an engaging virtual clinical scenario in Second Life for use in training on adverse events associated with medical infusion devices. The successful completion of this development ensured that a pilot study was performed in which 40 nurses were able to take part in the use of the virtual scenario. The face validity of the scenario was assessed for all participants in the form of a post hoc questionnaire and participants were recruited from a broad range of specialties.

The development of this virtual patient proved to be successful in its specific aim of developing a scenario. However, it ultimately proved deficient in providing a framework to guide future virtual patient development, for a number of reasons. Firstly the virtual patient, although affected by multiple events, was simplistic in design. The scenario did not incorporate much patient information, such as a pertinent history, and therefore was not entirely reflective of actual clinical practice. From a personal perspective this was probably due to my inexperience regarding virtual patient design. With hindsight, the scenario could have been made more engaging, forcing the user to retrieve more information regarding the virtual patient, which could have subsequently guided management.

Secondly, it was clear from early in the development phase that utilising a storyboard format in a Microsoft Word(Microsoft_Word, 2010) document and
then transferring this straight to Second Life was an insufficient method of developing virtual patients. It was evident that this storyboard, whilst a useful guide for both the 3D designer and myself, was not specific enough for the detail required in development. This resulted in a disparity between what was expected for development and what was subsequently produced. This resulted in many changes being made during development. If such changes were required following initial production, this meant that work had to be undone in the Second Life development phase and therefore this was not a time- and cost-effective resource for conducting virtual patient design. This problem could have been overcome from the outset by a more robust method of virtual patient design, in which an editable format of data could have been used.

The initial purpose of developing such a virtual patient was to further guide future virtual patients and produce an efficient development methodology through which, following an initial learning curve, a quick and reproducible method would be available for patient design. This study ultimately did not provide a method that could be deemed reproducible, as the reproduction of this method would be cumbersome for both designer and the Second Life developer in future productions. The reasons for this are twofold. Firstly, there was no specific framework demonstrated for a designer to design a virtual patient. A stepwise production was demonstrated in the storyboard, but this would not be transferrable to any future virtual patient design. Secondly, multiple datasets of virtual patient information would not be transferrable to a single virtual patient in Second Life. Multiple datasets would need to be
transferred to multiple virtual patients, with each patient requiring complex information coded within them in a unique format.

The concerning feature of this development, which demonstrated the complexity of virtual patient production even with a simplistic design process, was the attempted generation of an automated scoring methodology. The aim of the scoring method was perceived to be simple, in that it would provide a score for a correct response and this was to be coded into the virtual patient design to provide an objective measure of performance. An explanation for the delivery of inappropriate scores was not established, despite the 3D graphic designer attempting to determine where the additional scores were obtained. It was evident that the integration of an automated scoring system into a virtual patient design was more complex than previously thought and that further attempts to deliver an automated score would be difficult.

This study lacked an appropriate objective measure of performance, with the only evaluation being the face validity. On reflection, content validity could also have been integrated into a Likert-based questionnaire, but this opportunity was missed in the design of the evaluation. However, the evaluation did demonstrate positives regarding this design process with the successful integration of an orientation program, as the majority of participants felt that the orientation was adequate and that they understood how to interact within Second Life – a skill that is integral to this scenario and any future scenarios. Whilst many lessons were learnt of what not to do in virtual patient design, it was evident that an orientation program with a virtual
patient that was reflective of the scenario-based virtual patient was useful for orientation in any future virtual patient design.

The participants perceived the scenario to be realistic and interactions to be similar to real-life tasks. Further validity was conferred by positive responses to key questions concerning the responsiveness of the virtual patient and the virtual infusion device. These results were encouraging, as they suggested that such a virtual patient design was of some value despite the obvious limitations in the virtual patient development. It was evident that, if such positive responses were obtained, if the deficiencies in this design methodology could be overcome then further virtual patient design and development could be more engaging and worthwhile.

However there was a less consistent response to questions surrounding the future use of such a scenario. Less than 50% of participants thought that the scenario would be useful for technical training on infusion devices. This was not unanticipated, as the training scenario was an immersive clinical experience regarding the management of adverse events rather than a practical instructional session on initiating an infusion device. More positive responses were seen in terms of utilising the scenario as an assessment tool for students, which was poignant as our attempt to deliver an assessment within this simulation was futile.

Time taken to complete the study was measured for each participant. Although this cannot be considered as an objective assessment of
performance, it does provide meaningful data on the length of the simulation and whether there was any variability regarding age. The study, however, did not demonstrate any correlation between increasing age and time taken to complete the scenario. This was an unexpected finding, as technological, and more specifically, computer proficiency is generally thought to be associated with younger age. However, these findings are encouraging, as this implies that further virtual patients can be utilised by healthcare professionals of different ages with no difference in time taken. Age correlated with time taken was established as opposed to experience, as many of the nurse participants were of similar grade, i.e. band 5, but there was a wide variety of age between the nurses. Nurse grade would not necessarily have been an accurate reflection of experience, as a number of nurses prefer to remain at a certain level rather than progress to more advanced roles, despite having much more experience than their younger counterparts.

The results from this study were encouraging in terms of participant evaluation with an end product of a scenario that is acceptable. However the results from this study have to take into account the multitude of confounding variables between the different participants. There was a great deal of variation between the age of the participants, their experience, career promotion as well as their medical device experience. On reflection, this study could have focused more on nursing staff that had undertaken formal medical device training. These participants would have been better placed to give more informed responses as to whether this scenario is useful for either novice training or refresher training as opposed to more formal courses. In
addition, rather than random sets of nurses recruited, a more targeted approach could have been employed with a select group of nurses who frequently use infusion devices (i.e. only surgical nurses rather than emergency department nurses or paediatric nurses who use infusion devices much less frequently) and where the scenario involved an adult patient as opposed to a paediatric patient. If these factors had been taken into context from the outset, this may have lead to a more robust and meaningful study.

Overall, there were many limitations in this study, specifically in the area of virtual patient design. Further virtual patient design would require a complete overhaul of the methodology utilised from this study; however, certain attributes could still be used: primarily the use of a storyboard as an approximate guide for patient development as well as the development of an orientation scenario. The principal lessons, though, from this development were that virtual patient data would need to be presented in an easily editable format. Further and clearer instruction would be required between the developer and myself, which could be overcome through the data presentation. Also another method, rather than automated scoring, would be required for an objective assessment of performance.
3.5 Conclusions

This study has demonstrated that it is feasible to design and develop a scenario within a virtual world with focus on a specific clinical problem. However, a further redesign is required in order for future multiple, virtual patients to be produced. In addition an alternative method of assessment of performance is required. The next chapter will describe the design and formation of an alternative methodology, following the lessons learnt in this design, culminating in the production of a series of virtual patients.
Chapter 4

The Development of a Virtual Online Patient Simulation
Aim

To design and develop a series of virtual patients with surgical pathology using allied web technologies and implementing them into Second Life.
4.1 Chapter Overview

This chapter describes the design and development of a series of virtual patients in unique clinical scenarios in Second Life. The framework for design utilised a system incorporating allied web technologies to establish whether this format is reproducible for future virtual patient authoring and design.

4.2 Introduction

The previous virtual patient design highlighted a requirement for a more robust, reproducible methodology for development. It was evident that a clearer structure would be required, in which more patient detail could be incorporated. In order for this to occur, further information would be required regarding previous methodologies employed prior to undertaking the design and development process. This would be different from the previous study where a unique, exploratory design was undertaken.

The preliminary process would need to establish what type of virtual patient would be developed, as well as previous frameworks detailing the design process. Virtual patients have previously been described as possessing two different attributes: they may be either problem-solving or narrative (Bearman et al., 2001). The problem-solving virtual patient is focused on the ability of the user to retrieve information such as history, examination findings and investigations and to establish an appropriate diagnosis. In contrast, the narrative virtual patient is primarily focused on a personalised story and follows a longer timeline. For the purpose of our virtual patient development,
the problem-solving virtual patient was preferred, as this could be used in both a training and an assessment capacity.

Cook and Triola (2009) have previously described the wide variety in virtual patient design, such as differences in the way in which information is retrieved and requested and how the case progresses. The differences may be attributable to variation in cost, timeframe of design, the personnel and the information technology (IT) resources available. Huang et al. have demonstrated that the cost of developing virtual patients is expensive with 85% costing more than $10,000 per case and 37% more than $50,000 per case. (Huang et al., 2007) The average production time that they found in their survey of United States (US) medical schools that had developed virtual patients was listed as more than 16 months per virtual patient.

There have been strategies employed in order to attempt to ease the formation of virtual patients. Posel et al (2009) proposed guidelines, which may be utilised towards the development of virtual patients. These guidelines serve as an overview for production as opposed to being specific towards a particular interface. These tips include:

1. Determining case content and choosing a design model
2. Organising and storyboarding a case before start
3. Managing the case complexity and matching this to case objectives
4. Including assessment and feedback
5. Supporting an Individualised approach to learning
6. Using virtual patients to encourage collaborative learning
7. Tackling interactivity
8. Anticipation and navigation
9. Ensuring privacy and confidentiality of data
10. Integrating evaluation
11. Recognising the potential of expert traces and the use of script concordance
12. Choosing the right authoring application for the case

The aim of this study was to design and develop a methodology for virtual patient design, which could produce a series of virtual patients that could be implemented into the virtual world of Second Life. Furthermore, we sought to use the guidelines stipulated by Posel et al. (2009) as a framework for virtual patient development so that this might result in a reproducible method for virtual patient creation. Whilst these guidelines are theoretical in nature this study demonstrates its application in the development of our series of virtual patients with the purpose of guiding any future development of virtual patients we undertake, as well as other future virtual patient authors.
4.3 Methods

4.3.1 Outline

The method of virtual patient design followed a specific path (Figure 4a) namely the storyboarding of cases followed by the design of paper based cases and integration of this information into a case editor. This was followed by the application of this case data into a virtual patient web based player, which was subsequently transferred into a user interface in the virtual world of Second Life.

4.3.2 Development Team

A team with specific skill sets was convened to guide development of the virtual patients. These primarily consisted of members with specific virtual world development skills. These were:

- A project manager with expertise in managing virtual world and software development projects
- A developer, with proficiency in computer modelling using java and open source software, was used to program the Eclipse software
- A virtual world specialist with experience in Linden Scripting Language was used to transfer the information from the virtual web player into Second Life
- A 3D designer with specific expertise in Second Life development was used to develop the Second Life environment.
I, with a background in General Surgery, was employed for case design, development and guidance for development of clinical environments.
Figure 4a: The outline of development of a case

1. Case Planning in VUE
2. Storyboard of Case in Microsoft Word
3. Input of Case Content into Eclipse Editor
4. Upload of Case onto Virtual Web Player
   - Data regarding performance (CSV file) stored in web-player
5. Case stored on Imperial College Server
6. Case transfer into Second Life via Message Broker
   - Case accessed by Subject/Avatar

Data regarding performance (CSV file) stored in web-player
4.3.3 Personal Role

My role was integral, from the outset in planning the design to completing the development process. This involved planning the structure of the case and subsequently storyboarding the case into a Microsoft Word format. I instructed a software developer as to how the case would progress and they adapted existing software to produce a case editor for the uptake and storage of patient information. This required once weekly meetings for the whole of a working day, for the pair of us to discuss the editor, its function and the further steps that were required for its enhancement. Following the completion of the editor development I uploaded all of the case information into the case editor.

I also initiated and chaired twice-weekly meetings with two other software developers to guide on specific features and animations required within the virtual world of Second Life to heighten the realism of the simulation. This occurred for a period of four months and occurred simultaneously with the case editor development. Finally I tested all of the cases, upon completion, in the virtual web player and Second Life and initiated any amendments in the case editor with subsequent re-testing of the scenarios.

4.3.4 Timescale

The total production for the virtual patients was 10 months. Whilst the end result was three virtual patients at three different levels of complexity and an orientation case, each level constituted a unique virtual patient that required development therefore the total number of patients created was ten. This
development process cost approximately £60,000 with the funding provided by the Simulation and Technology Learning Initiative (STELI, 2013) from the London Deanery.

Below is a description of the design methodology used and the justification for its use according to some of Posel’s (Posel et al., 2009) tips.

4.3.5 Determining Case Content and Choosing a Design Model

A consultant surgeon and myself selected three general surgical conditions as a focal point for the clinical cases to be developed, as the targeted audience for the cases was postgraduate trainee surgeons. These conditions were lower gastrointestinal bleeding, acute pancreatitis and small bowel obstruction. These conditions were chosen for the virtual patient case development as all are frequently encountered in surgical training and all three conditions may present in a multitude of ways. This would then provide the potential for the production of cases at increasing levels of complexity but still retain a focus on these primary conditions. The decision was made from the outset of development that these cases would be used for assessment. An additional condition was selected - urinary retention -as a case that could subsequently be used as an orientation case for training towards the virtual patient management. This condition was selected as it is encountered frequently in both a clinical ward and emergency department setting.

Case design and development was based on a specific framework, to enable the end user to be able to elicit information and interpret the relevant
information whilst discarding inappropriate information. The rationale also was to ensure the user could establish multiple sources of information and make subsequent decisions based on all the information retrieved. Prior to commencement it was and still is essential to have such a simple framework in mind as this notion can be continually returned to especially when the nature of design becomes increasingly complex.

In order to further plan the cases it was fundamental to establish the optimal method for design. Following a literature review, I established that the main previous design methods that have been described for virtual patient design include the linear string and the branching design method. (Huwendiek et al., 2009) The linear string of pearls method consists of predetermined integral steps within a case that must be activated for the case to progress to completion. This contrasts with the branching design, where the learner may select a number of possible options within a case, which results in variable different end points. Whilst the branching design provides higher fidelity for the end user, it is significantly more complex in terms of design with numerous potential pathways developing over few design steps. Round et al. (2007) stated that if a virtual patient is designed with 3 choices at each level, after 4 levels there are over 100 levels, which, may have been entered. Therefore if the branching design were used in this study it would have made the design of one virtual patient extremely complex, as different decisions by a user could have resulted in multiple different virtual patient outcomes, which would have to be programmed. For the purpose of this study, therefore, in order to ease design either the linear string of pearls method was employed or a
combination of that method and a limitation of the branching method was utilised, where a selection of a management option by a user would only result in a restricted number of virtual patient alterations.

4.3.6 Organisation of the Case

For case planning it was essential to have a simplistic overview into which further information could be added and which served as a mind map of a case. In the series described I used VUE-Visual Understanding Environment (Tufts University, Massachusetts), an open source Java program, to plan the case development. This program ensured the appropriate mapping out of a case with critical steps in case development defined as nodes. Arrows linked these nodes therefore ensuring I could visualise a map of the case progression. If a case required multiple steps for progression then the dual utilisation of the linear and branching method was used (Figure 4b for acute pancreatitis case CT1 level). However if a case required a single step for progression the linear case was employed (Figure 4c for small bowel obstruction case CT1 level). Whilst alternatives to VUE may be utilised it was important for me to have a basic mind map of a case prior to further development as this would serve as the principal guidance to case development.

The case series described involved different difficulty levels, which provided increasing complexity not only for the end user but also within the design modality. In order to ease design, and justified from our experience, it was essential for me to focus principally on the more basic cases and ensure that
these were correctly created prior to commencement of the more complex cases.
Figure 4b: The combination of the branch design and the linear string of pearls method for the design of the Acute Pancreatitis case for the Junior Resident/ CT1 level.
Figure 4c: The linear string of pearls design for the Small Bowel Obstruction case for the Junior Resident/ CT1 level
4.3.7 Storyboarding the Case

All cases followed a generic outline in design. In order to follow the specific framework focusing on information elicitation, processing and decision-making, I designed all cases in the same format with information being input into the relevant sections of history, examination, investigation and management. This was to ensure a familiar process for the user so they would be able to recognise the disease process and initiate a management plan. This process of using a similar methodology to storyboard all cases ensured that I was easily able to transfer information to and from cases, reducing the time consumed on development.

In order for all the relevant information to be processed I categorised these under general broad headings (Figure 4d). These broad headings were then filled with the detailed information on which the case unfolds. The purpose of utilising multiple headings was to provide an easier route to designing the cases, as the design of a case under broad categories such as history, examination etc. may initially appear daunting. However, as the history section was divided into sub-categories such as gastrointestinal, respiratory, cardiovascular I found the process of information inputting much more feasible.
**Figure 4d: The categories of information used/case**

**HISTORY**

**History of Presenting Complaint**
- Gastrointestinal
  - Abdominal Pain
  - Nausea and Vomiting
  - Appetite and Weight Loss
  - Bowel Habit
- Respiratory
  - Shortness of Breath
  - Cough
  - Wheeze
- Cardiovascular
  - Chest Pain
- Neurological
  - Headache
  - Dizziness
- Urological
  - Dysuria
  - Frequency
  - Haematuria

**Past Medical History**
- Drug History
- Allergies
- Family History
- Social History

**EXAMINATION**

- Observations
- Respiratory
- Cardiovascular
- Abdominal
- Rectal
- Neurological

**BLOOD TESTS**

- FBC
- U&Es
- CRP
- LFTs
- Amylase
- Clotting
- INR
- PSA
- CEA
- AFP
- Ca 19-9
- LDH
- TFTs
- Glucose
- HBA1c
- Cardiac Enzymes
- Copper
- Zinc
- Magnesium

**IMAGING X RAY**

- Chest radiograph
- Abdominal Radiograph

**BEDSIDE INVESTIGATIONS**

- ECG
- Urine dipstick

**MANAGEMENT**

- Airway Management
- Breathing Therapy
- IV fluids
- Blood Products
- Catheterisation
- Renal Support Therapy
- Analgesia
- Anti-emetics
- Consult Specialist Colleague
I input the history information into a Microsoft Word (Microsoft_Word, 2010) document containing relevant questions for each body system. Corresponding patient answers were subsequently assigned for each question, thus developing a story for the virtual patient’s complaint. I compiled such questions and answers for each body system and for each history category, namely past medical, drug, allergy, family and social history, thus ensuring that complete patient details would be available.

I then categorised the examination findings into their relevant systems. In the same Microsoft Word document, a list of patient observations was detailed as well as specific examination findings for each system. For example, in the Acute Pancreatitis case, chest expansion was detailed as symmetrical with right-sided and left-sided inspiratory crepitations for the respiratory examination. Unique findings were depicted for each case. The examination findings, however, were developed with the proceeding cases in mind so that the primary information received during the preliminary cases could become relevant in the latter higher-level cases.

Investigations were broadly devised into the principal blood results and imaging results. Blood results were detailed with specific values and their associated reference ranges, which were derived from those principally utilised at the Imperial College NHS trust. A description of imaging results relevant to the case was detailed so that subsequent radiographs pertaining to that information could be found.
I implemented a differential diagnosis section, with the specific diagnosis and subsequent associated diagnosis. This was so that the end user would be able to demonstrate what their primary conclusion was to the virtual patient’s specific problem. The reason for inclusion of this section was that in the basic cases the management could be similar for different diagnoses, so this would then depict whether the user had insight into the pathology afflicting the patient.

I divided the management section into various subcategories. This was to establish a breadth of options that the user could implement in order to appropriately manage the patient. The options contained both relevant and inappropriate decisions for all cases, so that the end user would have to select the appropriate choice. For some of the options such as the intravenous fluids, a range of potential fluids was offered with their corresponding rates i.e. 2 hourly, 4 hourly etc. There was no single right decision in this instance, but a range of suitable options that could be deemed correct. It was appropriate for me to offer a range of options with a range of possible correct selections as this best reflects real clinical practice.

The implementation of information was supplemented by the collation of breath and heart sounds at this stage, as well as relevant images that would be required for development. I retrieved the heart and breath sounds from an Imperial College Heart and Breath Sounds compact disc that is dispensed to undergraduate medical students. The radiographs were obtained from Joint Photographic Expert Group (JPEG) images. The acquisition of such files and
animations was undertaken at an early stage of development, as the process to acquire these relevant tools might be time-consuming and laborious. It was also performed at an early stage as it might contain fundamental information for the case, e.g. for the Small Bowel Obstruction case the abdominal radiograph demonstrates dilatation of the small bowel and is fundamental for the end user to establish the case features.

4.3.8 Managing Case Complexity

The development of this series of virtual patients incorporated cases of increasing complexity. The reason for this was that the target end users would be at different stages of postgraduate surgical training, namely Foundation Year 1/ Intern, Core Trainee 1/ 2nd Year Resident and Specialist Trainee 3/ 4th Year Resident. I selected these specific training grades as they represent the separate different stages in United Kingdom surgical training, akin to the previously referred to Pre-Registration House Officer, Senior House Officer and Specialist Registrar. In order to ensure that the cases were designed to the specific training level, a designated event was the focal point for each specified case (Figure 4e). This focused event served to guide development and ensured that the cases were relevant for each trainee. Two specialist trainees (including myself), who had experience of all the training levels being evaluated, decided these principal events. Two consultant surgeons, both designated surgical trainers in the London Deanery, then further reviewed this. Following discussion, amendments were made regarding the focal point for each case.
To aid simplicity in case design and development, it was best to focus on a single event but ensure that this was appropriate for the end user and specifically appropriate for their training level. Further case design for the more complex cases retained the same development method under broad headings and subcategories. It was necessary for me to retain the same design or only use small variations for the development of simple and complex virtual patients, as this ensured that the design method was always reproducible, which assisted in the reduction of both time and cost.
Figure 4e: The essential themes for each case.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Training Level</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lower GI Bleed</strong></td>
<td></td>
</tr>
<tr>
<td>FY1</td>
<td>Not life threatening; Requires monitoring</td>
</tr>
<tr>
<td>CT1</td>
<td>PLUS: Significant bleed-requires transfusion</td>
</tr>
<tr>
<td>ST3</td>
<td>PLUS: Persistent bleed + normal endoscopic investigations-requires definitive management</td>
</tr>
<tr>
<td><strong>Acute Pancreatitis</strong></td>
<td></td>
</tr>
<tr>
<td>FY1</td>
<td>Simple Pancreatitis; No systemic upset</td>
</tr>
<tr>
<td>CT1</td>
<td>PLUS: Low urine output + exacerbation of COPD-requires intravenous rehydration + nebulisers</td>
</tr>
<tr>
<td>ST3</td>
<td>PLUS: Type II respiratory failure + acute renal failure-requires BIPAP and haemofiltration</td>
</tr>
<tr>
<td><strong>Small Bowel Obstruction</strong></td>
<td></td>
</tr>
<tr>
<td>FY1</td>
<td>Small Bowel Obstruction; requires conservative management</td>
</tr>
<tr>
<td>CT1</td>
<td>PLUS: onset of strangulation - requires diagnosis and proceed to laparotomy</td>
</tr>
<tr>
<td>ST3</td>
<td>PLUS: Post-operative anastomotic leak. Requires diagnosis and appropriate intervention</td>
</tr>
</tbody>
</table>
4.3.9 Inclusion of Assessment and Feedback

A variety of approaches may be utilised to ensure that feedback is given to the end user. The cases developed were to be used primarily in an assessment capacity as opposed to training, so feedback was kept to a minimum, but to ensure that feedback was given, I programmed erroneous selections in the management choices to discharge a response to the user suggesting that they had selected an incorrect decision. However, in order for our cases to be utilised in a training capacity, any inappropriate option selected could have had a suggestion highlighting the correct response. The methodology used for case design ensured that the cases could be used in either a training or assessment capacity if either were required. However it was imperative that a decision was made at the outset regarding whether the virtual patients were being developed for either a training or assessment purpose, as this subsequently affected the level of feedback given to the user. In summary, training cases can incorporate high levels of feedback to the user whilst this is not as essential for the purpose of assessment.

4.3.10 Individualised Approach to Learning

Clinicians often apply their own unique strategy towards patient management. In order to ensure a more immersive virtual patient, it was vital that the end user was presented with the opportunity to assess and manage the virtual patient to a high fidelity that reflected real practice. This ensured a higher level of satisfaction with the virtual patient. To ensure that the developed patients achieved this within the series; the end user was presented with all options
from the outset, i.e. they were able to retrieve information from the history, examination and investigations in any order they required or alternatively they could institute a management plan before any of the above listed. Whilst such a scenario may be atypical from the majority of users’ pathways, it was essential to ensure that individual users could categorically utilise their own personal approach.

4.3.11 Selection of the Appropriate Authoring Application

I designed the cases in a particular manner from planning to storyboard. However the vital step was transferring this case design into an authoring application, which was then easily transferable into a user interface. This was a critical step that did not occur in the previous study and ensured that a new design format had to be developed. It was essential that the authoring application could enable me to directly transfer the storyboard with minimal alterations.

In the series described, the program Eclipse was used as the case editor into which information could be input. Eclipse is an open source multi-language development environment, although the most frequent language used in it for development is Java. The purpose of the Eclipse editor was to produce XML files of data and store these within a retrievable database. A specialist programmer was employed to format Eclipse, so that I could enter data in order to create any case. The formatting of the Eclipse software required repeated face-to-face meetings between the developer and myself on a
weekly basis for a period of six months, to guide the proposed software
development and for a personal education in using the software. This was
further aided by a user manual (Appendix 9), which was produced by the
software developer to assist in inputting information for each case production.
During this development phase, the Eclipse software was installed on my
laptop to enable the input of information at my convenience. The format for
the case input was as similar as possible to the storyboard of the case in
Microsoft Word (Figure 4f). The variation occurred with the input of files and
animations that would be visible to the user. These files, e.g. abdominal
radiograph or animations such as chest expansion, were assigned a target –
desktop monitor and chest respectively – so they would subsequently have a
target for visualisation in Second Life.
Figure 4f: The input of questions regarding abdominal pain in the Eclipse Case Editor
An additional requisite was the ability for me to play through a case so that any corrections that might be required in the developed case could easily be established. For this purpose, the data stored from the Case Editor was retrieved through a web player. The web player, which was hosted on an Imperial College server, was formatted to communicate with the Eclipse editor so as to enable recently constructed or edited cases to be uploaded. This subsequently would ensure that I could play through the case, through a series of XML web pages (Figure 4g), to ensure that the logic determining the case progression was appropriate. If any errors were established or the case progression was deemed inappropriate, I could edit the case within the Eclipse software. The subsequent corrections were then uploaded again onto the database and the cases were retested.

The virtual web player was able to display the logical sequence through a case. However, for this case series it was necessary to be able to transfer the information from the web player into a specific environment in Second Life. For this to occur, a virtual world specialist in scripting was employed to create a message broker, which was able to relay messages from the player through to scripted objects in Second Life using http (hypertext transfer protocol).
Figure 4g: The virtual patient player and an example of the menu of options for the end user.
4.3.12 Tackling Interactivity

In order to ensure that the cases were a higher fidelity simulation; a strategy was employed to develop the cases so they could be implemented into the three-dimensional environment of Second Life. To enhance the fidelity, a specialist 3D graphic designer was recruited to develop an interactive virtual patient to relay information from the message broker and also display animations (Figure 4h). This developer had been extensively involved in the last virtual patient design and was thus responsible for the creation of an appropriate clinical environment, which consisted of an accident and emergency, a clinical ward and a high dependency ward (Figure 4i) to represent the potential locations of the virtual patients.

Each of these environments contained an additional affiliated room, which would contain the blood and imaging request and retrieval service. The reason for this additional room was to house a desktop computer, which would act as an imaging request and retrieval service. This provided a method of increasing the fidelity of the simulation, as in real practice the viewing of radiographs follows a similar process. The clinical environments were filled with a variety of different models of hospital equipment, all to serve the purpose of increasing fidelity.

A novel approach to this virtual patient design, as opposed to the design described in the last chapter, was that, although there were 10 virtual patients created, Second Life only housed a single virtual patient in any clinical environment, e.g. the clinical ward. This ensured that any case could be
selected for use and the data would then be transferred onto this single virtual patient. This produced a more effective development method for the 3D graphic designer, in that following the initial virtual patient development further patients that were developed could be transcribed onto this single virtual patient. This virtual patient containing the information of 10 developed virtual patients could then be reproduced into different environments, namely the emergency department or the high dependency unit, therefore producing a reproducible method of virtual patient design. It also meant that if any further virtual patients were to be developed, they could feasibly be transcribed onto this solitary virtual patient.
Figure 4h: The virtual patient experiencing a large per rectal bleed

Oh Doctor I'm sorry I couldn't help it. I'm scared now look how much blood there is!!
Figure 4i: The High Dependency Unit
4.3.13 Anticipation and Navigation

It could not be assumed that all end users had previously utilised Second Life before, unlike web interfaces. Therefore, with the integration of the virtual patient player into Second Life (Figure 4j) a standard interface was incorporated for the end user to utilise in navigating the virtual patient case. This retained a similarity to familiar web interfaces and ensured that the user could navigate through the case. As the design base was universal for all cases, the successful navigation through one case meant that all the subsequent cases could be successfully navigated, which is a justification for using the same design methodology for all cases in a series of virtual patients.

An orientation program was developed so that all users would obtain a level of proficiency before commencing the assessed cases. This involved my creating a short user manual (Appendix 10) explaining the basics of using an avatar in Second Life and the navigation through the cases. This was accompanied by the orientation case focusing on urinary retention. It was a requirement that all end users would navigate through the urinary retention case prior to the other cases. The use of an orientation case was particularly essential for two specific reasons: firstly, it ensured that the user was given adequate opportunity to familiarise themselves with an alien technology; secondly, as the virtual patient series were to be used for assessment this would negate any bias in testing, as each user had a similar level of familiarity prior to the main cases.
Figure 4j: The user interface in Second Life. This was integrated from the virtual patient player.
4.3.14 Integrate Evaluation

The case series described were to be used for assessment of trainees’ performance. Therefore it was essential to integrate an evaluation process that could be utilised by a clinician to formulate an assessment, as opposed to information that could only be interpreted by a technologist. A participant generation XML page was created within the virtual patient web player, through which end users details could be input. This was relayed to a phone in Second Life, which required a left mouse click and entering of user details to commence a case. This ensured that information could be retrieved regarding an end user’s performance through a case. A participant’s login and case progression would generate data being transferred, through comma separated value files, to the clinician’s computer as a Microsoft Excel file (Figure 4k). This would then enable an analysis of all the user’s selections in assessing and managing each of the virtual patients.
Figure 4k: A Microsoft excel file detailing a user’s participation through a case

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4.3.15 Ensuring Privacy and Confidentiality of Data

A candidate’s performance was a private assessment of their ability to assess and manage the virtual patient. The system described retrieving information on performance through comma separated files, demonstrating a confidential method of retrieving and assessing data as all the information was generated onto the host clinician’s computer. This was vital so that any assessment data could be confined to the relevant parties, where it could be utilised for training and assessment.

Furthermore, it was imperative that the case content was not a reflection of real patient case data, which could compromise their right to privacy. If such data were used, it would be essential to obtain both written permission from the patient and ethical approval. Within this case series, none of the data was based on any specified patient information.

4.3.16 Case Progression

Before a user began participating in the simulation, their initials were recorded in the virtual web-player and a unique identifier number was given to them. This ensured that a participant could login into the simulation before proceeding through it. The login process had 2 purposes: primarily to generate the specific information for that case onto the virtual patient; secondarily to generate a comma separated value (CSV) file to the web player. This CSV file could then be retrieved from the web player using Microsoft Excel (Microsoft, Redmond, Washington). This Excel file then
depicted each decision that a user made when managing a case, and could therefore be subsequently used for assessment of cases.

The participant would initially read the instruction manual and then log into the virtual clinical ward in Second Life as a pre-designated avatar. They then would input their unique identifier number into a telephone in the clinical ward. The appropriate case was selected, thus commencing the case. The first case they would undertake was the orientation case, prior to proceeding to the other cases. The purpose of each case was for the participant to assess the virtual patient through history taking, examination and investigations including blood profiles and radiographs. They were able to do this through selection of various options on the menu board, e.g. an examination finding or a blood result. This then enabled the participant to view this result and interpret the findings. They then selected an appropriate management plan based on the information retrieved. Upon completion of a case, the user would log out of the case thus ending it and also completing the CSV file.
4.4 Results

Below is a description of all three virtual patients created. This description incorporates all three training levels.

4.4.1 Virtual Patient 1

Mr Smith is a 60-year-old male who presents with four episodes of painless per rectal bleeding. The blood is dark red in nature with two-three clots passed in each motion. He has a past medical history of high blood pressure. On examination, his heart rate is 65 with a blood pressure of 118/72. Per rectal examination reveals dark blood on the finger with no intraluminal or external masses. His haemoglobin is 10 g/dL with normal renal and clotting function.

Following admission he progresses to have a further three episodes of per rectal bleeding. On assessment by the doctor, he proceeds to have another large bleed. He becomes haemodynamically unstable with a heart rate of 110 and a blood pressure of 95/51. His haemoglobin is now 7.9g/ dL.

He subsequently has an upper gastrointestinal endoscopy, which is normal, and an attempted colonoscopy. The colonoscopy is limited as the view is obscured by blood. He continues to have a further five episodes of bleeding. His Haemoglobin is 7.3 g/dL despite having had five units of blood transfusion.
4.4.2 Virtual Patient 2

Mr Hart is a 65-year-old man who presents with epigastric pain and two episodes of vomiting. His pain is burning in nature and radiates to his back. His past medical history includes Chronic Obstructive Pulmonary Disease (COPD) and high blood pressure. His observations are normal, but his abdominal examination reveals epigastric tenderness. His amylase is 1024 but his Glasgow score is 1, due to his age.

His breathing deteriorates on the ward where his oxygen saturations reduce to 90% on air. His respiratory examination reveals a high-pitched polyphonic wheeze. He also has experienced a reduced urine output, which is less than 30 ml over the last four hours. His arterial blood gas reveals a pH of 7.33 with retention of carbon dioxide (6.5). His serum creatinine level has risen to 142.

He is subsequently transferred to the high dependency unit. His breathlessness deteriorates despite bronchodilator therapy. His oxygen saturations are now 87% on fIO2 of 0.24. He has stopped producing urine over the last four hours and his serum creatinine has further risen to 328 with a serum potassium level of 6.4 despite aggressive intravenous fluid resuscitation. His arterial blood gas shows a mixed respiratory and metabolic acidosis with a pH of 7.24.
4.4.3 Virtual Patient 3

Mr Paul is a 63-year-old male who presents with central, intermittent abdominal pain. He has had two episodes of faeculant vomiting with absolute constipation. His past medical history reveals a previous appendectomy. His observations are normal but he has generalised abdominal tenderness. His blood profile demonstrates a white cell count (WCC) of 12.6. His abdominal radiograph displays dilated loops of small bowel.

Upon admission to a ward, his pain worsens. His heart rate increases to 110 and he becomes febrile. His urine output has been < 30 ml over the last two hours. Blood investigations reveal a WCC of 19.6 and a C-reactive protein (CRP) of 156. Arterial blood gas displays a pH of 7.32 with a lactate level of 2.6.

Mr Paul undergoes a laparotomy, where ischaemic jejunum is resected and a primary small bowel anastomosis is performed. He is progressing poorly post-operatively with continuing abdominal pain, three episodes of vomiting and no bowel movement. His heart rate is 108 and he has generalised tenderness. His WCC is 16.4 with the CRP at 173. His arterial blood gas displays a pH of 7.30 and a lactate of 2.4.
4.5 Discussion

The primary aim of this study was to design and develop a methodology in order to produce a series of virtual patients, with surgical pathology, that could be incorporated into a readily accessible virtual world platform. This was achievable through following guidelines specified by Posel et al. (2009). This was also achieved through the utilisation of allied web technologies; which when linked together was able to produce the end product within a cost- and time-effective modality.

The progress made in the development of these virtual patient cases was partially as a result of the errors made in the previous virtual patient design, described in the previous chapter. It was stipulated from the outset that this development would require a case editor that could easily upload information from the storyboard and subsequently transfer this information into a usable format, i.e. in this instance the virtual web-player. The case structure, specifically the outline of the history, examination, investigation and management ensured that the cases could be updated in a reproducible manner, which made subsequent case editing simpler following initial progress. In fact, following from this thesis a further eighteen virtual patients have been developed in three months with no additional cost, demonstrating the strength of this design and development methodology utilised.

However, this development process was not without limitations. In an ideal scenario the case design would have followed a complete branching design. The reason for not selecting this method was that the case design would
become increasingly complex following the selection of only a few decisions regarding virtual patient management. The alternative method, the linear string method, was utilised in some of the cases. The problem with this method is that real patient management involves multiple factors, whereas this design revolved around crucial individual steps for a virtual patient to progress and therefore such a design methodology could be perceived as inappropriately artificial. To compensate for this we attempted to combine the two methods to produce a limited branching method for some of the cases. This again was not ideal, as it is not entirely reflective of real patient management; however, it does provide a higher level of realism than the more simplistic linear string of pearls method.

Another problem encountered was that the information regarding the virtual patient was retrieved as a list of questions for the user to select. This again is not reflective of real practice and could be deemed too synthetic. A more appropriate method would have been for the user to type in a question and the patient delivers the answer. This would have provided the most realistic scenario and would have made the virtual patient experience more immersive for the user. However, in order to have developed this it would have required significant more cost and more development time, both of which were outside the remit of this study. Whilst the creation of an artificially intelligent virtual patient is the ideal which further development is to strive towards, it must be clear that not only is more significant cost required but also specific developers would be required with the appropriate skill to create artificially intelligent patients. This alone could significantly add to the start-up cost from
the outset, and this study was limited to a budget allocated to the development team from the STeLI initiative.

There were also limitations associated with the case editing through the Eclipse editor. The ease experienced with the Eclipse program was a reflection of its repeated use; however, initially editing proved to be challenging due to the Eclipse model. There were issues surrounding the ability to use the copy and paste function between separate cases, although not within individual cases. This meant that when subsequent cases of the same patient required re-entering of the same information, this had to be manually typed as opposed to using the simpler copy and paste function. This frequently led to a laborious process of continually re-typing information that could feasibly have been copied instead.

The editor appeared complex at initial exposure for information entry. This had the disadvantage that whilst any clinician may design a case, they may struggle to implement this information sufficiently and quickly into the editor. From a personal perspective, inputting information into the editor appropriately required multiple attempts before a level of comfort in its use was achieved. However, with subsequent repeated use and the use of the user manual it became significantly easier to develop multiple virtual patients. A significant learning curve would need to be overcome in order for any other clinician to be able to use the editor to develop further virtual patients.
The virtual environment of Second Life proved challenging, as there was a limited number of primitive objects that could be utilised within the same setting. This resulted in some of the realistic components of a clinical area, i.e. more patient or healthcare professional objects, being curtailed to ensure that the cases could function. Whilst this may have somewhat impacted on the fidelity in the environment; the cases were designed to be engaging enough to ensure that participants would find them challenging.

It is also questionable whether another virtual world should have been utilised. Previous virtual patient designs (Youngblood et al., 2007; LeRoy Heinrichs et al., 2008) have been incorporated into other platforms such as OLIVE. However, the use of Second Life has inherent benefits as opposed to other virtual worlds: the fact that it is free to use and can be downloaded onto a desktop ensured that this platform could potentially be utilised by all postgraduate surgical trainees. The use of other platforms is restricted as they are not available online, therefore the use of these virtual patient designs would be restricted to the few fortunate enough to access them.

Finally these cases were selected for assessment as opposed to training. The case content was reflective of conditions frequently encountered by surgical trainees. The premise for inclusion for the case content was that the surgeons at each level of training should be able to appropriately manage these cases due to their frequent exposure. The use of these patients for the purpose of training could have proved futile, as it would be assumed that any participating surgeons utilising this simulation would have a baseline level of
knowledge regarding these conditions; and the use of these patients for training would encounter a ceiling effect as only a limited amount of information would be added to participant’s baseline knowledge. For these cases to be used for training, the most obvious beneficiaries would be medical students on a surgical attachment, as they would gain sufficient knowledge and experience from assessing and managing these patients and this would result in a learning curve towards the subsequent management of further patients with similar conditions. An alternative method to ensure that such virtual patient cases could be used for the training of surgeons is the inclusion of rare pathology, infrequently encountered, so that the participant would acquire appropriate knowledge, skills and attitudes to be prepared for a subsequent encounter with similar patients.

Overall, this study has demonstrated a reproducible methodology for the design and development of a series of virtual patients, regardless of whether for use in training or assessment. This methodology, as stated, has been reproduced outside the scope of this thesis to further produce virtual patients, highlighting its success as a framework for development. The development process was made feasible through the learning points acquired from the design process described in the previous chapter. However, this design process is not fully complete, as is indicated by the limitations addressed in this study. The remaining challenge is to ensure that virtual patient design is as immersive and realistic as feasible. This would require continued work on the methods employed, outside this thesis. However, this study has provided a significant platform for further design to continue as well as for the virtual
patients to be disseminated into further educational use following appropriate validation.

4.6 Conclusions

This study has demonstrated the design and implementation of a series of virtual patients in Second Life. The methodology utilised was reproducible, such that further virtual patients were designed and developed along a much shorter timeframe and at a significantly reduced cost. However, whilst the development of these patients was successful it is essential to evaluate these virtual patients further.
Chapter 5

Implementation of Virtual Online Patient Simulation
Aim

To assess the face, content and construct validity of the virtual online patient simulation.
5.1 Chapter Overview

This chapter describes the use of the virtual patient simulation as an assessment tool for training surgeons. Surgeons of different specialist grades ranging from Intern/ Foundation Year 1 to Attending/ Consultant participated in the simulation, with their performance assessed post hoc. Each surgeon also provided his or her view on the simulation itself through a developed questionnaire.

5.2 Introduction

Patient assessment and subsequent management is the cornerstone of the art of practising medicine. The Accreditation Council for Graduate Medical Education (ACGME) has listed a series of clinical competencies, which are deemed integral to maintenance of the high standards of clinical practice (ACGME, 2010). These stipulate six core competencies, including patient care, medical knowledge, practice-based learning and improvement. The recent implementation of curtailed working hours, as previously described, has had a profound impact on training opportunities (Carlin et al., 2007; Sim et al., 2004; Kogan et al., 2006; Hutter et al., 2006; Whang et al., 2003; Debas et al., 2005) and hence potentially the achievement of competence. It is imperative that trainee doctors are regularly assessed to ensure that they are deemed safe for practice. Whilst assessment involves a number of key criteria, it is the decision-making process which is integral to safety of care (Jacklin et al., 2008).
The virtual patient simulation that has been developed provides an ideal opportunity to demonstrate a training surgeon’s decision-making process in the management of common surgical presentations. In order for this to occur, it was essential for different surgeons to manage the series of virtual patients and for them to be assessed with an objective performance score. Whilst this would provide convincing evidence for the efficacy of this simulation, it was also imperative to gauge the opinion of the trainees regarding the realism of the virtual patient interaction as well as the realism of the case content. The aims of this study were therefore to assess the face and content validity of the simulation as well as to determine the construct validity of the simulation as an assessment tool.
5.3 Methods

5.3.1 Development of the Objective Performance Score

Prior to developing a scoring system, previous performance scores regarding patient management were identified and reviewed. The main assessment tool that was apparent was the mini-CEX scoring system, which is currently utilised in surgical training in the United Kingdom. Upon my review of this, it was felt to contain certain categories that were appropriate for this virtual patient management system; however, there are certain categories, including ‘communication and listening skills’ and ‘time management’ that are not relevant for an online virtual patient interaction, in which information is retrieved electronically rather than through active communication.

A focus group was convened consisting of an attending/consultant surgeon and three senior residents/surgical registrars, including myself. All of the cases were run through and I demonstrated each salient point of the case. Following visualisation of each of the cases and the correct pathway to manage each case, it was established that a scoring system should have the following categories: history, examination, investigation, diagnosis and management section. The decision was made to assign a 7-point Likert scale to each category so that a numerical value could be applied to an objective measurement of performance.

I subsequently developed this performance scale (Table 5a) to include a score for unsatisfactory, satisfactory and superior performance to delineate
different levels of performance by the participating surgeons. Following this development, the group was reconvened to review the performance scale and appropriate amendments were initiated. In addition, decisions were made as to what a participant must do to attain each score on the performance scale. This would then be utilised to guide future case rating.

5.3.2 Development of Face and Content Validity Scale

In addition to the development of the objective performance score, it was necessary to develop a questionnaire to determine the participants’ opinion regarding the realism of the virtual patient interaction and the realism of the content of the clinical cases. In the focus group session to develop the objective performance scale, further discussion was initiated regarding appropriate questions that could be incorporated into both a face and content validity scale. Following this initial dialogue, I developed the face and content validity scale, which consisted of a 7-point Likert scale questionnaire, producing a 7-item face validity questionnaire and a 9-item content validity questionnaire. A similar pattern of implementation was then followed, with review of the questionnaire by the focus group with necessary amendments made.

5.3.3 Personal Role

In this study I was responsible for the development of all the outcome measures prior to commencing the study. I also recruited all the participants and was present as each of them proceeded through the simulation. I also
performed the rating of all cases, having been blinded towards the identity of the participants.

5.3.4 Timescale

This study lasted a total of 10 months for the completion of subject recruitment, participation and assessment.

5.3.5 Pilot Case Participation

Prior to commencing this study two senior surgical registrars were recruited to perform a pilot run-through of all the scenarios. This was all performed in the same setting for each participant. The purpose of this was to highlight any problems that might become apparent; this phase was successful and did not demonstrate any major problems regarding the logistics of proceeding through each case. Following this test period, the decision was made to commence participant recruitment.

5.3.6 Participants

The study recruited 63 participants. All participants were UK postgraduate surgeons and were recruited at different training levels, primarily Intern/Foundation Year 1 n=20, Junior Resident (Year 2 Resident)/Core Trainee 1 n=15, Senior Resident (Year 4 Resident)/Specialist Trainee 3 n=18 and Attending/Consultant n=10. All non-attending grades were recruited from within the pan-London, United Kingdom (UK) training scheme through electronic mail invitations. This was also supplemented by a brief
presentation of the study at the Junior Resident/Core Trainee annual educational meeting in order to obtain more participants. This was because initial interest in the study was low from this cohort, following the preliminary email invitation.

A total of 203 email invitations were distributed to the different training grades: Intern n=64, Junior Resident n=81 and Senior Resident n=58. Attending grades were recruited from both London teaching and community hospitals via a similar process, with n=46 email invitations distributed.

5.3.7 Setting

All online simulations occurred on a single laptop (my laptop) – an Apple MacBook 15 inch Pro-Intel Core 2 Duo, 2.5GHz (Apple Inc., California, USA). The study predominantly took place in the Research Laboratories of St Mary’s Hospital, Imperial College NHS Trust, London. Other locations where the study occurred were the Research Laboratories at Chelsea and Westminster Hospital and Northwick Park Hospital, North West London Hospital NHS Trust. The reason for these additional venues was to facilitate participation and ensure that it was easy for participants to take part in the study: those who performed the study at these venues were surgical trainees at these hospitals.
5.3.8 Study Design

All participants completed an orientation process prior to commencing the surgical scenarios. This involved reading the manual detailing how to use the software to proceed in the simulation (Appendix 10). This process was followed by a 10-minute period of familiarisation with Second Life and the use of the avatar. Subsequently, participants assessed and managed the single virtual patient, which was used as an orientation case. Post-orientation, a demographic questionnaire was completed. The participants then proceeded through the simulation.

The number of cases completed was related to the training level of the participant. Therefore the most junior trainee (intern) would complete 3 cases, level 1 cases only. The junior residents completed the level 1 and 2 cases whilst the senior resident and attending surgeons completed all three cases at level 1, 2 and 3. The cases were stratified according to the appropriate level of training, as it might then be feasible to ultimately develop proficiency-based training in which the junior surgeons are deemed competent at their level before being able to progress to the next level. I was present in close proximity while all the participants completed their relevant cases, to facilitate any potential problems that might occur with using the software; however, all the participants were instructed that my only role consisted of troubleshooting any software/hardware issues during their participation and that I would not otherwise be involved.
5.3.9 Objective Assessment of Performance

Two blinded assessors (a Senior Resident/Surgical Registrar and myself) assessed 40 cases (10% of the total cases) performed, with the inter-rater reliability determined for these cases using the Cronbach alpha coefficient. These cases were selected at random through the use of a random number generator. I rated the remaining cases. Ratings were conducted post hoc utilising the Excel sheet depicting each participant’s decision. All subject identifiers were removed from the Excel sheet prior to rating, to ensure that both raters were blinded and objectively rated the performance of the participants. The removal of identifiers was performed by a Senior Resident/Surgical Registrar who then maintained a database matching the Excel sheets depicting performance with the unique participant identifiers to ensure that the performance score could be matched to each participant following the completion of rating of all subjects.

The time taken to complete each case was also recorded in seconds. This was done as soon as a participant logged onto a case and then subsequently logged out of a case. I recorded all the times taken for each case on the stopwatch facility of an Apple iPod Touch (Apple Inc., California, USA). Additionally participants were asked to self-rate their performance on their final case performed on a rating scale (Appendix 11), reflecting the performance scale utilised by the raters, to determine if there was any difference between participants’ performance and their perceived performance.
IMPLEMENTATION OF VIRTUAL ONLINE PATIENT SIMULATION (IVOPS) PERFORMANCE SCALE

Date
Student Identifier
Student Code

Please follow the key given below and circle the number corresponding the participant’s performance:

<table>
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<tr>
<th>NA</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
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<tbody>
<tr>
<td>Not applicable</td>
<td>Unsatisfactory</td>
<td>Satisfactory</td>
<td>Superior</td>
<td></td>
<td></td>
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<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>ELEMENT</th>
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<tbody>
<tr>
<td>HISTORY</td>
<td>a) Gathers appropriate information</td>
</tr>
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<td></td>
<td>NA 1 2 3 4 5 6 7</td>
</tr>
<tr>
<td></td>
<td>b) Follows logical sequence</td>
</tr>
<tr>
<td></td>
<td>NA 1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>EXAMINATION</td>
<td>c) Examines relevant system</td>
</tr>
<tr>
<td></td>
<td>NA 1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>INVESTIGATION</td>
<td>d) Selectively orders appropriate diagnostic study</td>
</tr>
<tr>
<td></td>
<td>NA 1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>DIAGNOSIS</td>
<td>e) Makes appropriate diagnosis</td>
</tr>
<tr>
<td></td>
<td>NA 1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>MANAGEMENT</td>
<td>f) Institutes appropriate treatment</td>
</tr>
<tr>
<td></td>
<td>NA 1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>OVERALL</td>
<td>g) Progresses through case in logical sequence</td>
</tr>
<tr>
<td></td>
<td>NA 1 2 3 4 5 6 7</td>
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<tr>
<td></td>
<td>h) Demonstrates appropriate clinical decisions</td>
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<td></td>
<td>NA 1 2 3 4 5 6 7</td>
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</tbody>
</table>

Table 5a: The rating scale used to determine the performance score
5.3.10 Statistical Analysis

I analysed the data using SPSS version 17 for Mac (SPSS Inc., Chicago, USA). The internal consistency of the face and content validity scale was assessed using the Cronbach's alpha coefficient. In view of the non-parametric nature of the data, the Kruskal-Wallis test was used to assess for any differences between each user group for each case with regard to both performance score and time taken. Further group comparative analysis was performed using the Mann Whitney U Test to detect where the outcome difference lay between the specific groups. Participants’ perceived performance on their final case was compared with their objective assessment of performance using the Mann Whitney U Test.
5.4 Results

5.4.1 Demographics

There were 42 male and 21 female participants in this study, with an age range of 24-37 years. All participants were either surgical trainees or consultant surgeons, consisting of Foundation Year 1/ Intern (I) n =20, Core Trainee 1/ Junior Resident (JR) n=15, Specialist Trainee 3/ Senior Resident n=18 and Consultant Surgeon n=10. 57 of the 63 (90%) participants agreed with the statement that they found e-learning useful and 11 (17%) stated that they had previously used virtual world software.

5.4.2 Face/ Content Validity

The internal consistency of the face validity questions was high, with a Cronbach’s alpha coefficient of 0.87. An alpha value of > 0.7 is considered adequate in terms of research contexts (Bland and Altman, 1997). This was determined by calculating the Cronbach’s alpha between the different items on the questionnaire to ensure that the questionnaire was measuring the same general construct, i.e. the face validity. The median rating on the 7-item face validity questionnaire was 5 for the process of obtaining a history from the virtual patient (Table 5b). This contrasted with a median rating of 6 for examining the virtual patient, retrieving investigation information and managing the virtual patient. The median ratings were also 5 regarding specific questions on the realism of the clinical environments developed, namely the simulated emergency department, the ward and the simulated high dependency unit. The internal consistency of the content validity
questions was also high, with a Cronbach’s alpha coefficient of 0.957. All cases, aside from Acute Pancreatitis Level 2, had a median rating of 6 (1= strongly disagree, 7= strongly agree) regarding the cases being an accurate representation of a real-life scenario (Table 5c).
Table 5b: The results of the face validity questionnaire

<table>
<thead>
<tr>
<th>LIKERT-SCALE QUESTIONS TO ASSESS FACE VALIDITY</th>
<th>GROUPS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>INTERN Median (Range)</td>
</tr>
<tr>
<td>1. The process of taking a history from the virtual patient is realistic</td>
<td>6 (4-7)</td>
</tr>
<tr>
<td>2. The process of examining the virtual patient is realistic</td>
<td>6 (4-7)</td>
</tr>
<tr>
<td>3. The process of obtaining different investigations and their results for the virtual patient is realistic.</td>
<td>6 (5-7)</td>
</tr>
<tr>
<td>4. The process of managing the virtual patient is realistic</td>
<td>6 (5-7)</td>
</tr>
<tr>
<td>5. The simulated A&amp;E was a realistic representation of a real A&amp;E</td>
<td>5 (2-7)</td>
</tr>
<tr>
<td>6. The simulated ward was a realistic representation of a real clinical ward</td>
<td>5 (2-7)</td>
</tr>
<tr>
<td>7. The simulated HDU was a realistic representation of a real HDU</td>
<td></td>
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<tr>
<td>Likert Scale Questions to Assess Content Validity</td>
<td>Groups</td>
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<tr>
<td>------------------------------------------------</td>
<td>--------</td>
</tr>
<tr>
<td>1. The case Rectal Bleeding Level 1 was a realistic representation of a real-life clinical scenario</td>
<td>INTERN Median (Range)</td>
</tr>
<tr>
<td>2. The case Acute Pancreatitis Level 1 was a realistic representation of a real-life clinical scenario</td>
<td>6 (3-7)</td>
</tr>
<tr>
<td>3. The case Small Bowel Obstruction Level 1 was a realistic representation of a real-life clinical scenario</td>
<td>6 (3-7)</td>
</tr>
<tr>
<td>4. The case Rectal Bleeding Level 2 was a realistic representation of a real-life clinical scenario</td>
<td>X</td>
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<tr>
<td>5. The case Acute Pancreatitis Level 2 was a realistic representation of a real-life clinical scenario</td>
<td>X</td>
</tr>
<tr>
<td>6. The case Small Bowel Obstruction Level 2 was a realistic representation of a real-life clinical scenario</td>
<td>X</td>
</tr>
<tr>
<td>7. The case Rectal Bleeding Level 3 was a realistic representation of a real-life clinical scenario</td>
<td>X</td>
</tr>
<tr>
<td>8. The case Acute Pancreatitis Level 3 was a realistic representation of a real-life clinical scenario</td>
<td>X</td>
</tr>
<tr>
<td>9. The case Small Bowel Obstruction Level 3 was a realistic representation of a real-life clinical scenario</td>
<td>X</td>
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</tbody>
</table>

Table 5c: The results of the content validity questionnaire
5.4.3 Performance Analysis

Participants’ performance was analysed through a performance score and time taken to complete the cases. This was measured in seconds. The inter-rater reliability for the assessment of performance score between the two assessors was high, with a Cronbach’s alpha coefficient $\geq 0.811$ for 40 cases assessed from the three levels. I assessed the remaining cases. Both the performance score and time evaluations between the four groups are reported in Table 5d.

5.4.3.1 Level 1 Cases

Analysis of performance demonstrated widespread significant differences between the different user groups (namely Intern, Junior Resident, Senior Resident and Attending) for the three cases at level 1: Rectal Bleeding (median 48, 50, 54, 56, $p<0.001$), Acute Pancreatitis (median 47, 51, 55, 55.5 $p<0.001$) (figure 5a) and Small Bowel Obstruction (median 49, 53, 55, 56 $p<0.001$).
<table>
<thead>
<tr>
<th>LEVEL</th>
<th>CASE</th>
<th>METRIC</th>
<th>GROUP COMPARISON</th>
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<tbody>
<tr>
<td></td>
<td></td>
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<td>INTERN vs JUNIOR RESIDENT</td>
</tr>
<tr>
<td>1</td>
<td>Rectal Bleeding</td>
<td>Performance</td>
<td>48 vs 50</td>
</tr>
<tr>
<td></td>
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<td>0.074</td>
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<td>48 vs 54</td>
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<td>&lt;0.001*</td>
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<td>Time</td>
<td>1291 vs 1024</td>
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<td></td>
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<td>0.002*</td>
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<td>1291 vs 1049</td>
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<td>1291 vs 975</td>
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<td>0.003*</td>
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<td>1024 vs 1049</td>
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<td>1024 vs 975</td>
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<td>1049 vs 975</td>
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<td>0.265</td>
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<td>47 vs 51</td>
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<td>0.006*</td>
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<td>47 vs 55</td>
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<td>&lt;0.001*</td>
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<td>47 vs 55.5</td>
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<td>&lt;0.001*</td>
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<td>51 vs 55.5</td>
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<td>&lt;0.010*</td>
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<td>55 vs 55.5</td>
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<td>0.832</td>
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<td>Time</td>
<td>1478 vs 1119</td>
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<td>&lt;0.001*</td>
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<td>1478 vs 1381</td>
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<td>0.149</td>
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<td>1478 vs 1110</td>
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<td>0.007*</td>
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<td>1119 vs 1381</td>
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<td>0.849</td>
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<td>1119 vs 1110</td>
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<td>0.051</td>
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<td>49 vs 53</td>
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<td>0.001*</td>
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<td>1074.5 vs 976</td>
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<td>339 vs 475.5</td>
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<td>475.5 vs 334</td>
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<td>Case Description</td>
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<tr>
<td>Acute Pancreatitis</td>
<td>X</td>
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<td></td>
<td>41 vs 49</td>
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<td>41 vs 49</td>
<td>&lt;0.001*</td>
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<td>49 vs 49</td>
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<td>Time</td>
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<td>426 vs 497.5</td>
<td>0.052</td>
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<td>426 vs 422</td>
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<td>42 vs 45</td>
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<td>42 vs 49</td>
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<td>45 vs 49</td>
<td>0.051</td>
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<td>Time</td>
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<td>572 vs 617.5</td>
<td>0.605</td>
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<td>572 vs 457</td>
<td>0.196</td>
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<td></td>
<td>617.5 vs 457</td>
<td>0.204</td>
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<td>Rectal Bleeding</td>
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<td>425.5 vs 340</td>
<td>0.005*</td>
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<td>Acute Pancreatitis</td>
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<td>43 vs 49</td>
<td>0.012*</td>
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<td>571.5 vs 471</td>
<td>0.024*</td>
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<td>Small Bowel Obstruction</td>
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<tr>
<td></td>
<td>721.5 vs 437.5</td>
<td>0.004*</td>
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* Denotes statistical significance with p<0.05

Table 5d: All groups performance score and time taken for each case
Figure 5a: Performance of subjects in Pancreatitis level 1 Case
Further analysis revealed that the Attending group and the Senior Resident group performed significantly better than the Intern group for all cases (Rectal Bleeding: median 56, 54 vs 48, p<0.001; Acute Pancreatitis: median 55.5, 55 vs 47, p<0.001 and Small Bowel Obstruction: median 56, 55 vs 49, p<0.001).

Both the Attending and the Senior Resident group also performed significantly better than the Junior Resident group for the Rectal Bleeding Case (median 56 vs 50, p<0.001 and median 54 vs 50, p=0.003) and the Acute Pancreatitis case (median 55.5 vs 51, p<0.010 and median 55 vs 51, p=0.004). The Junior Resident group performed better than the Intern group for the Acute Pancreatitis case (median 51 vs 47, p=0.006) and the Small Bowel Obstruction case (median 53 vs 49, p=0.001).

Time analysis demonstrated that the Attending and the Junior Resident group completed all three cases significantly faster than the Intern group (Rectal Bleeding: median 975 vs 1291, p =0.003 and median 1024 vs 1291, p=0.002), (Acute Pancreatitis: median 1110 vs 1478, p=0.002 and median 1119 vs 1478, p<0.001), (Small Bowel Obstruction: median 1074.5 vs 835, p=0.003 and median 1074.5 vs 976, p=0.008). In contrast to the performance score metrics, the Junior Resident group completed the Acute Pancreatitis case faster than the Senior Resident group (median 1110 vs 1478, p=0.002).

5.4.3.2 Level 2

For all three cases, there were significant differences between the user groups in both performance and time. The Attending and the Senior Resident group performed significantly better than the Junior Resident group.
for all three cases (Rectal Bleeding: median 49, 47 vs 40, p<0.001) (Acute Pancreatitis: median 49 vs 41, p<0.001 and median 49 vs 41, p=0.001) (Small Bowel Obstruction: median 49 vs 42, p=0.001 and median 45 vs 42, p=0.002)(figure 5b). The time comparison demonstrated that the Junior Resident group performed the Rectal Bleeding case faster than the Senior Resident group (median 339 vs 475.5, p=0.020), which again contrasted the performance score metrics.

5.4.3.3 Level 3

Analysis of performance between the Attending and the Senior Resident groups showed a significant difference in the Rectal Bleeding case (median 47 vs 42, p<0.001) and the Pancreatitis case (median 49 vs 43, p=0.012) but not in the Small Bowel Obstruction case (median 54 vs 54, p=0.759). The Attending group performed all three cases significantly faster than the Senior Resident group: Rectal bleeding (median 340 vs 425.5, p=0.005)(figure 5c), Acute Pancreatitis (median 471 vs 571.5, p=0.024) and Small Bowel Obstruction (median 437.5 vs 721.5, p=0.004). The completion of the level 3 cases by the Attending group resulted in the defining of benchmark criteria for performance score and time taken for each individual case.

5.4.3.4 Self-Report

All user groups performed significantly better than their perceived performance in the final Small Bowel Obstruction case they undertook (Figure 5d): (p<0.001) for all groups (Attending median 56 vs 44.5, p<0.001; Senior Resident median 54 vs 47.5, p<0.001, Junior Resident median 42 vs 36, p=0.013 and Intern median 49 vs 40, p<0.001).
Figure 5b: Performance of subjects in Small Bowel Obstruction Level 2 Case
Figure 5c: Time taken by participants in the Rectal Bleeding Level 3 case
Figure 5d: Participants’ performance versus their perceived performance
5.5 Discussion

There is an increasing body of evidence that demonstrates the use of novel technologies to differentiate experienced from novice surgeons in terms of technical ability (Aggarwal et al., 2007; Seymour et al., 2002; Bloom et al., 2003). However, surgical training involves a plethora of other abilities, such as attitude, behaviour, communication and decision-making skills in the operating room, consulting room and postoperative suite (Aggarwal et al., 2004b). In fact, leadership in surgery has been described as incorporating several characteristics including integrity (Cuschieri, 2006), professionalism, resilience and decision-making (Patel et al., 2010; Rutkow et al., 1979). This study principally focused on whether this simulation could determine a surgical trainee’s decision-making abilities in managing a series of common surgical presentations.

This study was unique in that it was the first study to demonstrate a 3D online simulation as an assessment tool for surgeons in training. This was feasible through the recruitment of 63 surgeons as participants. A power calculation was not undertaken for this study: it was the first of its kind and therefore it would not be possible to ascertain the minimum sample size required to demonstrate the construct validity. The initial aim, therefore, was to recruit 20 surgeons in each group with a total of 80 surgeons. The concept of 20 surgeons in each group was derived from previous simulation studies, which have used similar numbers (Arora et al., 2011; Orzech et al., 2012; Aggarwal et al., 2006). However, within the time constraints of performing this study and the challenges of recruitment this was not possible.
There were various challenges in recruiting each cohort. The Foundation year 1/Intern grades proved to be the most forthcoming in agreeing to participate. However, the Attending/Consultant grade were the most challenging and frequently several email invitations had to be sent in order to entice study participation. The study uptake was so low in the Junior Resident/Core Trainee 1 group that a different recruitment approach had to be undertaken in order to improve participation; I attended a Junior Resident/Core Trainee training day, where I briefly presented the study in order to obtain more subjects. This approach proved to be a successful strategy, although I was still unable to obtain the target of 20 participants for this group.

There were also many instances of participants deciding to participate but subsequently withdrawing from the study with no reason highlighted; this was most apparent in the most senior grade of surgeons. It was also noted that many of the more senior attending/consultant surgeons declined an invitation to participate and therefore the participants from this group were the younger generation of attending/consultant surgeons. This potentially could have resulted in selection bias, as the age range was restricted to 13 years for all groups of participants, whereas in real clinical practice this range can be up to 41 years. The implications from this could have been that the participants could have offered a more favourable opinion of this new technology as an assessment technique, although this simply remains speculative.
Of note is that one third of the participants in this study were female, which is slightly higher than the current proportion of females in surgical training (Royal_College_of_Surgeons, 2011). However, the number in this study would have been higher due to the participation of the Intern/Foundation Year 1 group who are not necessarily trainee surgeons. Therefore this suggests that the participants in this study were fairly representative of those in surgical training in terms of gender. In terms of recruitment, a total of 63 surgeons represented a sufficient number, as well as a sufficient representation of gender although not necessarily age, to demonstrate the construct validity between the different grades, and represents a high participant number.

The aim of this study was also to determine the face and content validity of this novel simulation as well as provide an assessment tool for surgeons by establishing the construct validity. The virtual patient simulation demonstrated high face validity with median ratings of predominantly 6 on a 7-point Likert scale regarding the process of retrieving patient-specific information from the simulation. The exception to this was retrieving the history from the virtual patient, with a median rating of 5. The median face validity score regarding questions on the realism of the clinical environments developed was 5 with a wider range of ratings. An explanation for this is the Second Life virtual environments, where there were restrictions regarding the amount of primitive developed objects that could be utilised within the same setting. This resulted in some of the potential realistic representations of a
clinical environment, i.e. more patient or healthcare professional objects, being curtailed so that the cases could function. However, the compromise in realism of the environment was not demonstrated with the realism of the clinical content in the scenarios, with the simulation being perceived as having high content validity.

In retrospect, although this study demonstrated high face and content validity, the process of obtaining participants’ views on the simulation could have been improved. A process of performing semi-structured interviews regarding the strengths and weaknesses of the 3D simulation would have been far more valuable in assessing this unique simulation tool. The concern with the face and content validity scale was that a participant would select an appropriate number from the Likert scale but I would not obtain an insight from the participant’s selection as to why that number was selected. This could be exemplified by the fact that the median rating of the realism of the environment was 5 and not higher.

I have made presumptions as to why they may not have found the simulation completely realistic with regard to the limitation of objects and therefore limitations in the number of visual aids, such as a reduced number of hospital beds used in the simulation. However, this represents a presumption only. In essence for a future insight into improving this simulation or developing future simulations this study would have been much improved by using a detailed analysis of participants’ opinions of the simulation, especially as it is so unique and could yet prove to be a future innovative
training/assessment tool in clinical medicine. After beginning the study, various participants did give me informal feedback, outside the face and content validity score, of what their thoughts of the simulation were. If I had captured this information, it could have been useful for further virtual patient developments that have taken place following on from this study.

Eight of the nine cases demonstrated construct validity (i.e. the tool measured what it purported to measure) for performance analysis to differentiate between the different grades of training surgeon. The exception to this was the level 3 small bowel obstruction case. This demonstrated that the cases could be utilised for future assessments of surgical trainees at different levels of their training. However, this study depends heavily on the rating scale that was developed and utilised for this simulation. The rating scale developed was unique, in that this was the first instance it has been used to assess the management of virtual patients.

In this study, two independent raters assessed only 10% of cases. The reason for this was that the other rater was restricted by time constraints and therefore could not commit to performing more assessments of the participants’ performance. The other rater was also a colleague of mine who was developing virtual patients and therefore possessed an insight into the way in which participants would take part in the simulation, retrieve virtual patient information and subsequently manage the virtual patients. For the combined rating of the cases, there was a high inter-rater reliability - alpha coefficient > 0.811. It would have been useful to establish with more cases if
the inter-rater reliability would have remained so high and therefore strengthen the validity of the rating scale.

Another question that surrounds the rating of the cases is whether there would have been such a high inter-rater reliability if another assessor was used who had no previous experience of virtual patient design. The real question, therefore, is whether the high inter-rater reliability obtained was a reflection of a similarity in rating that would persist between multiple different raters or whether the reliability in rating was obtained due to chance between the two assessors used in this study and this effect might not be seen again if another rater, with no previous virtual world experience, were used. This question can only be answered by asking other independent raters to assess the performances in these cases and measuring inter-rater reliability.

Another discrepancy that exists is with the rating scale, in that exemplars have not been used for each item. Therefore it could be perceived as difficult for other raters to assess participants’ performance without a verbal brief to explain what constitutes a good or bad performance for each item on the rating scale. The development of the rating scale was performed following a review of the mini-CEX rating scale that is currently used to assess postgraduate surgical trainees. On this scale, the categories of unsatisfactory, satisfactory and outstanding are used to categorise performance in each domain. This was reproduced in this study. However the rating scale is open to criticism with regard to the lack of descriptors of what constituted a satisfactory or superior performance in each domain. This then
leads to the question of whether the study findings are truly representative or whether they have occurred as a result of the inadequacies of the assessment tool. However, the counter argument in the context of this study is there was some inter-rater reliability demonstrated for a percentage of the cases. In hindsight, descriptors should have been used for each of the domains, which would have led to a more robust assessment tool.

Upon reflection a significant volume of work was placed on the development of the virtual patients and recruitment of participants. However the study could have been vastly improved if a similar effort had been exerted to develop a rating scale for the assessment and management of virtual patients. Again a semi-structured interview format could have been adopted with a number of surgical trainers to determine what would be essential components of such a rating scale. This could have then been used in two ways: to rate the assessment and management of the virtual patients and also to assess trainees’ performance in the assessment and management of acute surgical patients and to provide an alternative assessment tool to those currently used such as the ‘mini-CEX’.

A similar model of computer-based simulation used for assessment has been employed in the United States Medical Licensing Examination-USMLE® step 3 examination (USMLE, 2012). This involves USMLE® step 3 examinees managing a total of nine computer simulations, which are all web-based. The advantage of this system in comparison to our virtual patients is that there is a free text entry system for an examinee to use to make orders, e.g. for
diagnostic investigations, with the system recognising over 10,000 terms. This provides a more realistic method for a trainee to obtain information or request investigations than the methods we employed. It was not possible, though, to compare our simulations as the case content is completely different for both simulations and the USMLE® computer-based simulations are not unique to surgery but involve all medical specialties. Whilst this has represented a significant advance in the use of simulation in assessment, its introduction has been the culmination of more than 20 years of research including the development of expert-based scoring algorithms (Dillon and Clauser, 2009).

In order to develop these algorithms several experts have been employed to rate cases, with considerable changes made to the scoring system over a 20-year period in order to develop an algorithm that generates an automated score. Within the remit of this research it would not have been feasible to generate such a scoring system, as the major time constraint was the development of the virtual patients themselves, which are completely distinct from the case based simulations used in the USMLE® examination. However, it is acknowledged that a limitation of our study is the absence of an automated scoring algorithm, but the primary scoring methodology used here could form a precursor to the development of further scoring methods that could be incorporated into the simulation. The next proposed step in this simulation is to develop a more rigorous method of scoring performance, which could eventually lead to the development of an automated scoring system.
Another method of performance assessment utilised for this virtual patient assessment involved measuring the time taken to proceed through cases. Time analysis demonstrated widespread significant differences, but the results were in contrast to the assessment of performance score. The main difference was found in the Junior Resident and Senior Resident groups, with the more junior group generally performing the cases faster. The explanation for this can be found in the way in which participants proceeded through the study. The Junior Resident group performed a total of 6 cases and the orientation case, whereas the Senior Resident group performed a total of 10 cases including the orientation case. During the study, the Junior Resident group performed all cases in one single sitting. However many of the Senior Resident group performed the cases at separate times, i.e. they would perform six of the cases in one sitting and return to perform the remaining three on a separate occasion. They would then proceed through the second set of cases at a slower pace, as they were familiarising themselves with the software again. This resulted in slower than expected times for them and unexpected results for time taken through the cases.

Ideally I would have had all participants perform all of their cases in one single sitting; however this was not practical as for the Senior Residents the total time required for the study was almost four hours and many of these participants could not commit to this whole timeframe in one single session. This differed from the Attending group, who scheduled themselves to perform the study in a single session as opposed to repeatedly attending to
participate in the study. The result is that it is not feasible to conclude whether time can be considered to be an accurate assessment metric in the management of these virtual patients.

This study also highlighted an interesting finding, in that all groups perceived their performance to be worse than their actual objective performance in the management of their final case, namely either Small Bowel Obstruction level 1, 2 or 3. This may be a generic perception of clinicians, which resembles findings from previous studies in which clinicians perceived their performance to be different to their actual performance (de Blacam et al., 2012; Davis et al., 2006). An alternative explanation is that the surgeons’ unfamiliarity with and first exposure to the software may have possibly resulted in them possessing less confidence in managing these virtual patients and thus self-rating themselves lower than their actual objective measure of performance. However it is difficult to establish from these scenarios whether such disparity between self-assessment and objective assessment may have an impact on real-life patient management, particularly as a novel form of simulation has been introduced here.

This is the first single player 3D virtual patient scenario in which subjects have been formally assessed on their individual performance. This study has demonstrated that it is feasible for 3D virtual patients to be utilised by trainees and subsequently for their performance to be assessed and benchmarked against more senior training groups. However, further work needs to be undertaken including the development of a more rigorous scoring
method prior to the dissemination of such cases to a larger cohort of trainees within a regional training scheme.

This unique form of 3D simulation has much potential that could be exploited. For example, such simulations could form a component of formal surgical examinations or informal regular assessments, or form part of the selection process for progressive surgical training such as residency (Cuschieri et al., 2001). However, it can be argued whether cognitive decision-making abilities obtained through such simulations are transferable to the real-life context of patient assessment. This was not determined in the remit of this study, but further work is being undertaken to establish whether the use of such scenarios could have an effect on patient care in the management of appendicitis and in the enhanced recovery programme for colorectal surgery. Another potential use is the development of 3D virtual patients with rare or infrequently encountered pathology, such as a patient with entero-cutaneous fistula. This will offer the trainee exposure and rehearsal for such cases prior to encountering them in real life.

The demonstration of the face, content and construct validity of these virtual patient cases has been encouraging and has provided preliminary validation of the 3D surgical virtual patient cases. However, it is acknowledged that further work is required to develop a more robust scoring system before such a simulation could be used for formal surgeon assessment and subsequently disseminated into the wider surgical community.
5.6 Conclusions

The face, content and construct validity of the virtual patients described as an assessment tool for training surgeons has been demonstrated within this study. The results have shown that this simulation can differentiate between different levels of experience and therefore demonstrate the potential to be utilised in surgical training in a multitude of ways. The next chapter will explore one such method: to simulate handoff in healthcare, and will attempt to determine its effectiveness towards clinical practice.
Chapter 6

The effect of handoff on virtual patient management
Aim

To use the previously developed virtual patients to establish whether the quality of handoff of care from an emergency physician influences the subsequent virtual patient management by a surgeon.
6.1 Chapter Overview

This chapter utilises the virtual patient development in a new clinical situation. It explores the suitability of the simulation to establish whether the quality of handoff has an effect on subsequent patient management. This was determined by mirroring current clinical practice through the initial management of emergency surgical patients by an emergency physician (level 1 - rectal bleeding, acute pancreatitis, small bowel obstruction), a handoff to the surgeon and the subsequent management of the virtual patients by trainee surgeons (level 2 - rectal bleeding, acute pancreatitis, small bowel obstruction).

6.2 Introduction

There has been an increasing focus on competency in communication, because poor communication has been demonstrated to be a major contributor toward healthcare error (Nagpal et al., 2010; Arriaga et al., 2011; ElBardissi et al., 2009). The Joint Commission in 2010 listed improved communication among caregivers as one of its national patient safety goals (Joint Commision, 2010). Within the healthcare paradigm, handoff is a principal means of communication. Handoff has been defined as ‘the transfer of patient responsibility or information from one healthcare professional to another in order to ensure patient care continuity and safety’ (Vidyarthi et al., 2006). Poor quality or incomplete handoffs have been cited as a major source of adverse events and near misses in clinical practice (Arora et al., 2005), with failures of handoff being attributed to inadequate communication as opposed
to individuals not performing the job to a sufficient level. (Cohen and Hilligoss, 2010; Solet et al., 2005; Gandhi, 2005)

Handoff is ubiquitous in a multitude of industries in which communication failure may result in damaging consequences. Patterson et al. (2004) identified a variety of strategies that have been incorporated in different settings, namely space shuttle mission control, nuclear power generators, railroad dispatch and ambulance dispatch service. A number of these strategies, such as writing a paragraph summary or the incoming person’s assessment of the current system status, have been cited as techniques that can improve the efficiency of handoff. Techniques have been identified that are predominant within Formula 1 motor racing (Catchpole et al., 2010) but are absent within healthcare, such as the use of checklists and feedback. There is a need to provide improved training in the delivery of handoff; however, previous reports observe that training in handoff communication is absent. (Horwitz et al., 2006; Sinha et al., 2007)

There has been an increasing focus on strategies to improve the handoff process. This has been demonstrated by Catchpole et al. (2007) who examined how the implementation of a simple handoff protocol designed with the assistance of experts from external industries can result in improvement of quality of the handoff process. A short protocol, which required 30 minutes of training time, resulted in a significant reduction in technical errors and the mean number of handoff information omissions in postoperative paediatric patients who had undergone complex heart surgery. The improvement of
handoff quality has also been demonstrated in a cohort of senior medical students following a simple training intervention (Marshall et al., 2009). This study involved training with the Identity, Situation, Background, Assessment and Recommendation (ISBAR) tool, which is a situational briefing tool; it was taught to various groups prior to management of a simulated trauma scenario followed by telephone interaction with a colleague. The number of imperative items mentioned during the handoff, according to a 20-point checklist, was significantly higher in the trained group as opposed to the control group.

Handoff occurs in a variety of interactions between different health care professionals. It frequently occurs in the emergency department, where information transfer takes place between the emergency physicians, or in transfer of care to an admitting hospital specialty (Reid et al., 2005). Previous research has principally focused on the analysis of handoff communication within this setting (Matthews et al., 2002; Apker et al., 2010) rather than enhanced communication, or assessment of the impact of handoff. Furthermore, there have not been any reports assessing the impact that handoff quality has on subsequent patient care.

This study sought to determine whether the quality of handoff from one clinician to another influences the quality of management for a patient. This was established by determining whether the quality of emergency department referral was correlated with subsequent patient management in a simulated setting. Secondly, the aim was to establish whether there was a difference in the quality of patient management between the same clinician managing a
patient whom they themselves have previously assessed, and a clinician reviewing a patient following referral from an emergency physician.
6.3 Methods

6.3.1 Subjects

The study recruited 20 participants, all of whom were UK postgraduate doctors of either Emergency Department Junior Resident-ED/ Foundation Year 2 n=10 (1st year Resident) or Surgery Junior Resident-JR1/ Foundation Year 2 to Core Trainee 2 n=10 (1st to 3rd year Resident) training grades. All these trainees were recruited from Imperial College NHS Trust or from the North West London NHS Trust and were initially invited to participate via email invitation. I also facilitated the recruitment of the emergency physicians by briefly presenting the study at an emergency physician training session at both the emergency departments of St Mary’s Hospital, Imperial College NHS Trust and Central Middlesex Hospital, North West London Hospitals NHS Trust. Additionally the data obtained from the Junior Resident/ Core trainee 1 group from the previous study, labelled as JR2 for this study, were utilised for comparison with the primary group of Surgeons (JR1).

6.3.2 Setting

The study took place in the Research Laboratories of St Mary’s Hospital, Imperial College NHS Trust and at Northwick Park Hospital, North West London Hospitals NHS Trust. The reason for the two venues was to facilitate subject participation and offer two sites where the study could be performed. All online simulations were conducted on a single laptop-Apple MacBook 15 inch Pro-Intel Core 2 Duo, 2.5GHz (Apple Inc., California, USA). A single
laptop was used to eliminate any discrepancies between variable computer processing speeds.

### 6.3.3 Study Design

The same orientation process as for the previous study was completed prior to commencement of the cases. The emergency department doctors then completed each of the level 1 cases and after completion of each case they recorded a handoff of the case. All voice recordings were made on the voice memo facility of a single 32GB iPod Touch (Apple Inc., California, USA). All the emergency physicians’ case assessments were completed prior to the recruitment of any of the surgeons.

Each surgical participant was recruited and subsequently randomly selected to receive a handoff from one of the emergency department physicians (Figure 6a). This randomisation was conducted by ordering each surgical participant from 1 to 10 in the sequence they were recruited. A number generated (between 1 and 100) from a random number generator was then assigned to each surgical participant. These numbers were then ordered sequentially and the surgeon was matched to an appropriate emergency department physician in number order i.e. the surgeon with the lowest random number received the handoff from the first emergency physician and the surgeon with the highest number received the handoff from the last emergency physician. After receiving the handoff from the voice playback facility of the iPod Touch (Apple Inc., California, USA); the surgical participant completed each of the level 2 cases appropriate to the level 1 case (Figure
6b). Post-simulation, both emergency physicians and surgeon participants completed a 7-point Likert scale evaluation questionnaire detailing the orientation process, the face validity and the potential future applications of the simulation.

6.3.4 Personal Role

I was responsible for the design of the study as well as the recruitment of all the participants. I conducted the study when the participants were progressing through the virtual simulations. I also rated all the cases as well as the handoff recordings.
Figure 6a: The randomisation process for surgeons receiving patient handoff

1. Recruitment of ED Junior Residents
   Listed 1-10 in order of recruitment

2. Recruitment of Surgery Junior Residents
   Listed 1-10 in order of recruitment

3. Random number generated for each Surgeon between 1-100

4. Surgeons re-listed from 1-10, according to the descending order of the random number generation

5. Surgeon matched to receive handoff from ED Junior Resident according to corresponding numbers from 1-10
Figure 6b: The study flow

Emergency Department
Junior Residents-ED
n=10

Assessment and Management of Level 1 Cases X 3
i. Lower GI Bleeding
ii. Acute Pancreatitis
iii. Small Bowel Obstruction

Handoff Recorded of Level 1 Cases x3

General Surgery Junior Residents-JR1
n=10

Assessment and Management of Level 1 Cases X 3
i. Lower GI Bleeding
ii. Acute Pancreatitis
iii. Small Bowel Obstruction

Handoff Received of Level 1 Cases x3

Assessment and Management of Level 2 Cases X 3
i. Lower GI Bleeding
ii. Acute Pancreatitis
iii. Small Bowel Obstruction

Assessment and Management of Level 2 Cases X 3
i. Lower GI Bleeding
ii. Acute Pancreatitis
iii. Small Bowel Obstruction
6.3.5 Outcome Measures

The primary outcome measure was the performance score used from the previous study to assess participants in the management of virtual patients. Both sets of participants – emergency department physicians and surgeons – received a score according to the checklist scale regarding their assessment and management of the virtual patients. I rated all of the cases with blinding as to the identity of the participants. The scores ranged from 7 to 56 as per the previous study.

The handoff recordings were assessed with a checklist scale adapted from the Hand-Off CEX (Farnan et al., 2010) (Table 6a). The Hand-off CEX instrument includes assessment of five domains: organisation, communication skills, content, clinical judgement and humanistic qualities, and an overall hand-off competence score. These domains were included in the assessment of handoff in this study, aside from the overall score. On the Hand-off CEX instrument there is also a domain for the setting, with a score allocated according to whether any interruptions occurred during handoff, whether handoff occurred in a noisy, chaotic area or a silent area, etc. This part of the score was excluded for our study as all handoffs were standardised in that they took place in a similar way i.e. post management of each virtual patient and on the 32GB iPod Touch (Apple Inc., California, USA). The Hand-off CEX instrument can exclude any of the domains, as there is a category of 'not observed' for any of the domains that is to be assessed. In essence our adaption of the instrument is the same rating scale as the Hand-off CEX with the setting category not observed.
The handoff scores ranged from 5 to 45, with each domain being rated on a 9 point Likert scale. I performed all of the ratings of the handoff for each participant and I was also blinded as to the identity of all the participants. This blinding process occurred through all recordings being uploaded to the desktop of one of my colleagues (a Surgical Registrar/ Senior Resident). They then distributed all the handoff recordings to me in a random sequence, with a random identity number that they stored. At the completion of the study, the handoff recording scores were matched to the appropriate participant. All ratings were also assessed after all data was collected from each participant at the end of the study. This was so that a minimum of three months had passed since the handoffs were recorded, to minimise possible bias if I had recollected a participant’s identity through recognition of their voice.

Other outcome measures were time taken to complete each case by both the emergency physician and the surgeons. The time taken for the emergency physician’s handoff was also recorded. Both of these times were recorded in seconds. All participants were also asked to self-rate their performance on their final case, on the same self-rating scale as the previous study, to establish if there was a difference between participants’ performance and their perceived performance. A secondary cohort of Junior Resident surgeons who assessed the level 2 cases, having assessed and managed the level 1 cases, received a performance score according to the same criteria as above, as well as having the time taken to complete each case measured. This secondary cohort data was taken from the data of the Junior Resident group from the previous study, to act as a comparison of whether there was any difference in
performance if subjects assessed a case having previously reviewed the same virtual patient earlier or if the subjects had reviewed the virtual patient having received a handoff from the emergency physicians.
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Table 6a: Adaption of Hand-Off CEX used for rating Handoff
6.3.6 Statistical Analysis

The data generated was analysed using SPSS version 17 for Mac (SPSS Inc., Chicago). The information retrieved represented non-parametric data and thus non-parametric statistical tests were used to analyse the data. The Spearman’s rank correlation was used as a comparative analysis to determine if there was a correlation between performance of case assessment and handoff score for the emergency department clinicians. This test was also used to determine if there was a correlation between time taken to complete the case and time taken for handoff. Further correlations were determined between the handoff score and the performance of the case assessment by the surgeon. The Mann Whitney U Test was utilised to compare the surgical doctors (JR1) with the second cohort of junior resident surgeons (JR2) who had previously completed the cases.
6.4 Results

There were 9 male and 11 female participants in this study, with an age range of 24-34 years. 16 of the participants stated they found e-learning useful and all 20 specified that they had not previously used virtual world software.

There was a significant positive correlation between the performance of the emergency department subjects in the management of the Rectal Bleeding case and their subsequent delivery of the handoff ($r=0.783$, $p=0.007$)(Figure 6c). However, the correlation between the performance scores and the handoff scores for the Acute Pancreatitis ($r=0.396$, $p=0.257$) and the Small Bowel Obstruction ($r=0.447$, $p=0.195$) were not significant.

For the group receiving the handoff, there were no significant correlations between the quality of handoff received and their subsequent virtual patient management for Rectal Bleeding ($r=-0.074$, $p=0.84$), Acute Pancreatitis ($r=-0.506$, $p=0.136$) and the Small Bowel Obstruction case ($r=-0.258$, $p=0.471$).

The relationship between the time taken to perform the cases and the time taken to deliver the handoff was significant for Small Bowel Obstruction ($r=0.673$, $p=0.033$) (Figure 6d), though not for the Rectal Bleeding ($r=0.532$, $p=0.113$) and the Acute Pancreatitis ($r=0.430$, $p=0.214$) cases. There were no significant correlations between the handoff time and subsequent time taken to manage the cases, i.e. Rectal Bleeding ($r=-0.28$, $p=0.434$), Acute Pancreatitis ($r=-0.506$, $p=0.136$) and Small Bowel Obstruction ($r=-0.103$, $p=0.777$). There was, however, a significant positive correlation between the
time taken to perform the handoff and the handoff score for all three cases (Rectal Bleeding $r=0.668$, $p=0.035$; Acute Pancreatitis $r=0.731$, $p=0.016$ and Small Bowel Obstruction $r= 0.817$, $p= 0.004$).

The surgeon group performed significantly better in the management of the Rectal Bleeding case than the cohort of surgeons who had continually managed the patient in both the emergency room and the clinical ward (JR1 vs JR2; median 44 vs 40, $p=0.012$) (Figure 6e). There was no significant difference between both groups in the management of the Acute Pancreatitis case (JR1 vs JR2; median 43 vs 41, $p=0.605$) and Small Bowel Obstruction case (JR1 vs JR2; median 43.5 vs 42, $p=0.115$). Regarding time taken to assess and manage the cases, the surgeons who received handoff for the Rectal Bleeding case performed the case significantly slower than the cohort who had managed the patients continuously (median 671 vs 339, $p<0.001$). However, there was no significant difference for time taken for the management of the Acute Pancreatitis case (JR1 vs JR2; median 529 vs 426, $p=0.149$) and the Small Bowel Obstruction case (JR1 vs JR2; median 640 vs 572, $p=0.177$).

The emergency doctor group also performed significantly better than their perceived performance in the final Small Bowel Obstruction case they undertook (median 49 vs 40, $p=0.004$)(Figure 6f), but this did not occur with the surgeon group (median 43.5 vs 40.5, $p=0.165$).
Figure 6c: The correlation between the emergency doctors’ performance and the handoff in the assessment of the Rectal Bleeding case

$r=0.783$, $p=0.007$
Figure 6d: The correlation between the time taken to perform the Small Bowel Obstruction case and the time taken for handoff.

$r = 0.673$, $p = 0.033$
Figure 6e: The performance of the general surgery JR1 group with the general surgery JR2 group in the assessment and management of the Rectal Bleeding case.
Figure 6f: The difference between the participants’ performance and their self-reported performance in the Small Bowel Obstruction case.
6.5 Discussion

This study has been an innovative study in that it is the first to establish whether handoff quality impacts on patient management, albeit with virtual patients. The overall findings have demonstrated that handoff quality does not impact on subsequent virtual patient management by a receiving surgeon. These findings were unexpected, as the perception is that a poor handoff will potentially result in compromised patient care (Arora et al., 2005; Arora and Johnson, 2006; Horwitz et al., 2012). Therefore this study has resulted in more questions as to whether handoff influences quality of care rather than a definitive answer as to whether a good handoff results in subsequent good care quality. It is not clear from this study if the results are an anomaly or represent genuine findings.

The suggestion is that these findings have occurred due to study limitations rather than being a true but unexpected finding. Firstly, this study used low subject numbers. For similar reasons as in the previous virtual patient study, a power calculation was not carried out as the study was completely unique and no previous similar studies existed. The sample size sought for both the emergency physician and surgeon groups was twenty participants within each group. In essence the sample size was dependent on the number of emergency physicians recruited, as the number of surgeons recruited would have to be the same in order for unique handoffs to be matched to each surgeon.
The recruitment of the emergency physicians proved to be challenging. Primarily this was due to the fact that emergency physicians work a full shift system and frequently did not want to participate outside their normal working hours. Also it would not have been feasible to conduct any of the study during their normal working day, which was possible with surgeons during both this and the previous study; the reason being that both the emergency departments from which participants were recruited have a high volume of patients and therefore the emergency physicians were busy with their clinical practice. It was also not possible to conduct the study in other local hospitals, as I was unable to obtain an Internet connection in other North West London hospitals, which had a protected firewall connection and therefore I was unable to access Second Life. Thus a total number of ten participants in the emergency physician group were recruited and the surgeon group number was matched accordingly.

Another reason why these study findings have resulted in unexpected results may be due to the method of rating of performance. The performance scale from the previous study was used once again, with myself rating the cases. Again using another rater to assess performance and identifying the inter-rater reliability could have improved this study; however, it was not possible to obtain another rater who had the time available to assess these cases. As discussed in the previous chapter, such a rater would have had to have some insight into the virtual patient development and the previous rater was unable to commit to these assessments. The same principle also applies for the assessment of the handoff itself. This would have benefited from assessment
with two raters and determining inter-rater reliability. The concern is whether what I perceived as a high scoring performance in the handoff could be interpreted as a much lower performance by another rater. Therefore inaccuracies in handoff rating could have accounted for the unexpected results. However the Hand-off CEX rating scale utilised did contain exemplars for each domain, which guided the assessment of the handoff process; therefore it is also feasible that the handoff rating is reasonably accurate.

Another factor regarding handoff assessment is whether the Hand-off CEX was the most appropriate tool for assessing handoff in this situation. Currently there is no gold standard training or assessment criterion for handoff (Telem et al., 2011; Marshall et al., 2009), and for this particular study the Hand-off CEX contained appropriate domains, which were deemed relevant for handoff assessment. One concern with the use of this rating tool is that each domain was measured on a 9-point Likert scale as opposed to the 7-point Likert scale that was used for the assessment of performance. Ideally the rating scale we used for handoff assessment should have used the same point scale as for the performance measurement. However in this instance the most appropriate handoff rating scale used a 9-point Likert scale.

In essence, though, the findings from this study could represent genuine findings that handoff quality from emergency physician to surgeon does not influence subsequent patient management. It is presumed that handoff quality should influence subsequent patient management, but there is a lack of evidence to support this notion: in fact, to my knowledge, this is the first study
that addresses the question of whether handoff quality influences subsequent patient management in either a simulated or real setting. It is definitely a worthwhile question and one which demands to be addressed further in either a simulated or a real setting to determine whether further studies may support the findings from here or demonstrate that these results were an anomaly.

A positive finding that has been identified is that there was a significant positive correlation between the quality of handoff and the time taken to perform the handoff, which is reflective of previous findings (Lyons et al., 2010). The implication from this is that sufficient time should be taken to transfer all of the relevant information from the delivering to the receiving clinician. This is not always feasible in an emergency department where physicians are under time constraints to have assessed, managed and transferred care within a four-hour timeframe. Therefore it is appropriate that the emergency physician should ensure that they take the appropriate time to transfer all relevant information to the receiving surgeon.

It is important, though, to note that in this study the handoff process was artificial, in that the handoff delivery by emergency physicians is normally a two-way telephone discussion with the surgeon. This is so that if the emergency physician does not initially communicate relevant information, it is possible for the surgeon to ask for the information, prompting the emergency physician to deliver the appropriate details. Ideally in this study the emergency physicians would have managed the virtual patient and delivered the handoff to the surgeon in a live conversation, followed by the surgeon assessing the
virtual patient immediately thereafter. Whilst this would have been the optimal study design, it would have been very difficult to coordinate both the emergency physicians and the surgeons being available at the same time. Therefore the compromise of recorded one-way handoffs was used in this instance.

This study has also demonstrated an interesting finding in that the surgeon who received a handoff assessed the Rectal Bleeding case significantly better than a group of surgeons who had assessed the patient from the outset in the emergency department. However, this finding was not apparent with the Small Bowel Obstruction and the Acute Pancreatitis case. Therefore it is reasonable to presume that this finding is an inconsistency with anticipated findings. The reason why this isolated result may have occurred is that the handoff group took a significantly longer time to assess the case and hence was more thorough in the assessment, as opposed to the other group with prior knowledge of many of the clinical features of the virtual patient, which they did not retrieve. Whilst this would not have resulted in any potential difference in the virtual patient management, it would have resulted in different scores being obtained, as the history domain on the performance score would have potentially received a lower rating. However these findings were not transparent with the Small Bowel Obstruction and Acute Pancreatitis case and therefore this represents only a possible explanation for the Rectal Bleeding case and, much like the other study findings, should be interpreted with caution.
6.6 Conclusions

This study is the first to assess the impact of the quality of handoff on the quality of subsequent patient assessment and management. It has also demonstrated an alternative use of the virtual patients to mirror real clinical events, rather than simply being used for the assessment of surgeons of different training grades. Whilst this is a unique study, the inferences that can be made from the findings are restricted due to the limitations mentioned. This is a study worth repeating on a larger scale in a simulated setting or within a real clinical setting; however, such a study would represent a large undertaking, particularly considering some of the difficulties encountered within this study.
Chapter 7

Discussion
7.1 Chapter Outline

This chapter provides an overall discussion of the entire body of work presented in this thesis. It principally describes the role that Second Life may fulfil in the future of this technology. This is subsequently followed by an interpretation of the findings from this thesis, the implications of the findings and what is required to further advance this study topic. Finally a conclusion is made on whether innovative virtual world technologies can enhance healthcare education.

7.2 Role of Second Life

At the beginning of this period of research, Second Life was portrayed as a revolutionary software that could alter the way in which we interact online, change the way in which major corporations conduct business (Forbes, 2007; Entrepreneur, 2006) and could impact on the way in which education is delivered. Gartner, an American information technology research and advisory company (Gartner, 2007) had predicted that by 2011, 80% of active internet users would have a ‘Second Life’ within a virtual world. Therefore the concept of this piece of research work was established on the premise that virtual worlds, specifically Second Life, would generate a mass following such as that of online social networking services such as Facebook (Facebook Inc., California). Indeed there is still published work heralding Second Life as an innovative, novel educational platform (Papadopoulos et al., 2013; Melus-Palazon et al., 2012; Veronin et al., 2012) The aim of this thesis was therefore to determine if virtual worlds could be used to enhance healthcare education,
with the focus centred on the use of Second Life as a platform for the
development of simulations.

As this research progressed it became increasingly obvious that there had
been a shift in the perception of Second Life and its capabilities. As time has
passed, interest in Second Life has been waning, with certain media groups
posing the question ‘Whatever happened to Second Life?’ (BBC_News,
PC_Pro). This therefore leads to the questions of where has it gone wrong for
Second Life and how does this relate to the research that has been described
in this thesis?

The general perception of Second Life by its users is that it is viewed as a
massively multi-player online game. However, this is in contrast with Linden
Laboratories (Linden Lab, California), the developers, who have primarily
perceived their creation to be a massive online community (Gigaom). This
disparity has therefore resulted in the focus being on improving facets of the
community rather than improving the usability of the software. One of the
main attractions of Second Life is the facility to provide a platform for 3-
dimensional user-generated content; but despite this obvious benefit, when
attempts are made to develop objects, users encounter a complex interface
and usability problems that inhibit many developments from being completed
to the degree that was initially expected. This is similar to the experience that
has been encountered in this research, where initial attempts to develop a
virtual patient within Second Life resulted in a very simple design. The
subsequent attempts to create virtual patients required different development
phases in order to generate an easy-to-use interface for research participants to utilise. Due to the more complex virtual patient design, more primitive objects were utilised for the incorporation of the virtual patients into Second Life. This resulted in a ceiling effect for the fidelity of the simulation, as it was no longer possible to ensure that the virtual environment reflected a real-life environment as closely as possible. Examples of this ceiling effect include not being able to incorporate other non-participant patients in the virtual ward and not being able to integrate some of the properties that are normally located adjacent to a patient, such as storage drawers, the patient’s table etc. This is a prime example of limitations that have been experienced in Second Life and have resulted in many frustrations with its use.

The other problem that Second Life has encountered is that its main revenue stream was from users owning land in Second Life. Users would then, despite the problems described, build properties on this land for other users to inhabit and generate further income for themselves. However, as growth in numbers of users has slowed (lliveis), there are fewer and fewer visitors to these establishments and as a result it is no longer feasible for the user to continue to finance this land. The reducing use of Second Life has been an increasing concern with respect to the development of educational simulations, specifically the ones developed within this body of work.

As the simulations developed in this thesis have been primarily focused on enhancing education rather than an instrument to generate income, how financially viable is it to continue to develop such simulations in Second Life?
It has become obvious towards the end of this research period that the development team that I have been working with throughout this body of research have migrated to other virtual worlds in order to pursue further simulation developments, as other virtual worlds offer more advantages than Second Life. Alternative virtual worlds, such as Unity (Unity Technologies, San Francisco) may offer more benefits than Second Life such as being more cost-effective, having an easier development interface, offering enhanced usability and being accessible from other platforms such as tablets and smartphones. In order for the use of virtual world technologies to be used in healthcare education in the future, it is clear that there is a strong possibility that such developments should and could occur outside of Second Life.

7.3 Thesis Findings

This thesis has presented a body of work, which has focused on whether virtual worlds can be used to enhance healthcare education. This has occurred through a series of principally exploratory studies, revolving around the use of a virtual world environment/simulation in order to improve either the training or the assessment of different healthcare professional groups, namely medical students, nurses and training surgeons. The key question is how these studies can be interpreted as one entity in order to answer the question of whether virtual world technologies can enhance healthcare education.

From the first study it was clear that a virtual world designed operating theatre could serve as an environment that could be used to train novice medical students. It was demonstrated to provide more benefit than no training, which
reflects current practice. However, it did not provide any benefit in comparison to the two other training methods that were utilised. There are reasons why this could have been the case, which have previously been described. However, irrespective of the reasons, this provokes the question of whether the Virtual World Operating Theatre warrants implementation into a training programme. In order for this to be the case, such a technology should first do no harm and should also maximise the benefit for the student user. Whilst the former is true in that there is no obvious harm proposed by implementation of the Virtual World Operating Theatre, it does not appear to offer any significant benefit to the students. Therefore in this instance it can be perceived that a virtual world technology does enhance healthcare education, but it does not offer any greater benefit than other training modalities.

This then leads to the progression towards the development and subsequent use of the virtual patients. The laborious method of developing the virtual patients through an initial period of trial and error eventually led to the development of a comprehensive series of virtual patients. The virtual patients were successfully tested as an assessment tool, with their face, content and construct validity demonstrated. Therefore the conclusion that can be drawn from this research study is that such a tool can be implemented into a more formal assessment method. Indeed, with the demonstration of expert-consultant/attending performance in terms of performance scores obtained, it would be clear for each training grade the score that needs to be achieved in order to achieve expert performance.
This, though, leads to a more important question, which the work in this thesis cannot answer, relating to the predictive validity of performance managing these virtual patients. What does expert performance in the management of these virtual patients mean? Does expert performance in the management of these virtual patients relate to expert performance in the management of real patients? If a trainee achieves expert performance in the management of a virtual patient with acute pancreatitis or small bowel obstruction, does that imply that following the admission of a patient with such pathology by that trainee, no further review by a consultant/attending is required, as the real patient has already been assessed by a supposed expert? In the United Kingdom the Royal College of Surgeons Emergency Surgery Guidelines (Royal_College_of_Surgeons_Emergency_Guidelines, 2011) stipulate that all general surgery patients who do not necessarily require an emergency operation should be discussed with a consultant surgeon within 12 hours and reviewed within 24 hours. However if a trainee has achieved expert performance for the management of these conditions, then is there a necessity for this discussion or review by another ‘expert’?

These questions remain not only from this study but from previous virtual patient studies too. Despite numerous virtual patient studies, there is no evidence supporting whether a strong or poor performance translates to a matching real-life performance. The first study in this thesis, although not addressing virtual patients, was able to demonstrate a positive real-life effect following the operating theatre training encountered, regardless of which method was used. In essence the logical next step following the virtual patient
design and implementation is to address the question of how the performance in the management of virtual patients transfers to real performance. Another critical question that has not been answered within this thesis is how the management of the virtual patients within a virtual world relates to other simulation techniques, namely the management of web-based virtual patients or simulated patients.

It can be perceived that virtual patients developed in the virtual world can enhance healthcare education in a broad sense, as this simply provides another technology that can be incorporated as an education technique. However the most pertinent two questions still exist: how do these virtual patients compare to other associated technologies? and is the appropriate management of virtual patients in this simulation a reflection of real-life performance? Whilst the last question could be described as a criticism of the thesis, it must be noted that numerous virtual reality surgical simulation studies exist which demonstrate a difference between novice and expert performance, although there are only a few noted studies, which display a transfer into real-life practice.

The final study produced completely unexpected findings. This, as previously suggested, is likely to be due to the study design and the low number of participants. In the context of this reasoning it is not feasible to identify whether this study offers any input into the question of whether virtual world technologies enhance healthcare education, although it has demonstrated an
alternative methodology of how a virtual patient simulation can be utilised to simulate other real-life tasks aside from virtual patient management.

From this period of research, it is difficult to justify whether any of the simulations/training methods could be implemented effectively into current training. In my opinion the only training method that easily could be included into current training is the lecture for educating the pre-trained novice in preparation for the operating theatre. This would be easy and quick to implement; it would be in a format that easily could be introduced into a training curriculum and in a presentation that could be easily interpreted by the students. This, of course, represents a current method used for training and does not represent any innovative advance using the technology presented. However, in my opinion there are too many questionable points that surround the findings from the studies presented.

The questions that surround the study findings presented in this thesis principally centre on the outcome measures that have been used. These have been previously noted, but in order to highlight these I will list the main concerns. In the operating theatre study there was no inter-rater reliability demonstrated for the observed behaviour score and there was no construct validity identified for the knowledge multiple-choice questions. In the infusion device study there was no outcome measure due to the automated scoring method not being successful. In both the virtual patient studies, the performance score demonstrated construct validity but had never previously been used in any other studies. Therefore a question that arises from this
thesis is whether the study findings are a reflection of genuine phenomena whether they represent shortcomings in the study design, which appears to be the case with the final handoff study. The only way to clearly answer this question is for the studies to be repeated to establish whether similar findings are obtained. If, as expected, the findings are similar, then obviously the findings can be construed as genuine. However if they are different then it is a reflection of the study design and the conclusions from the research studies are irrelevant.

Despite there being questions surrounding the outcome measures that have been used, a substantial volume of the work presented was devoted to the development of the virtual patients. Two methods have been demonstrated, showing how the virtual patients can be utilised in a simulation context: the virtual patient assessment and the application in establishing the causal effect of handoff. There could potentially have been other ways in which these virtual patients could have been utilised in different contexts. In the first study, a training effect was demonstrated when the pre-trained novice was educated regarding the operating theatre. I believe a similar effect could have been demonstrated if either medical students or first year post-graduate doctors assessed the virtual patients with an instructor; therefore receiving training. Using the concept of the ‘zone of proximal development’ (Vygotsky, 1962) these doctors could have received personalised training for the management of these virtual patients. This could then have been a training intervention with the cohort assessing and managing similar real cases in a pre- and post-test study design. This would be difficult to co-ordinate as it is somewhat
dependent on the presentation of similar patients within an emergency surgical setting; however, this could demonstrate a training effect and reflects a level 3 effect on Kirkpatrick’s model of learning evaluation as it results in a behavioural change. (Kirkpatrick, 1954)

Another method to establish if the use of the assessment and management of the virtual patients is akin to real-life patient management would be to observe the surgeons who took part in the virtual patient study, managing real patients with similar pathologies, and assessing them on the similar rating scale. With the use of non-parametric statistical correlation methods it would then be possible to determine if there was a correlation between real and virtual patient management. This would not reflect a causal effect as a result of the virtual patient simulation, but merely a correlation; but it would carry greater significance than the current findings regarding whether virtual patient management is reflective of real-life patient management and vice versa.

Another method, by which the virtual patient model could be tested to determine if it could be integrated into a formal assessment, would be to correlate the performance of managing these virtual patients with examination performance in formal surgery examinations such as the Membership of the Royal College of Surgeons (MRCS) examination. If there was a strong correlation between both performances, then the virtual patient case could be incorporated into formal surgical examinations. However, in my opinion, it could only form a small part of an examination process rather than a
significant portion or the principal component of an examination, due to the lack of evidence of translation into real-life behaviour.

A key question from this body of research, and in fact any simulation studies, is whether the mainstream implementation of any of the simulation presented in this research will result in improved patient outcomes. The presumption is that the implementation of either the virtual world operating theatre training simulation or the virtual patient simulation would result in better education for the trainee, who will be better prepared for real patient encounters and this will result in better patient outcomes. This represents a speculation from the research presented, with no evidence generated to support this. However, following the research described in this thesis, further virtual patients have been developed regarding the management of peri-operative colorectal virtual patients (Beyer-Berjot et al., 2013). The intention for these virtual patients is to demonstrate the appropriate management decisions that are required for the assessment and management of enhanced recovery colorectal patients who have undergone a colonic resection for colorectal carcinoma. These virtual patients are to be assessed and managed by the members of the colorectal team within the surgery department with patient outcomes (morbidity and mortality and other secondary outcomes) assessed pre- and post-training intervention. The intention is to establish whether training on the virtual patients will result in a difference in patient outcome. Of note is that these virtual patients were developed in Second Life soon after the completion of this thesis and prior to the use of new virtual worlds, such as Unity (Unity Technologies, California).
7.4 Thesis Reflection

This thesis has consisted of two elements: the design and development of simulations and the subsequent testing or validation of these simulations. In retrospect, much of the focus and input into this work has revolved around the design and development phase. This frequently involved progressing through each development with much undoing and re-doing of developments in order to create a feasible product. Whilst these phases required much time and effort, this impacted the latter phase of validation where significantly less planning and design of the studies was undertaken.

Frequently, the development of the virtual patient was occurring concurrently with the testing of the participants, particularly in the main focus of the thesis regarding the development of the surgical virtual patients. In essence this thesis may have benefitted from a strategy change from the outset, with the following steps:

1. Planning of development
2. Development of the simulations
3. Planning of validation
4. Validation studies

Whilst the planning and development of the simulations as well as the validation studies were undertaken, particularly with steps 2 and 4 occurring concurrently, this affected step 3, the planning of the validation studies, with this phase not receiving the attention it was due. This resulted in quick
strategies for participant recruitment and quick development of outcome measures with a limited focus on this phase. In hindsight, if this stage had been paid more due attention, this would have led to a more robust piece of work.

However a possible explanation as to why this phase suffered was that in the simulation group I was working with, the strength of this group was based on the previous validation of simulations, particularly virtual reality simulators. Within these simulators, performance metrics are derived automatically from the performance on these simulators such as time, path length and number of errors when conducting simulations. My research was the first to involve the actual development of the simulations as well as the development of assessment tools in the simulation. Therefore this process of dual development represented an unknown entity and required much more input in both development phases than previously anticipated; therefore as a result the development of the assessment tools was not sufficient. For future work perhaps such a thesis could be restricted to the development of the simulations and simple piloting of these, with another body of work focusing on the validation of the simulations. Through this method the development of the simulations and assessments could be perfected prior to attempting to validate the simulations. Since this thesis, I have developed another fifteen virtual patients, which represents more than the total from the work presented in this thesis, therefore the body of work could certainly have focused more on the development phase.
However the decision was made early in the research programme to perform validation studies for the simulation and admittedly improvements could have been made. The main focus of these must rest on the outcome measures that have been used. There has been an inconsistency in the Likert scales that have been used, with variable numbered scales i.e. a 6-point scale for the first study, a 7-point scale for the surgical virtual patient study and a 9-point scale for the handoff study. However the rating scale for the final study was based on the handoff mini-CEX scale and hence a 9-point assessment scale was used. Overall, with improved planning a more consistent approach to the assessment scales could have been used.

In addition, the outcome measures could be improved in future work with the use of descriptors of performance in the rating scales. This would have ensured that the rating scales could have been used repeatedly and provided a clear description of the components towards each level of performance. This shortfall in the rating scales represents a flaw in the body of the work, as much of the interpretation of the study findings is based on the results generated from the rating scales used. For future work, it would be beneficial to pilot assessment scales prior to implementing them in the validation of the simulations in order to ensure that more robust studies are undertaken.

7.5 Future Work

Subsequent to this thesis, the development of the virtual patient has been further utilised to guide the development of a multi-player virtual patient. This development has revolved around a virtual patient who has sustained a
severe blast injury following a major incident bomb explosion (Cohen et al., 2012). They are brought into the emergency room and have to be managed by the trauma team. Medical actors play members of the trauma team who initiate actions following the commands of the trauma team leader. The unique element of this scenario, compared to the virtual patients I had developed, is that the team members are able to initiate synchronous instructions, such as examining body systems or ordering diagnostics through the use of a web-based menu system, from a tablet device or laptop rather than a menu that is present in the virtual world scenario.

The role of the trauma team leader is played by the study participant, with both their clinical/technical and non-technical skills assessed according to a modified Advanced Trauma Life Support (ATLS) assessment scale and a Trauma Non-Technical Skills Scale (T-NOTECHS) respectively (Cohen et al., 2013). From the study, inter-rater reliability was assessed on both the technical and non-technical skills of the participant’s performance with an intra-class correlation of 0.73 and 0.59 demonstrated respectively. The conclusions from the study were that it was feasible and reliable to assess the technical and non-technical skills in a virtual environment regarding a major incident scenario. This study has demonstrated how the virtual patient development can be adapted to further produce different virtual patients for alternative uses, in this instance a multi-player trauma scenario.

It is completely feasible, due to the reproducible nature of the virtual patient design, that further virtual patients could be designed for other medical
specialties. This could not only include emergency patients but also ward-based patients and patients that may be encountered in elective care. The potential to develop these virtual patients is limitless and an alternative pathway is to expand the number of single-user virtual patients for the use of other healthcare professionals, such as nurses, physiotherapists and occupational therapists etc. However, what is key to this development is a rigorous form of assessment of performance so that such virtual patients can be feasibly integrated into training curricula. In fact, if such work is commenced it is imperative that the end goal is for full integration of these patients into training curricula across the health professional spectrum. There is also potential, within this developing area of research, for it to be a requisite that proficiency is obtained in the management of virtual patients prior to being allowed to manage the real patient.

There is scope with this virtual patient design for it to be combined with other virtual reality simulators to create a breed of ‘hybrid’ simulation. For example, training surgeons could assess a series of pre-operative cases regarding a specific clinical condition, with the main case decision focusing on operating on the virtual patient. Subsequently the operation in question may be practised on a virtual reality simulator until proficiency is achieved. Finally, different post-operative scenarios could be presented for the training surgeon to complete the training pathway. This training paradigm could then be incorporated into a surgical unit, with all members of the unit trained on this pathway, similarly to what has been described with the colorectal patients.
Virtual world environments may also be used to showcase/pilot new equipment designs for healthcare professionals. Novel equipment such as the redesign of the United Kingdom (UK) resuscitation trolley (Walker et al., 2012) could be feasibly displayed in the virtual world and demonstrated to clinicians. The added advantage of demonstrating it within a 3D virtual environment is that the methodology for the utilisation of this equipment may be displayed within the virtual world. Subsequent focus groups in the virtual worlds could be convened to establish relevant clinicians’ opinions regarding equipment prior to subsequent real-life development and implementation.

Previous safety implementations, such as the WHO Safe Surgery Checklist could have been piloted in a virtual world environment prior to dissemination into a large multi-centre clinical trial (Haynes et al., 2009). The virtual world environment would have been advantageous, as all the clinicians from different global centres who were co-coordinating the study could have met within the virtual environment, established the study process, visualised the demonstration of this process and regularly followed-up within the virtual environment to discuss the study proceedings. In large multi-centre clinical trials this could have potentially enhanced the process for the clinical study.

The exciting future research question though is to establish how virtual worlds can be utilised to educate patients. It is feasible for patients to undertake training within this environment. For patients undergoing an elective operative procedure, it is possible to experience their pathway, from outpatient operative decision to discharge from care, in a virtual environment prior to
undertaking the real event.

An example of how this could be achieved is through the development of a virtual world colonoscopy pathway. This would involve developing an area in the virtual world demonstrating different facets of the colonoscopy, such as indications for procedure, alternative investigations, pre-procedure preparation including bowel prep, procedure explanation, sensations and awareness during procedure and post-procedure explanation. A cohort of patients due for colonoscopy could receive this information and be compared to a group who received information through written leaflets and a control group who received no information. Outcomes that could be assessed are knowledge regarding the procedure, anxiety, the amount of peri-procedure sedation required and time to discharge post-procedure. The effect of the virtual world could also be extended to a local community of patients as opposed to individual patients.

The virtual world can also be exploited for healthcare facility design. The proposed architecture of real-world facilities could be displayed within the virtual world with alterations being made following suggestions from the patient community. This would ensure that patients for whom the facilities are being targeted are engaging with the design process. These virtual world models would then lay the platform for real-life design.

The future work described is a snapshot of the way in which virtual world environments can be manipulated to enhance healthcare education. This
thesis has provided a starting point to demonstrate the feasibility of the simulations that can be generated and subsequently implemented. However, whilst this work has demonstrated the early stages, there already exists the technology, and the capability to generate further technology, to expand the remit of the virtual world in healthcare education.
7.5 Concluding Remarks

The development and application of virtual world simulations and environments for healthcare professional education has been described. From this thesis, it is inconclusive as to whether innovative virtual world technologies can enhance healthcare education as there are too many questions that surround the results from the studies. However, it is acknowledged that there is potential for further work to produce more immersive simulations, more rigorous assessment methods and translation into a real life effect, before virtual world technologies can be integrated into training programmes.

The future for virtual worlds is expanding and progressing, although not in Second Life, and it is imperative that medical education nurtures and incorporates this new technology. The implications of using this technology are far-reaching and can ensure that all training healthcare professionals obtain a similar level of exposure to clinical practice either virtually or in reality. This thesis has been unique in that it has demonstrated the potential role of utilising this novel technology whilst also acknowledging the potential pitfalls that can occur in the development and validation of the use of this technology in education. This, though, has potentially provided a stage for the expansion of this technology in both research and clinical practice if the errors in study design are eliminated for the future.
The World Wide Web provides a plethora of healthcare information. However, much of the information is unregulated and therefore susceptible to inaccuracies. Virtual worlds offer the opportunity for healthcare groups to develop specified areas focused on educating students and trainees with concise but reliable information, as well as the development of simulations. It remains to be seen which pathway virtual worlds progress along, but their inherent benefits against the traditional web technologies provide a platform, which still could be explored further and exploited despite the findings from this thesis.

The benefits that virtual worlds can provide for training include the fact that training may take place either within an academic/hospital setting or remotely at a trainee’s convenience. The application of such technology may also ensure that training for healthcare professionals is more structured and, in some instances, not restricted to chance encounters. The further development of virtual patient scenarios will enable training to occur in a safe, structured environment where errors can be made and corrected.
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PC_PRO Whatever happened to Second Life?


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Appendix
### OPERATING THEATRE INDUCTION CURRICULUM

**PRE-OPERATIVE STAGE**

| Knowledge | Possesses knowledge of the specific patient undergoing the operation  
|           | Possesses knowledge of the operating procedure  
|           | Enters the operating theatre via the correct door  
| Attitude  | Arrives at the operating theatre suite before the patient enters the anaesthetic room  
|           | Enters the operating theatre before the start of the operation  
|           | Introduces themselves to the operating team  
| Skills    | Dresses appropriately for the operating theatre  
|           | Uses hand gel before entering the operating theatre suite  
|           | Always wears identification in the operating theatre suite  
|           | Correctly performs gowning and gloving  

<table>
<thead>
<tr>
<th><strong>INTRA-OPERATIVE STAGE</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Knowledge</strong></td>
</tr>
<tr>
<td>Knows the layout of the operating theatre and its relevance to infection control</td>
</tr>
<tr>
<td>Knows the different members of the operating team</td>
</tr>
<tr>
<td>Knows the basic relevant anatomy for the operative procedure</td>
</tr>
<tr>
<td>Knows the basic instruments for the relevant procedure</td>
</tr>
<tr>
<td>Knows about different patient positioning depending on the procedure</td>
</tr>
<tr>
<td>Knows that an instrument and swab check is performed at the completion of the procedure</td>
</tr>
<tr>
<td><strong>Attitude</strong></td>
</tr>
<tr>
<td>Displays awareness of the roles of the different members of the operating team</td>
</tr>
<tr>
<td>Seeks permission to observe the operating procedure</td>
</tr>
<tr>
<td>Is polite to the operating team throughout the procedure</td>
</tr>
<tr>
<td>Always respects the patient’s dignity</td>
</tr>
<tr>
<td>Continues to display interest throughout the whole operative procedure</td>
</tr>
<tr>
<td>Responds to any request from the operating team</td>
</tr>
<tr>
<td>Reads into and responds appropriately to events in the operating theatre</td>
</tr>
<tr>
<td>Displays interest in the procedure and enthusiasm to learn</td>
</tr>
<tr>
<td>Appropriately excuses themselves if feels faint or unwell</td>
</tr>
<tr>
<td><strong>Skills</strong></td>
</tr>
<tr>
<td>Adheres to sterility</td>
</tr>
<tr>
<td>Asks questions to the operating team at the appropriate time</td>
</tr>
<tr>
<td>Only engages in case specific communications</td>
</tr>
<tr>
<td>POST-OPERATIVE STAGE</td>
</tr>
<tr>
<td>----------------------</td>
</tr>
<tr>
<td><strong>Knowledge</strong></td>
</tr>
</tbody>
</table>
| **Attitude**         | Exits the operating theatre at the appropriate time  
|                      | Reflects by discussing the operative procedure with either members of the operating team or amongst fellow students |
| **Skills**           | Disposes of used hats, masks and theatre clothing appropriately |
Appendix 2 Operating Theatre Observation Rating Scale

Imperial College
London

STUDENT OBSERVATION SCALE

Date
Student Identifier
Student Code

Please follow the key given below and circle the number corresponding the student’s performance

<table>
<thead>
<tr>
<th>NA</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not applicable</td>
<td>Not done</td>
<td>Not done well</td>
<td></td>
<td></td>
<td></td>
<td>Done very well</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>STAGE</th>
<th>CATEGORY</th>
<th>ELEMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRE-OP</td>
<td>KNOWLEDGE</td>
<td>a) Prior knowledge of patient if opportunity presents</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NA 1 2 3 4 5 6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b) Prior knowledge of operating procedure</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NA 1 2 3 4 5 6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>c) Entry into operating theatre via correct entry door</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NA 1 2 3 4 5 6</td>
</tr>
<tr>
<td></td>
<td>ATTITUDE</td>
<td>d) Entry into operating theatre before case commences</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NA 1 2 3 4 5 6</td>
</tr>
<tr>
<td></td>
<td>SKILLS</td>
<td>e) Dressed appropriately (scrubs/footwear/hat/mask)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NA 1 2 3 4 5 6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>f) Wears ID badge</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NA 1 2 3 4 5 6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>g) Gowned and gloving using closed method</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NA 1 2 3 4 5 6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>h) Placement of gloved hands-Clasped mid-chest</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NA 1 2 3 4 5 6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>i) Back of gown closed using tag</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NA 1 2 3 4 5 6</td>
</tr>
<tr>
<td>STAGE</td>
<td>CATEGORY</td>
<td>ELEMENT</td>
</tr>
<tr>
<td>---------</td>
<td>-----------</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>INTRA-OP</td>
<td>KNOWLEDGE</td>
<td>a) Understands layout of operating theatre NA 1 2 3 4 5 6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b) Aware of operation flow (from anaesthetic room to theatre recovery) NA 1 2 3 4 5 6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>c) Aware of different members of operating team NA 1 2 3 4 5 6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>d) Demonstrates basic appreciation of relevant anatomy NA 1 2 3 4 5 6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>e) Demonstrates basic appreciation of different instruments NA 1 2 3 4 5 6</td>
</tr>
<tr>
<td></td>
<td>ATTITUDE</td>
<td>f) Introduces themselves to operating surgeon NA 1 2 3 4 5 6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>g) Introduces themselves to members of nursing staff NA 1 2 3 4 5 6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>h) Appreciates different roles of team members NA 1 2 3 4 5 6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>i) Asks permission to view operating case NA 1 2 3 4 5 6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>j) Asks permission to view case notes NA 1 2 3 4 5 6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>k) Remains polite and courteous to entire operating team throughout procedure NA 1 2 3 4 5 6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>l) Demonstrates active interest throughout operating case (continued observation) NA 1 2 3 4 5 6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>m) Acknowledges and responds to any request made by operating team NA 1 2 3 4 5 6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>n) Appropriately excuses themselves if feeling unwell/ faint NA 1 2 3 4 5</td>
</tr>
<tr>
<td></td>
<td>SKILLS</td>
<td>o) Adopts appropriate position to view operating case NA 1 2 3 4 5 6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>p) Adheres to sterility (does not touch drapes or compromise sterility) NA 1 2 3 4 5 6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>q) Asks questions to operating team at appropriate time NA 1 2 3 4 5 6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>r) Engages in case specific communications only NA 1 2 3 4 5 6</td>
</tr>
<tr>
<td>STAGE</td>
<td>CATEGORY</td>
<td>ELEMENT</td>
</tr>
<tr>
<td>--------</td>
<td>----------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>POST-OP</td>
<td>KNOWLEDGE</td>
<td>a) Exits operating theatre via correct exit point</td>
</tr>
<tr>
<td></td>
<td>ATTITUDE</td>
<td>b) Exits operating theatre at appropriate time (after all surgeons have left)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>c) Reflects on case by discussing with either - operating team member - amongst fellow students</td>
</tr>
</tbody>
</table>
**Appendix 3 Operating Theatre Self-Report Scale**

**Imperial College**  
**London**

**STUDENT SELF-REPORT**

Date  
Student Identifier  
Student Code

Please read all the items below and using the scale, indicate how confident or aware you are of each of the following features of an operating theatre. (Circle one for each item):

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not at all aware/confident</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>STAGE</th>
<th>CATEGORY</th>
<th>ELEMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRE-OP</td>
<td>KNOWLEDGE</td>
<td>a) Acquiring prior knowledge of the patient’s condition</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b) Acquiring prior knowledge of the operating procedure.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>c) The correct entry door into the operating theatre</td>
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<td>ATTITUDE</td>
<td></td>
<td>d) When to enter the operating theatre</td>
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<tr>
<td>SKILLS</td>
<td></td>
<td>e) Dressing appropriately for the operating theatre</td>
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<td></td>
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<td>f) Gowning up for a case</td>
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<td></td>
<td></td>
<td>g) Gloving up correctly</td>
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<tr>
<td>STAGE</td>
<td>CATEGORY</td>
<td>ELEMENT</td>
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<td>-------------</td>
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<td>-------------------------------------------------------------------------</td>
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<tr>
<td>INTRA-OP</td>
<td>KNOWLEDGE</td>
<td>a) The layout of the operating theatre</td>
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<td></td>
<td></td>
<td>b) The flow of the operation including inc. anaesthetic and recovery rooms</td>
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<td></td>
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<td>c) The composition of a surgical team</td>
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<td></td>
<td>d) The role of each member of a surgical team</td>
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<td></td>
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<td>e) Use of common operating theatre equipment. (E.g. suction, diathermy, etc.)</td>
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<td></td>
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<td>f) The relevant anatomy involved in the case</td>
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<td></td>
<td>ATTITUDE</td>
<td>g) Introducing yourself to the surgeons</td>
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<td></td>
<td></td>
<td>h) How to introduce yourself confidently/clearly to the rest of the team</td>
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<tr>
<td></td>
<td></td>
<td>i) The importance of teamwork in the operating theatre</td>
</tr>
<tr>
<td></td>
<td></td>
<td>j) Asking for permission to view the operating procedure</td>
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<td></td>
<td></td>
<td>k) Asking for permission to view the case notes</td>
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<tr>
<td></td>
<td></td>
<td>l) Appropriate behaviour – acting professional</td>
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<td></td>
<td></td>
<td>m) How to communicate with theatre team-members in the operating theatre</td>
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<tr>
<td></td>
<td></td>
<td>n) To excuse yourself when unwell/feeling faint</td>
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<tr>
<td></td>
<td>SKILLS</td>
<td>o) Adopting the appropriate position to observe a case</td>
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<tr>
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<td>p) Adhering to sterility</td>
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<td></td>
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<td>q) Asking questions at the appropriate time</td>
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<td></td>
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<td>r) Asking questions regarding the procedure</td>
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<tr>
<td>POST-OP</td>
<td>KNOWLEDGE</td>
<td>a) The correct exit door in the operating theatre.</td>
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<td></td>
<td>ATTITUDE</td>
<td>b) The appropriate time to exit the operating theatre</td>
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<td>c) Discussing the outcome of the procedure with a member of the team.</td>
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</table>
Appendix 4 Operating Theatre Knowledge Multiple Choice Questions

Imperial College
London

Date
Student Identifier
Student Code

Operating Theatre Knowledge MCQs

Please answer true or false to the following questions

1) Good operative care should include:
A – Explanation of the procedure to the patient before surgery
B - Careful positioning of the patient and use of padding to protect bony prominences
C - The availability of patient notes and imaging in theatre at the time of surgery
D - Counting of swabs and instruments once
E - Identification of the patient before induction

2) The following may pose a risk to patient safety during surgery:
A – Placement of diathermy pads on bony surfaces
B – Draping of the patient using green or blue drapes
C – An absence of preoperative surgical marking
D – A full operating list
E – The use of lasers during surgery
3) The following statements are true

A- Green or blue drapes may be touched by ungloved or dirty hands
B- Theatre lights with sterilised handles may only be used when scrubbed.
C- All instruments, swabs and sharps should be accounted for at procedural completion
D- Chlorhexidine is an adequate alternative to Betadine during scrubbing
E- Contact precautions are only necessary for surgeons during high-risk procedures

4) The following statements are true

A- It is the responsibility of the scrub nurse to ensure that a swab count is performed
B- It is acceptable to wear theatre shoes outside of the operating environment
C- Patients are transferred straight from the ward to the operating theatre
D- Operating Department Assistants (ODAs) are not an essential part of the operating team
E- It is not necessary to report all sharps injuries sustained in theatre to occupational health

5) The following statements are true

A- It is essential to wear a hat in the operating theatre
B- The correct entry into the operating theatre for a student is via the anaesthetic room
C- The surgeon and the scrub nurse are responsible for documenting the operation note
D- All operating theatre staff should be gowned and gloved
E- The full operating team consists of the surgeon, anaesthetist and nurse
6) The following statements are true

A-All theatre staff should wear gloves

B-The anaesthetised patient should only be transferred to the operating table following permission from the surgeon

C-It is only necessary to clean the operating theatre at the end of the day

D-The main operating theatre room door should be kept open during the procedure to maintain a positive pressure environment

E-Food and drink may only be consumed in the operating theatre between cases

7) The following statements are true

A-Sterile personnel must keep their hands in sight at all times

B-Scrubbing up involves washing elbows first and hands last

C-Sterile personnel should remove all hand and wrist jewellery prior to scrubbing up

D-All members of the operating theatre team are responsible for maintaining patient confidentiality

E-Selection of the appropriate operative position is decided by the surgeon only

8) The following statements are true

A-Double gloving prevents all sharp injuries

B-The operating surgeon is always the first person to scrub up

C-The cuffs of a surgical gown should be worn over the gloves

D-During an operative procedure the top of the draped operating table is considered sterile, whilst the edges and sides are considered contaminated

E-Instruments should be passed individually from scrub nurse to surgeon during the operation
9) The following statements are true

A-Instruments should be piled on top of another in the instrument tray
B-During an operative procedure the whole surgical gown is considered sterile
C-Operating Theatre surgical scrubs may be worn outside the operating theatre environment
D-The student is not a member of the operating team
E-All the same instruments are used for open and laparoscopic surgery

10) The following statements are true

A- The student should introduce themselves to every member of the operating team
B- The student should ask for permission to view the operating case from the surgeon
C- The surgeon is purely responsible for patient safety
D- The surgical assistant is the only member of the team that can question the main surgeon’s actions
E- The student can ask questions and interrupt the surgeon at any time in the case
Have you ever been in an operating theatre before?

If not you are eligible to participate in our study, where you will watch a live operation & learn about the do's and don'ts of the operating theatre.

**STUDY STRUCTURE**

Each participant will have the opportunity:

To attend an operating theatre case twice

To learn how to scrub up for an operation

In addition:

Most participants will receive instruction about the operating theatre design and function

Who is eligible?

Medical students with no previous operating theatre experience

When?

Most weekdays in March, April, May & June

Where?

St Mary's Hospital, Paddington

Interested????

Please contact

Vishal Patel

Clinical Research Fellow
Department of Biosurgery & Surgical Technology
Imperial College

v.patel20@imperial.ac.uk
STUDENT EVALUATION OF TEACHING

Date
Student Identifier
Student Code

Below are a number of statements regarding the teaching you received today. Please read each statement carefully and indicate your level of agreement or disagreement by circling the appropriate number on the scale below. Please ensure that you respond to all statements.

REGARDING THE TEACHING I HAVE JUST RECEIVED:

<table>
<thead>
<tr>
<th>Statement</th>
<th>1</th>
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<th>3</th>
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</thead>
<tbody>
<tr>
<td>1. I found it easy to understand</td>
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<td>2. I found it useful for familiarising myself with the operating theatre</td>
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<td>3. I found it relevant to my level</td>
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<td>4. I found it contained everything I needed to know before entering the operating theatre</td>
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<td>5. I believe it should be made available to all students</td>
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<td>6. I would recommend it to my colleagues</td>
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<td>7. It has provided me with additional knowledge that I did not previously have</td>
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</table>
For the students who received training in the Virtual World Operating Theatre or Simulated Operating Suite ONLY

<table>
<thead>
<tr>
<th>The simulated environment was a realistic representation of the operating theatre</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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<th>6</th>
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</thead>
</table>

For the students who received training in the Virtual World Operating Theatre ONLY

<table>
<thead>
<tr>
<th>1. The Second Life introduction was adequate</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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<th>6</th>
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<tr>
<td>2. I understood the ways in which I need to interact with other people in Second Life</td>
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<td>2</td>
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<td>4</td>
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</tr>
<tr>
<td>3. I was able to navigate easily within Second Life</td>
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<td>2</td>
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</table>
Appendix 7: Storyboard for Virtual Patient Case

Avatar arrives at the training centre and receives instructions and directions to the nurse changing room

Posters remind user to change into appropriate clothing and wash hands

Nurse changes into uniform, washes hands and walks into ward. Attention is drawn to Serious Incident Report station outside main office

The environment is realistic, crowded, noisy and distracting

Nurse goes to nurses’ station in ward for handoff. Colleague rushes handoff verbally rather than going through information sheet. Misinformation is given and attention directed to Bay 1

Colleague quickly tells nurse that patient in bay 1 is Mr Robert Smith who has been admitted following a lap cholecystectomy and is on morphine PCA. Says that his buzzer has rung a couple of times but that she doesn’t have time to see him yet (patient is actually on insulin). If nurse doesn’t check the medical history then there is potential for patient to suffer harm as new nurse doesn’t know patient is diabetic and will think he is being given morphine for pain

Goes to Bay 1. Should wash hands again in view of patient

Clicks on notes at the end of the patient’s bed. Displays patient’s medical history, prescriptions & infusion information – should notice that he is on insulin not morphine being given

Should go to the end of the bed to check the prescription, infusion chart, product being infused, dosage, rate of infusion etc.
Event 1: Alarm sounds - nurse must check why it's sounding (an occlusion).

By this point the nurse should have realised there is a serious problem as patient's glucose has not been checked all night and the insulin infusion rate may be incorrect.

In order to solve the occlusion issue nurse should choose the appropriate option. Other choices just waste time.

Once patient has rolled over, timer (5 seconds), nurse should go back to trying to work out why she was told patient on morphine but actually on insulin only give 2 seconds to do this before patient

- Check Medical History
- Roll Patient over (CORRECT)
- Check infusion machine
- Take patient BP
- Take patient Blood Glucose (Finger prick test)
- Kinks in the tubing
- Talk to patient (patient responds that they are not feeling well)

Only rolling the patient over will clear the occlusion.

Event 2: Patient tells the nurse he doesn't feel good. Reason: suffering from hyperglycemia

Go to the machine to check it matches chart, including amount remaining in syringe and the expiry date - (Should notice by now that insulin not morphine and needs to attend to patient. However an alarm sounds distracting them)

Clicks on the infusion machine, next to the bed. Displays current infusion information. Patient then rolls on one side

The Nurse will need to click on device again to see what problem is – device will say that it's an occlusion. Action is to STOP the alarm.
Patient reports he is feeling very odd (thirsty, tired & feeling dizzy & anxious). He is agitated, sweating and having difficulty speaking.

Nurse needs to perform a glucose check then compare against chart and use sliding scale to work out whether insulin level is correct. Again before she has chance to do anything……

Medical emergency - the nurse is given around 3 minutes to resolve the problem. Dialog box could come up with similar options such as:
- Check Medical History
- Roll Patient Over
- Check infusion machine
- Take patient BP (Not priority but could be checked)
- Take patient Blood Glucose (Finger prick test) (Will help indicate its hyperglycaemia) (CORRECT)
- Talk to patient (shows they are’ non-coherent) (MAY HELP highlight it’s an emergency because of signs)
- Check prescription chart

Nurse should do a finger prick test to check the patient's glucose levels against the sliding scale (pg 4 of prescription chart)

Nurse should check 21mmols against sliding scale & work out from this that levels are too low & more insulin needs to be given

When nurse clicks on finger prick test box then ‘21 mmols’ should show on the screen afterwards

When checking prescription chart – see insulin not morphine and that levels not checked through the night as should have been – chart will be blank during night shift = Clinical incident

Must have 2 nurses present to make changes so nurse must call for another nurse to come and help to reset pump (via touch screen)

Dialogue box with options to change the second infusion pump (dextrose) to saline, continue with glucose or another false alternative
Appendix 8 Infusion Device Scenario Training Questionnaire

Below are a series of questions and statements regarding the Second Life training you have completed today. Please read each question carefully and ensure you respond to each aspect of the questionnaire.

Age (years)  
Gender (M/F)

Profession

Speciality

Grade (if applicable)

Previous computer experience (tick as appropriate)
- Basic (Only for limited tasks and may need help)
- Competent (Word Processing, Email & Internet browsing)
- Intermediate (Specialist packages, e.g. statistics or editing)
- Advanced (Programming experience)

Have you used computer games before? (tick as appropriate)
- I have never used computer games before
- Have tried a few times but do not play regularly
- I regularly play computer games (more than once per week)
- I play computer games daily
**Second Life (Please circle as appropriate)**

Have you used Second Life before? Yes or No

If yes, approx. how many times? 

1-5  
6-10  
10-50  
>50

What did you use it for?

Do you own a headset? Yes or No

Do you have access to a computer, which is less than 3 years old? Yes or No

Do you have regular access to broadband internet Yes or No

**Previous Medical Device Training (Please circle as appropriate)**

Have you had any previous Medical Infusion Device Training? Yes or No

If yes, then what format did this teaching take?

- Formal course Yes or No

If Yes then please give details

- Dedicated ward based teaching Yes or No

If Yes then who gave the teaching?

- Informal / ad hoc ward teaching (e.g. with mentor) Yes or No

If Yes then who gave the teaching?
## Overall Training Scenario Evaluation

Please read each statement carefully and indicate your level of agreement or disagreement by circling the appropriate number on the scale below. Please ensure that you respond to all statements.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly disagree</th>
<th>Strongly agree</th>
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<tr>
<td><strong>Technical</strong></td>
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<tr>
<td>The second life introduction was adequate</td>
<td>1 2 3 4 5</td>
<td></td>
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<tr>
<td>I understood the ways in which I needed to interact with other people in second life</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>I was able to navigate easily within second life</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>The second life scenario was a good representation of a real clinical environment</td>
<td>1 2 3 4 5</td>
<td></td>
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<tr>
<td><strong>Scenario</strong></td>
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<tr>
<td>The scenario was a realistic clinical situation</td>
<td>1 2 3 4 5</td>
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<tr>
<td>The tasks that I had to perform in the scenario are similar to those that I would do in my job</td>
<td>1 2 3 4 5</td>
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</tr>
<tr>
<td>The patient responded appropriately to interventions</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>The medical device responded appropriately to interventions</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>I would perform the same assessments and interventions (e.g. checking BM) in real life</td>
<td>1 2 3 4 5</td>
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<tr>
<td><strong>Overall</strong></td>
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<tr>
<td>This training scenario is useful for familiarizing staff with the clinical use of an infusion pump</td>
<td>1 2 3 4 5</td>
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<tr>
<td>This simulation is useful for training in medical devices</td>
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<tr>
<td>This simulation is useful for refresher training in medical devices</td>
<td>1 2 3 4 5</td>
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</tr>
<tr>
<td>This simulation is should be used as part of assessment for nursing students</td>
<td>1 2 3 4 5</td>
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</tr>
<tr>
<td>I would recommend this scenario to colleagues</td>
<td>1 2 3 4 5</td>
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<tr>
<td>I would recommend this scenario to nursing students</td>
<td>1 2 3 4 5</td>
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Using the Case Editor
Doctor Assessment Project
(IVOPS)
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1 Introduction

The Doctor Assessment Project (IVOPS) will form part of a series of work to create the software to handle Virtual Patient (ViP) cases and more complex multi-character, multi-player scenarios, primarily in Second Life or similar virtual 3D environments, for training and assessment purposes.

In DAP, the virtual patient case is a defined series of steps where information is given to a doctor. The doctor has to make choices on the basis of the information given, affecting which steps he next sees. The choices made by the doctor and the time taken to do so will be recorded for analysis and scoring. It is expected that around 80 doctors, falling into four distinct skill/seniority levels, will be assessed using the virtual 3D environment of Second Life. The doctors will log in as avatars, which will give them an environment where they see and interact with animated patients. It is possible that the software will be used for subsequent projects and other cases.

This document focuses on the use of the parts of the software used to edit and review cases in IVOPS. The main editing environment will be set up in Eclipse and the information will subsequently be exported to a database on the same machine through use of a web application running on jboss and MySQL. This web application also allows the case designer to review the flow of the case without needing to make cases available to Second Life.
2 Using the Editor

2.1 Workspace

2.1.1 Setting the Workspace

The first time you go into Eclipse you will need to set the workspace

Open up the Eclipse program.

Select: File – Switch Workspace – Other

This should show the workspace DAP\cases and if it does, use Cancel.
If not, select it using Browse and hit OK. Eclipse will reboot into the right Workspace.
2.2 Projects

2.2.1 Creating a New Project

For each case we need to first create a new project. Use: File - New – Java Project – Panc1 (or IVOPS1 or whatever)

The package explorer window should be open, with a Panc1 node. If not, use Window – Show View – Package Explorer.

2.2.2 Opening up an Existing Project

Just open up Eclipse and normally you should see the DAP project in the package Explorer tree on the left of your screen. If not, check you have the correct workspace set.
If you still can't see the project, use File – Import – General – Existing Projects into Workspace, then browse to the workspace in the package explorer – you should find the DAP1 project.

If you can't see the package explorer tree to the left of your screen, try Window – Show View – Package Explorer.

Depending on how you exited Eclipse previously, you might see a tab for your project mvp file above the central area, if so select the tab. If not, open up the project in Package Explorer using the little + box to the left of the project name (it may already be open). Double click on the mvp file. This should bring up the mvp file using the MVP Model Editor, and a new tabbed region will open in the centre of the screen. It should have just one line starting +platform:/resource/ . If you end up with several lines starting <?xml, the file has opened using a text editor. Close it down and instead of double clicking on the mvp file in package explorer, use right-click then - Open With – MVP Model Editor.

Open up the top line by selecting the + and you should see the Case. You are now ready to edit.

2.3 Cases

2.3.1 Adding a New Case from Scratch

File – New – Other – Example EMF Model Creation Wizards – MVP Model – Next
File name: case1.mvp
Next
model object: Case

If you don't use Panc1 and case1.mvp, make a note of the project and filename – or learn where to find it in the Eclipse Package Explorer-you'll need them later. Please try and make sure the mvp filename has no spaces in. Different operating systems react differently to spaces, so even though it may work okay on one machine it might not on another.

(If the properties view isn't available) Right click on Case – Show Properties View

Add the properties of the Case –
Uid: Uniquely identifies the case. You won't be able to save this to the database if it has the same Uid as another case.
Name: A neutral name, such as Case 2, Part 1 (This is what the participant sees, so using Pancreatitis would be a bit of a giveaway). Required.
Description: A record of what the case is about. Useful as documentation.
Patient Name: The name of the patient.
2.3.2 Adding a New Case based on a Previous Case

Drag and Drop between cases has proven problematic. The best way to start a new project, based on a previous one is to create the project as normal, but instead of using the Example EMF Model Creation Wizards step, copy the mvp file in the left hand window to the new project. Use right click - refactor – rename, to give the mvp file a new name. Make sure that the first thing you do is change the case uid property to something else, or you may end up overwriting your old case in the database! Then edit the new case appropriately.
2.3.3 Tying up the Case with Second Life (Targets and Files)

Each case needs to include a list of targets, which are the objects it knows about in Second Life. It also needs a list of the files/animations that it could request to be displayed. These two lists both have unique identifiers. These should be unique across cases to avoid confusion. And that means you should only duplicate an id for an animation in two different cases if you want exactly the same animation to play.

2.3.3.1 Targets

We need to specify the targets in Second Life, the things that will display the text or files, or the things that will be animated. For each case we need to create a separate Targets child element under the Case. Right click on Case to bring up the menu. New Child, Targets. Then right click on Targets to create each individual child Target. Edit both the Target Id and Name properties (in the properties view), to 1 and "monitor", or whatever you have agreed with whoever is handling the target list in Second Life. Although the id must be unique to be played correctly through the player, it is the name of the target that it currently passed through to Second Life.
2.3.3.2 File/Animation List

The second thing we need to create is a list of files and animations and their unique identifiers. This is done similarly to Targets. So right click on Case - New Child – Files And Animations. Right Click on the newly created Files and Animations node, to add each individual child File Or Animation. Then edit the properties.

Id: The unique number associated with the animation
Name: A description of the file or animation (for the benefit of the person editing)
Filename: The location of the file on the editor machine. (optional)
Output Type: "file" or "animation" (optional)

Unlike with targets, it is the unique file-animation id that is passed through to Second Life and these are what must be conveyed to whomever is handling the Second Life animations.

The Output Type is an example of a dropdown selection. If you click on value and instead of the cursor going where you expected a little triangle symbol appears on the right, this is a dropdown box selector. Click on the symbol and a selection of options should appear. Click on whichever you want to fill in the values.
2.4 The Step

2.4.1 Adding the First Step to the Case

If you copied the mvp file, you'll need to edit the elements already there. Otherwise even the largest case starts with a single Step. This Step represents the initial state of the patient. Here you will detail what is available for the interaction between participant and patient initially.

Right click on Case, New Child and add a Step. This is the starting state of the patient. It will default the Id to 0 and that's fine, but any subsequent Steps will need a different Id. The Case should always have one, and only one, first child Step. Any other Steps added directly to the Case must have higher id numbers.

2.4.2 Adding Steps Elsewhere

Of course the patient may – in fact usually will – move to different states during a case. In general you know if it needs to be a new state if the responses will be different (even though the choices might be the same). Typically the two main causes of a patient getting better or worse, is treatment and time.

It is also possible, if a participating doctor is only allowed to do something after (s)he has done something else first, to use a new step to differentiate between the states of the doctor. For example, if the doctor is forced to wash his hands before examining the patient, you can model the hand-washing in one step and make an examination available in another, effectively preventing the doctor from examining the patient until he's washed his hands.

We will see that things the doctor can do are modelled by tasks, and time related progression by time checks. It is possible to create new steps as responses to either of these, and these responses will be dealt with in the appropriate later sections.

2.4.3 Deleting and Modifying

If you make a mistake and want to delete a node, be it a step, a target or whatever, select it and hit the Delete key, or find Delete in the right click menu.
To edit, select the node and use the property view.
2.5 Tasks

2.5.1 Adding the Tasks

Next you need to create the child tasks. A task is an instruction to Second Life to offer some text or a file and get back a response. The Step can have many of them. Normally you would never create a "Task" per se, but would use one of the four flavours of task made available: Display Text, Display File, Diagnoses and Go.

A group of tasks of the same priority will be made available as a menu, and you would have to select one of the menu options for the task to be shown, whereas a single task will be shown immediately. But which flavour should you be adding?

The task type you are likely to use the most, as it's the most flexible, is Display Text. If you primarily want to deliver text or a submenu, this is the one you will be using. The submenu is made up of child tasks, to this one, so when the participant doctor selects it, it will display any text and the names of all its children as a submenu.

If you primarily want to display a file, or set an animation going, without text, use the Display File option.

If you want the give the participant a choice of diagnoses, with an opportunity to get them to say how likely they think each one is, use the Diagnoses option.

The Go option is for when you need to move to a new Step after a group of tasks. By placing the Go after the group in the sequence, it means that they will go to the new step, only when the participant doctor decides he's finished with the group of tasks.

2.5.2 Ordering and Prioritising Tasks

The tasks can be presented sequentially or together or any combination. If you create several tasks under the Step, each one will have a Sequence Group Number property. If the tasks have the same number they will be displayed together. If they have a different number, the groups will be displayed sequentially in numerical order. The sequence group number defaults to zero, so by default multiple tasks will be displayed immediately as a menu on reaching the step.

When multiple tasks are offered at once, they form a menu of choices for the participant to select from. The task selected will then be displayed as normal.
2.5.3 Property Details for the Tasks

2.5.3.1 Display File

If you primarily want to display a file, or set an animation going, without text, use this option.

Name: The name shown in the editor. Also the menu option if found with sibling tasks in the sequence group.

Sequence Group Number Defines the order in which tasks will be displayed and whether it will be displayed with others.

List Order Number If it is displayed in a menu group, the list order sorts the menu options

File Or Animation A dropdown selector of the file or animation is to be used.

Target A dropdown selector of the Target in Second Life where the file/animation should be displayed.

Duration Additional time, in seconds, that the task would take to complete. (More about case scenario time later.)

Go to Step When there are multiple Steps defined in the case, this says on completion of the task, go to this other step. For small cases you should normally use a child Step. Every Step reflects a state of the patient. In creating a child Step, you know the patient got there through this particular Task, but if you go to a Step, not only are you saying that the patient is in exactly the same state as it would be coming from another route, you also lose sight of how you got there. For large cases it can be difficult to find a highly embedded step and you might want to bring the steps up to the top level and refer to them using go to step.

2.5.3.2 Display Text

The task type you are likely to use the most, as it's the most flexible, is Display Text. The properties are:

Name: The name shown in the editor, also the menu option if found with sibling tasks in the sequence group.

Sequence Group Number Defines the order in which tasks will be displayed and whether it will be displayed with others.

List Order Number If it is displayed in a menu group, the list order sorts the menu options

Text Body The text to be displayed.

Target A dropdown selector of the Target in Second Life where the text should be displayed.
Duration  Additional time, in seconds, that the task would take to complete. (More about case scenario time later.)
Go to Step  When there are multiple Steps defined in the case, this says on completion of the task, go to this other step. See the caveats above!

2.5.3.3 Diagnoses

A parent group of possible diagnoses, which the participant will be asked to grade by likelihood.

Name:  The name shown in the editor, also the menu option if found with sibling tasks in the sequence group.
Sequence Group Number  Defines the order in which tasks will be displayed and whether it will be displayed with others.
List Order Number  If it is displayed in a menu group, the list order sorts the menu options.
Target  A dropdown selector of the Target in Second Life where the text should be displayed. Depending on how this is handled in world, the requested target might be ignored!
TextBody  Any text to be displayed.
Duration  Additional time, in seconds, that the task would take to complete. (More about case scenario time later.)
Go to Step  When there are multiple Steps defined in the case, this says on completion of the task, go to this other step. See the caveats above!

2.5.3.4 Go

A use very sparingly, Go to option. If selected this task will offer nothing to the participant, but will go straight on to the next step (or a Go to step). This might be used as part of a menu of tasks to allow the participant to move into another stage of the case.

Name:  The name shown in the editor, also the menu option if found with sibling tasks in the sequence group.
Sequence Group Number  Defines the order in which tasks will be displayed and whether it will be displayed with others.
List Order Number  If it is displayed in a menu group, the list order sorts the menu options.
Target  A dropdown selector of the Target in Second Life where the text should be displayed. Depending on how this is handled in world, the requested target might be ignored!
Duration  Additional time, in seconds, that the task would take to complete. (More about case scenario time later.)
Go to Step When there are multiple Steps defined in the case, this says on completion of the task, go to this other step. See the caveats above!
2.6 Creating Children of the Tasks

2.6.1 Child Step – Goes to a New State after the Task

I've already mentioned that tasks can take a Step as a child. This means that if the participant selects the task, the patient will move to a new state. For example, giving a patient fluid should rehydrate them, so you move them to a Step where they are more hydrated.

2.6.2 Child Tasks – Creates a Sub-menu

Display Text can also take two other types of children. First, it can take sub tasks. Unlike the child tasks of a Step, these will not be sequenced and will all appear at once. Any values placed in the Sequence Group Number will be ignored. The effect of this is to create a sub-menu of the child tasks, which will be displayed alongside any text. If any of these sub tasks are themselves Display Texts, they too can have child sub-tasks, allowing complex nested menus of options.

2.6.3 Child Responses – Adds Multiple Simultaneous Responses

One other issue arises. What if you want things to be displayed simultaneously? As we've seen, multiple sibling tasks just create a menu, so you need a different type of node, called a response item. A child Response Item works a bit like Display Text or Display File, except that it doesn't have children. Instead it creates a display that runs alongside the Display Text. So if you want to create a text message alongside say a file display, the way to do it is create a Display Text and a child Response Item. The text might direct the participant to look at the animation – "Please check the monitor to the right of the patient. The Response Item is then used to display the file on the monitor. Multiple Response Items can be used together, so the sound of breathing might be played together with the animation of the chest rising and falling and a nurse-bot is animated to apply a facemask.

The properties of Response Item are

Name: The name shown in the editor. Not seen by the participant.
Display Type: A dropdown list of text, file-or-animation, url, choice-group. Neither of the latter two are available at the moment, but might be implemented later.
Target: A dropdown selector of where the response is to be displayed in SL.
TextBody: For Display Type text, the text to be displayed.
FileOrAnimation: For Display Type file-or-animation, a dropdown selector of the file-animation list.
2.7 Time and Time Checks

2.7.1 Real Time and Scenario Time

By default each task selected is logged along with the time into the running of the case. The time in the case is not necessarily the same as the time taken for a participant to run it. Both the real time and scenario time are held. If a task takes substantially longer in the case than it would take in real time, you can add an extra duration in seconds. Typically lab-based investigations, imaging, etc., should have the extra duration added to get a scenario time.

The extra time should recognise how long it would take in the real world between the doctor ordering the investigation and the completion of the task, for the doctor to get the feedback, including waiting times and so on.

There is no facility at the moment to order an X-Ray and then be interrupted when the duration has passed; it is just assumed the duration will pass unless a time-check fires.

2.7.2 Time Checks

Sometimes the patient will change state with time, rather than due to anything the participant did. This is modelled using time checks. A time check will be made after every task selected, and if the conditions hold, the patient will move to a new step. The time check can be placed against the whole case or just a specific step (as a child node). If against a step, the time checks will only be made after tasks are selected in the specific step.

There are two clocks available to check against, the total scenario time of the running of the case, and the scenario time of the step. The condition is that the elapsed time is either after the specified duration (in seconds), or occasionally before it. Time Checks modelled on the scenario clock against the case only ever fire once per log in.

As with a task, the step to go to can be specified either by creating a new Step as a child of the time check, or by linking to another step specified elsewhere in the case.

If a time-check fires because the task would have completed later than the task duration, it is assumed the new step is reached in scenario time at the duration time of the time check. If the clock shows after the time check before any duration is added, no compensation is made.

For example: an X-Ray request takes 30 minutes.

If when the X-Ray is requested, 22 minutes are present on the scenario clock and there is no time check, the scenario time after the request would be 52 minutes, and the X-Ray would be displayed as normal.
If a time check is set for after 25 minutes, the scenario time after the time check fires will be 25 minutes, not 52 minutes.

But if the X-Ray request comes in at 28 minutes, it still will be at 28 minutes after the time check fires, not 25.

The properties of Time Check are

Name: Just used to identify the Time Check in the editor
Clock: Which clock to check against, scenario or step
Duration: How long to wait before the time check fires
Divert When: after-duration, before-duration (normally should fire after-duration)
Go to Step: Dropdown selector if going to a step defined elsewhere in the case.
3 Saving and Trying Out the Case in the ViPPlayer

3.1.1 Making the Case Available for Use

Use File - Save in the main Eclipse menu. Then open up a web browser. If you are working on a local machine, use http://localhost:8080/VipPlayer, otherwise you'll need to know the IP address of the machine running the server (which should be inserted instead of local host).

There are five options available on the left hand side menu:
- Update an Edited Case
- Test a Case
- Login as Participant
- Data Maintenance and Views
  - Configuration Maintenance
  - Participant Maintenance

Saving the file in Eclipse doesn't make it available to use. First you have to update the case. This is true whether it's the first time or if you've made a few changes.
So go into Update an Edited Case. Use the browse button to find the relevant mvp file and select the name into the textbox. Then use the Upload Case button underneath to transfer the mvp from your machine to the server.

If the file is successfully uploaded, there will be a short pause as everything gets analysed for obvious errors such as no first steps or duplicate target ids. If there are errors these will come up on the next screen and you will need to address these in the editor.

If there are no errors the upload will give you the description and identifier of the case in the mvp file. It will tell you if the case is a replacement version of a current case that is already uploaded and if so which one. READ THIS CAREFULLY. It should stop any errors where you have given two different cases the same id by mistake.
If you decide that the output is what you expected, either that it is a new case or a replacement for one with a similar description, press the Update button. This will load/upgrade the case in the database. The next screen should be one informing you that the case has been successfully uploaded into the database and it will offer you a test case option. This will let you try out the flow of the case in the web browser. It will use a test participant, and will not log the tasks.

3.1.2 Testing a Case

To test the case without updating, use the Test a Case option on the main left hand menu. This will take you to a selection of the cases available in the database. Only the latest loaded version of any case will be available. There is no option to roll back, so make sure you take regular backups of the mvp files. These are the master descriptions of the case.

To test the case as a participant, with the audit trail, start using the Login as a Participant option. This will ask for the user name and id of the participant. I have preloaded a participant with an id of −1 as a tester, which will not have an audit trail. Use the preloaded participant 1 instead. You can edit the participant list and so you can create a different tester participant if you want. Ideally test participants should use very different numbers to the live participants.
3.2 Data Maintenance

3.2.1 Maintaining the Participant List

Before using the case as a participant, it is necessary to create some using the Edit Participant facility. The only field to fill in other than Id and Name is status. This may be normal or tester, a tester being a participant for whom records of the tasks will not be kept. You will be able to select these from a dropdown. At least one tester with an id of -1 is expected, and this is the login id for testing the case after an update.

Only the id is used to cross check in the database, so live participants won't have to worry about getting their names right, but because the application is not password protected, it is a good idea to use non-sequential numbers of at least five digits, so if the wrong id is typed in, it will error out, rather than just log against the wrong participant.

The status for live participants should be band1, band2, band3, or band4. (These are available from the same dropdown as tester and normal.) This allows for up to four grades of clinician to be logged against the participant for later analysis. It doesn't matter what bands the participants are placed in at the time of running the cases, all cases will be available to all participants. Any grading will only be used later when the scores are analysed. If you don't want to grade the participants immediately, you can use normal – but obviously never use tester!

To add a new participant, fill in the creation template (under "Create a Participant").

To find a participant in the list, you can fill in a search template (under "Find a Participant"). If you leave the template blank, all participants currently added will shown in the returned list. A button to the right of each participant will take you to a maintenance screen, which will allow you to edit a participant's details, change the grading, etc.

The maintenance screen will also let you delete a participant. Once doctors have started using the system, I strongly recommend against tidying up by deleting participant records. Extra-unused participants won't matter, but deleting a participant who has run a case will potentially cause issues during the analysis.

3.2.2 Editing the Configuration

Don't edit the configuration record and don't add to it! The only reason this is available is for initial set up and so that you can see where the intermediate files are stored, which may need to be conveyed whoever is handling the backup strategy. In future releases it is likely to be a read-only screen.
IMPLEMENTATION OF VIRTUAL ONLINE PATIENT SIMULATION (IVOPS)

ORIENTATION GUIDE
WELCOME TO THE VIRTUAL LEARNING HOSPITAL

You will arrive in the reception area of the Virtual Learning Hospital (picture above)

You will be instructed to enter either Hospital 1, 2 or 3.

Please follow the instructions and enter by left clicking on the door.

You will now be in the clinical region, which is pictured below
Please refer to this picture to orientate yourself in the room when reading about different areas
You will now be in the Accident and Emergency area. In order to start a case please touch (left click) the phone at the nurse’s station.

You will then need to type in local chat /10 username, id
You will be given your username and id prior to commencing a case

You will receive a message stating ‘old phone’.

At this point you may select which case you should start.
You will be informed of which case to select
To select the case click on the magnifying glass icon (bottom right) to fix your
camera and then left click on the case you have been instructed to
commence. To unfix the camera, click on the STAND UP icon (pictured above
at the bottom of the picture).

You will then receive a message from the Nurse standing in front of the Case
Selection Menu. Notice that message is delivered by the nurse and also on
the top of your screen. This message is in your HUD (Head Up Display).
During the cases you will receive information within your HUD, which is
relevant to the case.
Please walk over to the patient where you will see the patient communicating with you through a speech bubble. This will be the method of communication from the patient.

There are occasions where the patient’s response extends beyond the speech bubble. You will realise if this occurs as the speech bubble is filled. To read the remainder of the text, left click on the speech bubble and you will have the text (IN GREEN) appear on the bottom left of the screen.
Communication with the patient will be through the menu in front of you. This menu will enable you to establish the patient’s history, examine the patient, check the patient’s investigation results and to manage the patient.

To take a history click on the history menu:
If you want to ask questions about a specific system, left click on History of Presenting Complaint

If you would like to ask about e.g. abdominal pain left click on ‘Gastrointestinal’
You will then have choice between abdominal pain/ nausea and vomiting/ appetite and bowel habit.
Select abdominal pain and then a new menu with questions will appear.
By left clicking a specific question the answer will appear in the patient’s speech bubble.

To move back on the menu i.e. if you have finished asking about abdominal pain and now would like to ask about appetite you can click the move on button.
Alternatively, if you would like to return to the main patient menu, click on the green button (bottom right) of the menu board.

To examine the patient click on the examination option of the main patient menu and then select the appropriate examination.

To select observation left click on this option. This will then initiate the observation monitor, which is next to the patient’s bed. You can then use your camera to zoom in on the observation monitor, which will display various patient observations.
During patient examination listen carefully as you will be able to hear breath and heart sounds.

To palpate the abdomen left click on the abdomen option and then left click on the abdominal palpation section. You will then see green circles appear on the patient, which represents different abdominal regions left click on any of them to assess for any tenderness and view the response in the bottom left corner.

- Green numbers represent Heart Rate
- The white number represents oxygen saturations
- The lower blue number represents the respiratory rate
- The red numbers represent the blood pressure
- The yellow numbers represent the temperature
To review blood tests left click on this option on the main menu. You then need to walk into the resource lab where on the wall you will see an option of blood tests, which you can select by left clicking on the test.

The blood result will appear on the adjacent wall.

You may select as many blood tests as you feel relevant. To scroll through results use the grey scroller on the blood results board (see above).

To check the Arterial Blood Gas the same process needs to be followed i.e. left click on the main patient menu and then select from the resource lab. Finally look at the results board for the ABG.
To review X rays left click imaging X ray on the main menu and then walk to the resource lab.

You will face a computer screen, which has X ray options. Please select the X ray you would like to review.
You will then receive the X ray result on the next screen.

Occasionally you will have to select an imaging study from the main patient menu. The result of this may come up on the blood results screen. In order to read the complete report; LEFT CLICK on the results screen and the complete report will be in GREEN TEXT on the bottom left of the screen. This feature will only occur in some of the cases of the surgical ward.

In order to retrieve the main patient menu after visiting the resource lab please click on the green button on the main menu.
To select differential diagnosis, left click on this from the main menu and select two differentials only.

To initiate patient management select management from the main menu. The menu board will display the following options:
You may select anyone of the management options that you feel is relevant to the particular patient.

E.g. If you wanted the patient to have Hartmanns 1L over 6 hours, left click on IV fluids, left click on Hartmanns, then left click on 6 hours

You can use similar methods to select analgesia, antibiotics etc.
In order to complete the case select decision to admit and select whether to admit or discharge the patient.

Leave this option until the end as this will complete the case.
SURGICAL WARD CASES

If you are a CT 1 or above, you will participate in the surgical ward/ HDU cases.

You may be required to access various charts in order to proceed within the case.

To do this left click on Inventory, which is the suitcase on the side.

This will bring up your inventory.

Within the recent items section you will see various folders containing the charts for all of the relevant cases.

If you are in SURGICAL WARD CASE 1 left click on the same named folder and you will have access to the relevant charts.

To open one simply left click on it and you will retrieve the image as shown below.
You may also be required to retrieve various imaging reports.
In order to do this walk into the resource lab and you will see the imaging report i.e. the CT scan report on the blood results screen.
To access the full report Left click on this and the full report will be displayed in text below (similar to the text displayed after clicking on the speech bubble).

THANK YOU FOR READING THIS GUIDE AND GOOD LUCK!
Appendix 11 Self Report Questionnaire for Virtual Patient Study

IMPLEMENTATION OF VIRTUAL ONLINE PATIENT SIMULATION (IVOPS)

Date
Student Identifier
Student Code

Please follow the key given below and circle the number, which you feel describes your performance in the last case.

<table>
<thead>
<tr>
<th>NA</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not applicable</td>
<td>Performed poorly</td>
<td>Not performed well</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>ELEMENT</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>HISTORY</td>
<td>a) I gathered the appropriate information</td>
<td>NA</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>b) I followed a logical sequence</td>
<td>NA</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>EXAMINATION</td>
<td>c) I examined a relevant system</td>
<td>NA</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>INVESTIGATION</td>
<td>d) I ordered the appropriate investigations</td>
<td>NA</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>DIAGNOSIS</td>
<td>e) I made the appropriate diagnosis</td>
<td>NA</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>MANAGEMENT</td>
<td>f) I instituted the appropriate treatment</td>
<td>NA</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>OVERALL</td>
<td>g) I progressed through the case in logical sequence</td>
<td>NA</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>h) I demonstrated appropriate clinical decisions</td>
<td>NA</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>