Preparing for Simulation-Based Education and Training Through Web-Based Learning: The Role of Observational Practice and Educational Networking

by

Jeffrey J.H. Cheung

A thesis submitted in conformity with the requirements for the degree of Master of Science
Institute of Medical Science
University of Toronto

© Copyright by Jeffrey J.H. Cheung 2014
Preparing for Simulation-Based Education and Training Through Web-Based Learning: The Role of Observational Practice and Educational Networking

Jeffrey J.H. Cheung

Master of Science
Institute of Medical Science
University of Toronto
2014

Abstract

Simulation and Web-based Learning (WBL) are both educational approaches that are increasingly applied in medical education. However, little is known about how these two instructional approaches may be integrated to improve learning outcomes. A prospective three-arm experimental study of different WBL preparation materials was conducted. Thirty undergraduate medical students with no prior experience in central venous catheterization (CVC) were randomly assigned to one of three preparatory interventions: tradition reading materials (TM), observational practice (OP), or OP and educational networking (OPEN). Participants then completed a simulation-based training workshop in CVC and a delayed retention test. Performance was assessed by a task-specific checklist, global rating scale (GRS) and by measuring time to competency. Main findings reveal a significant linear trend across the TM, OP and OPEN groups in time to competency. This exploratory study demonstrates the potential utility of Web-based observational practice and collaborative learning for improving the efficiency of simulation-based training.
Acknowledgments

The journey that has been my MSc has been an interesting learning experience to say the least. Thanks to my supervisor Adam Dubrowski from whom I’ve learned so much, to my thesis committee members, Clare, Kim, & Darius for their endless support and understanding, and to my fellow lab mates, for the intellectual discussions and moral support. Faizal, I always feel like I’ve learned something new after our discussions. David you’re a boss! A-aron, and Kinga it’s been a pleasure getting to know you both. And of course Jansen – without your help and expertise none of this would have been possible!

As well, this study was made possible through support of the wonderful staff of the Surgical Skills Centre at Mount Sinai Hospital. Jason, Lisa, Serenity, Dionne, & Shunne thanks for always being there to help out in a pinch. As well as, many thanks to the wonderful simulation team at the SickKids Learning Institute, in particular Emily and Donna for always being there for me to bug and borrow equipment.

And finally I liked to acknowledge the agencies and institutions that funded my MSc studies, the Ontario Graduate Scholarship, the National Sciences and Engineering Research Council of Canada, the Institute of Medical Science, and the School of Graduate Studies at the University of Toronto.
Table of Contents

Acknowledgments........................................................................................................ iii
Table of Contents........................................................................................................ iv
List of Tables ................................................................................................................ vii
List of Figures............................................................................................................... viii
List of Appendices ....................................................................................................... x
Chapter 1 Introduction .................................................................................................. 1
  1.1 The Medical Education Landscape ...................................................................... 2
  1.2 Simulation-Based Medical Education................................................................. 5
  1.3 Simulation-Based Education and Training (SBET) vs. Simulation Augmented
      Education and Training (SAET) ........................................................................... 8
  1.4 Web-Based Learning and Simulation in Medical Education............................ 9
  1.5 Preparation for SBET through WBL ................................................................. 10
  1.6 Preparation to Facilitate Psychomotor Learning ............................................... 11
    1.6.1 Motor and Cognitive Theories of Learning ................................................. 11
    1.6.2 Traditional Reading Materials versus Observational Practice ................. 28
    1.6.3 Computer-Supported Collaborative Learning (CSCL) ........................... 31
    1.6.4 Surgical Training vs. Clinical Training - Internal Jugular Vein (IJV)
      Central Venous Catheterization (CVC) ............................................................... 33
Chapter 2 Research Aims and Hypothesis ................................................................ 36
  2.1. Purpose and Rationale ..................................................................................... 36
  2.2. Research Questions and Hypothesis ................................................................. 38
Chapter 3 Methodology .............................................................................................. 39
  3.1. Overview of Study Design ............................................................................... 39
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.2.</td>
<td>Participants, Recruitment and Group Assignment</td>
<td>41</td>
</tr>
<tr>
<td>3.3.</td>
<td>Research Apparatus and Intervention Design</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>3.3.1. “Learning Central Venous Catheterization” Website and Materials</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>3.3.2. Intervention Group Design</td>
<td>52</td>
</tr>
<tr>
<td>3.4.</td>
<td>Study Protocol</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td>3.4.1. Preparation Session</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td>3.4.2. SBET Workshop and Retention Test</td>
<td>57</td>
</tr>
<tr>
<td></td>
<td>3.4.3. Assessments</td>
<td>58</td>
</tr>
<tr>
<td>3.5.</td>
<td>Data Analysis</td>
<td>59</td>
</tr>
<tr>
<td></td>
<td>3.5.1. Demographic and survey data</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>3.5.2. MCQ data</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>3.5.3. CVC performance data</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>3.5.4. Website activity data</td>
<td>61</td>
</tr>
<tr>
<td>Chapter 4</td>
<td>Results</td>
<td>63</td>
</tr>
<tr>
<td></td>
<td>4.1. Demographics and Survey Results</td>
<td>63</td>
</tr>
<tr>
<td></td>
<td>4.1.1. General Perspectives and Use of Web-Based Learning and Educational Networking</td>
<td>64</td>
</tr>
<tr>
<td></td>
<td>4.2. MCQ Data</td>
<td>68</td>
</tr>
<tr>
<td></td>
<td>4.3. CVC Performance Data</td>
<td>68</td>
</tr>
<tr>
<td></td>
<td>4.3.1. Inter-Rater Reliability</td>
<td>68</td>
</tr>
<tr>
<td></td>
<td>4.3.2. Expert-based Metrics</td>
<td>68</td>
</tr>
<tr>
<td></td>
<td>4.3.3. Time and Number of Trials to Competency</td>
<td>73</td>
</tr>
<tr>
<td></td>
<td>4.4. Preparation Behaviour and Website Activity</td>
<td>77</td>
</tr>
<tr>
<td>Chapter 5</td>
<td>Discussion and Conclusion</td>
<td>85</td>
</tr>
<tr>
<td></td>
<td>5.1. General Perceptions and Practices Around WBL, Social Networking, and CSCL</td>
<td>85</td>
</tr>
<tr>
<td></td>
<td>5.2. Preparation Affects Efficiency of Learning</td>
<td>87</td>
</tr>
</tbody>
</table>
5.3. Theoretical Insights and Implications ................................................................. 91
  5.3.1. Early and Late Mediation of Observational Practice Benefits .................. 92
  5.3.2. Effects of Collaborative Interactivity on Observational Practice .............. 94
5.4. Learner Perceptions on Preparation Activities .................................................. 96
5.5. Summary, Limitations, and Future Directions ............................................... 98
5.6. Conclusions ....................................................................................................... 101
References .............................................................................................................. 103
Appendices ............................................................................................................ 111
List of Tables

Chapter 3, Table 1. List of differences in the spot the difference activity videos..................46

Chapter 4, Table 1. Summary table of WBL perspectives and use characteristics of undergraduate medical students.................................................................65

Chapter 4, Table 2. Summary table of social networking and CSCL perspectives and use characteristics of undergraduate medical students.................................................................67

Chapter 4, Table 3. Summary of mean checklist score and GRS score during the initial and final trials of the SBET workshop and the retention test trial. .........................................................69

Chapter 4, Table 4. Differences in preparatory behaviour on the spot the difference activity between OP and OPEN groups.................................................................78
List of Figures

Chapter 1, Figure 1. Fitts and Posner (1967) three stage model of motor learning. .....................13

Chapter 1, Figure 2. Schematic representation of the Atkinson-Shiffrin memory model (1968) .................................................................................................................................19

Chapter 1, Figure 3. Baddeley’s original conception of the working memory model (Baddeley & Hitch 1974) ...........................................................................................................20

Chapter 1, Figure 4. Baddeley’s (2000) revised working memory model........................................21

Chapter 3, Figure 1. Participant grouping and overall schematic of the study design from preparation, to physical training, to retention testing.................................................................40

Chapter 3, Figure 2. Screenshot of the “Learning Central Venous Catheterization” course website .................................................................................................................................43

Chapter 3, Figure 3. Instructional video (demo video) hosted on the “Learning Central Venous Catheterization” course website ................................................................................................44

Chapter 3, Figure 4. Interactive Checklist with the option of expandable and collapsible details. ........................................................................................................................................45

Chapter 3, Figure 5. A screenshot of the video spot the difference activity from the OPEN website. .................................................................................................................................50

Chapter 3, Figure 6. A screenshot of a paused portion of Video A and B of the spot the difference activity demonstrating the synchronicity of the videos in both time and camera angle........51

Chapter 3, Figure 7. A screenshot of the collaborative learning activity discussion forum and the instructions provided for the participants in the OPEN group. ........................................52

Chapter 3, Figure 8. Intervention Groups. This figure outlines the differences in the preparatory materials received for the TM, OP, and OPEN groups. .......................................................55
Chapter 4, Figure 1. Mean checklist scores for the initial and final SBET Workshop trials, and Retention Test trials……………………………………………………………………………………………………..71

Chapter 4, Figure 2. Mean GRS scores for the initial and final SBET Workshop trials, and Retention Test trials………………………………………………………………………………………………..72

Chapter 4, Figure 3. Mean time to competency in minutes vs. group……………………………………..74

Chapter 4, Figure 4. Mean number of trials to reach competency vs. group………………………………..76

Chapter 5, Figure 1. The hypothetical progression of schema development for CVC throughout the study………………………………………………………………………………………………………………90
List of Appendices

Appendix A: “In-house” CVC instructional handout.................................................111

Appendix B: Task-specific checklist and GRS for CVC........................................124

Appendix C: Pre-intervention survey and pre-preparation MCQ...........................127

Appendix D: Post-intervention survey and post-preparation MCQ.......................133

Appendix E: Post-training survey........................................................................143
Chapter 1
Introduction

This thesis explores the role of various web-based activities in preparing novice learners for simulation-based procedural skills training. This chapter will provide a brief introduction to the current landscape of medical education practice, simulation in the context of medical education, the current state of the knowledge around simulation, and its importance. Following this, the role that pre-training preparation plays within simulation–based education and training (SBET), as well as some of the theoretical implications for simulation instructional design and curriculum integration will be discussed. A review of the pertinent learning theories from both motor learning and cognitive psychology will be provided, which will be followed by a discussion of the various approaches to designing web-based preparatory material for simulation training, with specific reference to the theoretical approaches of observational practice (OP) and computer-supported collaborative learning (CSCL) environments also called ‘educational networking’. The potential benefit of these approaches in the context of psychomotor skills training will be also reviewed.
1.1 The Medical Education Landscape

The roots of current practice of post-graduate medical education can be traced back to the tradition of Halstedian training first established in John Hopkins Hospital in 1889 (Carter 1952). This model of training follows a time-based model of immersion and medical apprenticeship and remains to this day the cornerstone of residency training, particularly the surgical specialties (Long 2000). This model is based on the premise that within this amount of time in the training environment, medical trainees will be afforded the necessary exposure to learning opportunities to become competent physicians. However, there have been recent changes within the realm of post-graduate medical education that have made it increasingly apparent that this time-tested system of medical education is no longer sufficient in today’s medical education landscape. Increasing restrictions to resident duty hours (Leach 2004), the increasing cost of healthcare, and an emphasis on operating room efficiency have limited time for surgical training and teaching (Reznick & MacRae 2005). As well, with the increasing sub-specialization of surgical specialties, the constant advancement of technology to improve delivery of medical care, and an increased focus on the reduction of medical error (Moorthy et al. 2003), these factors together have resulted in a severe decrease in the amount of surgical exposure residents are afforded today compared to what was likely originally envisioned by Halsted himself.

Though it is difficult to argue against this tried, tested, and true, tradition of apprenticeship in medical training, there are clear impetuses to move away from this model of medical education. Specifically, there has been a recent interest in the competency-based medical education (CBME), with a marked focus on learner and program outcomes. Though this idea in medicine is not a new one (McGaghie et al. 1978), there have been several trends that have revived interest in CBME. According to Frank et al. (2010), these trends are:

1) A focus on curricular outcomes
Due to an increased call for public accountability of training, medical educators are tasked to ensure that all medical graduates are competent for practice upon completion of training.

2) An emphasis on abilities

- It is argued that organization of curriculum around abilities or competencies would counter the current over-emphasis of knowledge over skills, attitudes, and higher order aspects of practice (Talbot 2004).

3) A de-emphasis on time-based training

- The development of a learner’s abilities should be the emphasis of training.
- This approach may lead to improved training efficiency and greater engagement than in training than current time-based models of training (Long 2000).

4) The promotion of learner-centredness

- Allows for flexibility in training for each learner on each learning task.

North American post-graduate education has already seen a steady shift towards a CBME framework. Both the Accreditation Council for Graduate Medical Education (ACGME) and the Royal College of Physicians and Surgeons of Canada (RCPSC) have developed educational frameworks outlining core competencies residents are expected to achieve during their training, i.e. the ACGME outcomes project and CanMeds physician competency framework respectively (Frank 2005; Swing 2007). With this shift towards CBME, there has been a push towards establishing the necessary accreditation standards, training objectives, examination outlines and in-training evaluations that would be required in in the assessment of competency for medical trainees.
Perhaps more concerning than the growing pains of the system due to this shift to CBME is changing demographic of patients in the healthcare system, patients that have served and still serve as the primary medium for medical trainees to learn. That is to say, patients are older and sicker than before, and present with more complex medical ailments (Reznick & MacRae 2005). The average patient is no longer represents a good model for trainees to learn for both surgical and non-surgical procedures and skills (Norman et al. 2012). As outlined by Norman (2012), according to the United Kingdom’s National Health Service data, from 2000 to 2010 it is shown that:

- “Admitted patients spend shorter hospital stays
  7.8 to 5.6 days (2000-2010)
- Patients are less suitable for learning
  More elderly patients with chronic illness and multi-system disease
- Fewer patients admitted overall to the hospital
- More patients are cared for on an outpatient basis
- Wards are less suitable for learning
  Cases are more homogenous (procedure orientation)”

This trend is particularly concerning in light of the fact that clerkship and residency educational experiences are guided by the nature of patient care demands, as opposed to specifically identified competencies that are to be learned. It also points to the gradual erosion of the quality of clinical education if clinical education is to be dictated by patient care demands (Norman et al. 2012). Even disregarding the obvious ethical problem of having learners practice on patients, learning opportunities have become increasingly rare and it is apparent that alternative training opportunities are thus extremely important if we are to ensure adequate training of future medical professionals. The shift towards any form of CBME is contingent upon the availability of learning opportunities. The use of simulation has thus been identified as an important means to
circumvent this shortage of learning opportunities that medical education currently faces (Norman et al. 2012). Educators are already moving towards using simulation for both training and assessment of competencies (Aggarwal & Darzi 2006). Simulation will undoubtedly play a very important role in the way we train, assess, and maintain clinical skills for the future of all health professionals.

1.2 Simulation-Based Medical Education

Simulation has long history as an educational tool. Despite its ancient roots, when pondering simulation, one often conjures images of high tech machines such as flight simulators for airline pilots, or perhaps immersive virtual reality training environments for soldiers. Though these simulators do represent means to use simulation for training, they fail to capture the full gamut of what simulation represents. Simulation is best thought of not as a technology but rather as a pedagogical tool. Or as more exactly defined by Gaba (2004) “simulation is a technique, not a technology, to replace or amplify real experiences with guided experiences that evoke or replicate substantial aspects of the real world in a fully interactive manner.” Separating the technology from the educational approach of simulation has been a problem for simulation-based medical education (SBME). But for the purposes of this dissertation, the operational definition of simulation will follow Gaba’s (2004) definition, which focuses on simulation as a technique as opposed to any specific technology.

SBME, i.e the application of simulation for the purposes of medical education, has existed at least since the 17th century, in France where birthing manikins were used in training (Issenberg et al. 1999). Since this time, simulation has grown to become a central thread in the very fabric that is medical education (McGaghie et al. 2010). Over the past thirty years, and especially in the last decade, there has been a great interest in the use of SBME to improve patient care and safety (Gaba 2004; Ziv et al. 2003). This has led to widespread adoption of SBME practices in many major academic teaching hospitals in North America.
The advantages of simulation and the state of SBME have been outlined by several meta-analyses (Issenberg et al. 1999; Issenberg et al. 2005; McGaghie et al. 2006; McGaghie et al. 2009). Issenberg et al. (1999) recognizes some of the advantages of simulation for medical training, specifically that simulation serves as a valuable means for learners to engage in acquisition and practice of clinical skills in the absence of real patients and allows for learners to receive ‘professional feedback with opportunities for repetition and feedback’. The development of the field’s understanding of SBME is demonstrated later by Issenberg et al. (2005), where from the body of research literature the authors were able to generate a set of general recommendations for the conditions of practice for SBME that were deemed most important for learning (in order of importance):

1) Provides opportunity for feedback

2) Repetitive practice

3) Integration of simulator training within overall curriculum

4) Practice with increasing levels of difficulty

5) Adaptable simulator to multiple learning strategies

6) Simulator captures clinical variation

7) Embedded in a controlled environment

8) Allows for learner-centred instruction

9) Clearly defined learning outcomes that are measured

10) High fidelity (realism) simulation, a valid approximation of the clinical reality

Despite these general findings, the authors cite that early SBME research lacked methodological rigour making it difficult to generate any firm conclusions or recommendations on the use of simulation. This lack of an understanding of simulation and a lack of methodological rigour still
plagues the SBME research today. Although simulation has become a valuable tool for both training and assessment of health professionals (Aggarwal & Darzi 2006; Kneebone et al. 2004; Reznick & MacRae 2006), the genesis of this movement towards the adoption of simulation primarily stems from increased public awareness about medical education and concerns about patient care and safety with regards to the traditional Halstedian apprenticeship model of medical education and training. That is to say that it has been the ethical imperative associated with the use of SBME that has truly driven its rapid adoption within the medical community (Ziv et al. 2003), as opposed to the perceived educational benefits that simulation provides. This focus on the ethical imperative of SBME is reflected in the existing body of research examining SBME, where the majority of research describes the use of simulation in a particular clinical setting or specialty, or seeks to justify simulation’s merit as an educational tool. Little work in the field has sought as to or clarify the instructional design features, from which a specific SBME interventions is created, that promote learning (Cook et al. 2008). Cook et al. (2008) classified the research in the simulation field into these very categories:

1) Descriptive – describes the development of a simulator or program of simulation training

2) Justification – compares the effectiveness of simulation to that of no intervention, championing SBME as an effective tool for medical education

3) Clarification – compares the effectiveness of different educational interventions of SBME with another, resolving the specific characteristics of SBME design that influence learning effects.

This work found that there was a distinct lack of research done to clarify exactly how simulation worked or how to better design simulation. This finding was followed by a call for more research to discern the question of ‘why’ SBME works and how it can be made better.

This gap in the literature is highlighted by a recent meta-analysis from Cook et al. (2011) that shows decisively that simulation is ‘effective’, meaning that SBME interventions have large
positive effects on knowledge, skills, and behaviours of learners and moderate effects on patient outcomes. However, this is when compared to no educational intervention. To put this more plainly, these results demonstrate that an educational intervention (i.e. simulation) works better than no educational intervention, which truly underscores the lack of understanding surrounding the use of simulation in healthcare. As a result, the authors argue that the focus of research in this field must shift to address the clarification questions around why and how simulation works. Though reviews of the current literature around the instructional design features that promote learning have provided some general “best practices” for designing SBME (Issenberg et al. 2006; McGaghie et al. 2010; Cook et al. 2013), they have also highlighted the lack of research around these instructional design features (Cook et al. 2013).

1.3 Simulation-Based Education and Training (SBET) vs. Simulation Augmented Education and Training (SAET)

Clarifying the instructional design of SBME interventions is only one approach to improving learning outcomes and training efficiency in medical education. It is additionally important to elucidate how other instructional methods may be used to enhance or improve learning from simulation. The line of inquiry of how best to engage in curricular integration of simulation with other instructional content and pedagogical approaches has been identified as an important future direction of research for in SBME (McGaghie et al. 2010; Motola et al. 2013). This notion is also reflected in recent calls to clarify the nomenclature by which SBME is designed (Haji et al. 2013). Specifically, it has been argued that simulation interventions in which simulation is the sole source or focus of instruction should be referred to as simulation-based education and training (SBET), whereas interventions in which simulation is delivered in tandem with other pedagogical approaches (e.g. clinical teaching) is best referred to as simulation-augmented education and training (SAET) (Haji et al. 2013). The difference between these two varieties of SBME is fundamental, and affect the theories that help guide the research, the research questions that may be asked, as well as the overall interpretation of the study’s results. The premise of this dichotomy is thus that we should be careful of the comparisons we
make and the conclusions we draw from the existing literature in simulation, and that future research in SBME should reflect carefully about the specific research questions of interest and what the design of a particular study is best suited to address and what it is not suited to address. Overall, this approach of integration highlights the understanding that SBME is not an island unto itself, rather it must interact with various other aspects of an increasingly complex and large body of educational practices that are contained within a medical education curriculum (Issenberg 2006). For the purposes of this dissertation, the term SBET will be used to describe simulation activities that are the sole source of physical training of psychomotor or clinical skills.

1.4 Web-Based Learning and Simulation in Medical Education

Aside from simulation, one particularly important educational approach that has been explored in medical education is web-based learning (WBL). On its own, WBL is another growing area of research that, like simulation, has experienced broad and rapid adoption. Again paralleling simulation, WBL interventions within medical education are often poorly characterized within the existing literature and the current research has not focused on elucidating the instructional design aspects that may lead to its effective use (Cook et al. 2010). Although digital technologies are used in almost every aspect of contemporary medical education, our understanding of how best to harness the potential of WBL as an educational tool rather than as an administrative tool has failed to progress in the last decade (Ellaway & Davies 2011). Nonetheless, once again akin to simulation, WBL is a pervasive instructional method that is playing an increasing role in medical education and has already been put to use in most North American medical schools (Johnson et al. 2007; Kamin et al. 2006). As both these instructional approaches are used, and will continue to be for some time, how WBL and SBET may be integrated to improve medical education is an important line of inquiry. However, despite the fact that WBL and SBET are often used in tandem within current curricula, few studies examining WBL in medical education have systematically explored its use in conjunction with SBET (Cook et al. 2010). Thus, examining how to best employ WBL technology in a more
integrative approach with simulation to improve medical education is an important direction for research in this field.

1.5 Preparation for SBET through WBL

Though we may not entirely understand the instructional elements that optimize learning from WBL interventions, the fundamental ability of WBL to overcome barriers of space and time may be of immediate benefit to SBME. One potential means of applying WBL to SBET would be in the form of preparation prior to physical training in the simulated environment. This offers the practical benefits of anywhere-anytime access to educational materials and also provides the opportunity to improve learning by engaging in spaced repetition of materials (Kerfoot et al. 2010). Preparation is a critical part of learning with simulation, as most SBET interventions contain some component of preparation (e.g. review of instructional reading materials or video) prior to actual physical practice. It is this preparation that may be enhanced through the use of WBL activities. However, how best to prepare for physical practice in SBET in general, let alone through WBL, is poorly defined. Given that many SBET research studies employ a variety of preparatory methods (handouts, videos, live demonstrations, etc.), it is evidently appreciated that different approaches to prepare for simulation training are important for the success of SBET. However, this appreciation is often implicit and thus is often a neglected component of SBET when designing or describing interventions in the existing simulation literature. Thus, although it is often recognized that preparation for clinical learning through simulation is of value (Van Sickle et al. 2006), this notion has not yet been extended to the activities used to prepare for simulation training itself. This line of inquiry is particularly important given the expanding use of simulation in medical education, along with growing awareness of its associated costs (Zendejas et al. 2013). A potential benefit of effectively applying WBL to the preparation for SBET is that it may provide the opportunity to enhance the efficiency of SBET, by facilitating or augmenting learning in advance, and most importantly outside of the costly simulation environment. This in turn may make better use of expensive
simulation equipment (Norman et al. 2012), in addition to reducing requirements on faculty time and resources in simulation facilities.

1.6 Preparation to Facilitate Psychomotor Learning

In the current literature, preparation for SBET for clinical skills is often facilitated through the use of either traditional reading materials (with or without images) (Anastakis et al. 1999; Chandra et al. 2008), by providing an expert model of the skill being trained (e.g. live demonstration or an instructional video) (Sidhu et al. 2007; Brydges et al. 2010), or a combination of the two (Naik et al. 2001). For reasons that will be made apparent in the section below, these approaches to preparing for simulation training are clearly different with respect to the mechanisms by which they facilitate knowledge and skill acquisition among learners. However, little research in simulation has sought to differentiate the impact of these different modalities of preparation and their potential effect on learning during the physical practice of clinical skills in the simulated setting. If we are to develop and use such preparatory materials effectively (either through WBL or by other means of delivery), it is important that we understand how it may be possible for individuals to learn psychomotor skills – which includes clinical skills – in the absence of physical practice. However, first we must understand how learning occurs from the perspectives of both motor and cognitive theories.

1.6.1 Motor and Cognitive Theories of Learning

Learning is described as a relatively permanent change in behavior. The process by which it occurs has been examined by researchers from both motor and cognitive perspectives.

1.6.1.1 Motor Learning Stages

In one of the preeminent theories of motor learning, Fitts and Posner (1967) postulate that all motor skill acquisition occurs in three phases of learning:

1) Cognitive Phase (verbal-cognitive)
2) Associative Phase (refining phase)

3) Autonomous Phase (minimal conscious thought)

During the initial cognitive phase, the learner must generate a representation of all the necessary motor movements necessary to complete the skill. In this phase the learner must recognize the task, the specific movements required, their intensity, distance, and incorporate the necessary instructional and feedback information regarding the task or skill. Essentially, the learner is primarily tasked with figuring out what is to be done and the appropriate strategies to achieve the movement or skill. This obviously involves a large amount of cognitive activity and is considered to be mediated largely by verbal-cognitive processes with the major gains being in understanding of ‘what to do’ as opposed to the execution of the specific motor patterns necessary for the movement or skill themselves. This phase is characterized by large errors in the skill, with highly variable and inconsistent performances, but also with large dramatic gains in performance, likely due to the learner trying many different ways of solving the problem (i.e. applying multiple strategies and retaining only those that are good and discarding the inappropriate strategies). Following this cognitive phase of learning, the learner will enter the associative phase once they have identified the most effective means to complete the task. Here more subtle adjustments are made in the skill performance, leading to more gradual but consistent improvements. Here learners will begin to associate environmental cues with the movements for goal achievement and learn to identify and correct errors in their performance with a focus on how to do the particular movement patterns as opposed to selecting what pattern of action is to be produced (as during the cognitive phase). This associative phase is marked by a decrease in variability, an improvement in overall skill performance, and is argued that the verbal-cognitive aspects learning the skill have largely ceased. And finally according to this theory, the final stage of motor skill acquisition involves the automatizing of the skill in the autonomous phase, which is characterized by minimal attentional requirements for the accurate performance of the skill, very efficient movements, and decreased variability in performance. Once automaticity is achieved, the task can be completed with minimal interference from other simultaneous activities, particularly those pertaining to cognitive-verbal processes – other motor
tasks may still interfere with performance in this autonomous phase. Regardless, the hallmark of this autonomous phase is the ability of a performer to execute the motor task or skill with the appearance of not having to ‘pay attention’ to this task. This final autonomous phase is not necessarily reached by all learners. Figure 1 outlines these three phases of motor learning as described by Fitts and Posner (1967).

Another prominent motor theory describing the stages of motor skill acquisition is Gentile’s Two-Stage Model, which postulates two phases of learning (Gentile 1972, Gentile 2000). In the initial stage of learning, similar to the cognitive phase discussed by Fitts and Posner (1967), the learner must acquire a representation of the necessary requirements of the movement. This includes the goal of the movement or task, the appropriate strategies to achieve this goal,
and an understanding of the environmental factors that are critical to the organization of the movement pattern to be executed. Gentile (1972) describes this discerning of different environmental cues specifically as learning to distinguish the regulatory (i.e. relevant) and non-regulatory features of the environment.

Moving from this initial stage of learning, the second stage of motor skill acquisition is described as the fixation/diversification stage. The goal of the learner is now to refine their movements in the execution of the task or skill. This includes learning to adapt the skill to changing skill and environmental conditions, and ensuring consistent and efficient performance of the skill. Depending on the nature of the skill itself, the characterization of the learning will change. If the skill is considered a closed skill, one where the environment plays a minimal role in the execution of the skill (e.g. unchanging conditions such as a free throw shot in basketball) then the variability in the movement will decrease with repeated practice. If the skill is an open skill, where there are changing environmental conditions, the acquisition of the skill will require movement diversification (e.g. catching a football from various positions, with differences in relative movement speeds, and angles).

These models of the progression of skill acquisition describe the characteristics of skill acquisition as a learner progresses from a novice, to a skilled performer, to an ‘expert’. However, as stated earlier, the development of automaticity or true expertise in a particular task or skill is not always likely. According to Ericsson et al. (1993) what determines this level of skill acquisition is practice, more specifically, deliberate practice. A learner must engage extensively in deliberate practice, according to Ericsson et al. (1993) some 10,000 hours of strategic, focused, goal-oriented practice with the aim of achieving improved performance in components of a skill. This idea of deliberate practice being sufficient in and of itself to achieve expertise is a popular idea that has taken root not only in popular culture but also medical education. Training in various domains of clinical skills has been modeled after this requirement for 10,000 hours of deliberate practice to obtain expertise (Ericsson 2004; Ericsson 2007; Ericsson 2008; McGaghie et al. 2011a; McGaghie et al. 2011b). Though this number does vary and individual differences such as working memory (see section 1.6.1.3) capacity do come to play depending upon the level
of trainees and the task of interest (Kulasegaram 2013), it would be safe to assume that at least a minimum level of competency in most clinical skills can be achieved through extensive deliberate practice. The popularity and success of the deliberate practice approach to medical education has led to the development of several recommendations for the design of medical training (Issenberg 2002):

1) “Repetitive performance of intended cognitive or psychomotor skill in a focused domain with

2) Rigorous skills assessment, that provides learners with

3) Specific informative feedback, that results in increasingly

4) Better skills performance in a controlled setting”

The practical application of deliberate practice has been demonstrated in a series of experiments examining what has been dubbed simulation-based mastery learning. These studies have demonstrated improved learning outcomes for several clinical skills including paracentesis (Barsuk et al. 2012a), lumbar puncture (Barsuk et al. 2012b), central venous catheter insertion (Barsuk et al. 2010), cardiac auscultation (Butter et al. 2010), and thoracentesis (Wayne et al. 2008).

1.6.1.2 Schemas and Representations of Actions

These stages of motor skill acquisition describe the learning of a task through various characteristic phases, but do not explore the specific mechanisms through which this acquisition occurs. One attempt to explain the mechanisms of skill refinement is Schmidt’s motor schema theory (1975), which does so by emphasizing the role of memory structures in skill acquisition and performance. This concept of a schema was borrowed from psychology where schemas were described as abstract mental or memory representation best conceptualized as rules, concepts, or generalizations (Head 1926; Bartlett 1932). In psychology, schemas serve as an outline or general rules by which new memories and thoughts may be organized. Schemas represent what
is generally true of a situation or event, not the specific details of any one event, explaining the reconstructive nature of memory recall and false memories (Loftus et al. 1978). With regards to motor schemas, they may be thought of in a similar manner, as a set of generalized rules of a particular movement, task, or skill. In Schmidt’s motor schema theory, the most important aspect of skill acquisition revolves around the idea of a generalized motor program (GMP). It is this motor program that contains information about:

1) Initial conditions prior to movement (bodily position, weight or shape of tool etc…)

2) Parameters of the GMP (e.g. force, angle, direction, velocity etc…)

3) Augmented feedback regarding the movement outcome (e.g. where did the thrown dart land on the dart board?)

4) Sensory feedback or consequences of the movement (how the movement felt, sounded, and looked)

This information is stored within short-term memory (see section 1.6.1.3) for enough time for the recall and recognition schemas pertaining to the skill to be generated. These two schemas serve as the memory structures responsible for producing the movement (recall schema) and for movement evaluation (recognition schema). Through a process of refinement, as the GMP is initiated in varying conditions, the schema or rules for the performance of this skill become better characterized with the resulting movement outcome and sensory feedback information from each of these varying conditions. These conditions would include varying input parameters to the GMP, and initial starting conditions prior to movement. From this perspective, motor learning can be described as a primarily a process of rule learning as opposed to the learning of specific movements. This is especially true for open skills where the influence of environmental factors create constantly varying conditions for the movement to be performed, thus no two consecutive trials will likely be exactly the same. When learning new novel skills, schema theory suggests that this initial representation of the skill or its rules around the parameters of the skill will likely be based upon those of a similar movement already known to the learner. Through
practice this would then undergo the same process described above, i.e. through the use and refinement of recall and recognition schemas for the new skill.

Similarly to motor schemas, from social learning theory it is also known that the learning and performance of all behaviours, including psychomotor skills (e.g. performing a clinical skill), require what are known as a mental representation of actions (or ‘action representations’) for these specific behaviours (Bandura et al. 1974; Carroll & Bandura 1990). For psychomotor skills acquisition, these action representations can be developed in three ways (Calvo-Merino et al. 2005; Rizzolatti et al. 2001; Wolpert et al. 2001):

1) Physical practice (i.e. performing the movement)

2) Mental imagery (i.e. rehearsing the skill in one’s mind)

3) Observational learning (i.e. modifying one’s own mental representation based on watching someone else perform the skill)

These representations of actions thus are in accordance with the stage theories of motor skill acquisition and Schmidt’s motor schema theory, which suggest there is the creation of a mental representation of the skill to be learned, followed by a period of refinement of this representation or schema through a form of practice. However, this line of reasoning introduces mental imagery and observational learning as alternative means to physical practice to refine these representations of the skill.

1.6.1.3 Memory Systems and Cognitive Load Theory

With regards to the storage and retrieval of these motor schemas or representations of actions, the theoretical constructs of these memory systems are once again borrowed from psychology. Once incoming sensory information has been attended to, moving from sensory memory to the conscious memory systems, it enters the primary memory stores before it may be moved into secondary memory stores for long-term storage. The most acclaimed and accepted model of the human memory system is Baddeley’s working memory model (Baddeley 1992;
Baddeley 2000; Baddeley 2003; Baddeley & Hitch 1974), which embedded the terms short-term memory and long-term memory into popular culture. This model built upon memory models of Atkinson and Shiffrin (1968), which first proposed the flow of information through the cognitive system from sensory, short-term, and long-term memory systems. Short-term memory, as the name suggests, serves as a temporary storage for discrete chunks of information (in the form of mental representations); and is estimated to have the capacity of 7±2 items or elements (Miller 1956). Unlike short-term memory, long-term memory is thought to be of near limitless capacity and was the final storehouse of learned information that had come through sensory inputs mediated through short-term memory. This model however required that information be rehearsed acoustically within short-term memory in order for the information to be stored into the semantic code of long-term memory, lest it be forgotten. Baddeley’s (Baddeley & Hitch 1974) working memory model replaced this static concept of short-term memory with that of an active concept working memory that was divided into several buffers for the different modalities of information. The visuospatial sketchpad stores visual semantic information, the phonological loop stores auditory information, and the more recent addition of the episodic buffer (Baddeley 2000) allows for multimodal storage of information and communication between different modalities of stored working memory (i.e. visuospatial sketchpad and phonological loop), as well as the all-important access to long-term memory. Thus, episodic memory allows for the storage of auditory, visual, and semantic information, as well as the ability for these representations to be transferred to and from long-term memory stores. Controlling the action from above is the central executive that does not store any information itself but serves as the director of the activities within and between the memory buffers. Figure 2 describes the Atkinson-Shiffrin memory model. Figure 3 presents the original conception of Baddeley’s working memory model (Baddeley & Hitch 1974). Figure 4 demonstrates the re-conceptualization working memory model by Baddeley (2000).
Figure 2. Schematic representation of the Atkinson-Shiffrin memory model (1968).
Figure 3. Baddeley's original conception of the working memory model (Baddeley & Hitch 1974). The central executive does not act as a memory buffer but directs the activity of the other working memory components, i.e. the visuospatial sketchpad and the phonological loop. In this model there was no means for communication between the auditory and visual semantic code of memories represented in the visuospatial sketchpad and phonological loop respectively. As well, there was no means mechanism to facilitate the interaction of these components of working memory with long-term memory.
Figure 4. Baddeley’s (2000) revised working memory model including the episodic buffer in addition to the visuospatial sketchpad and phonological loop. The lower boxed items represent the modality or code of information stored within each of the storage buffers for working memory.
This interpretation of short-term memory in the working memory model represented by the phonological loop and visuospatial sketchpad is supported by several decades of studies that suggest that these components of working memory do exist. These data also support neuroscientific evidence of the localization of function for visual, auditory, and spatial information (Carlesimo et al. 2001; Postle et al. 1997; Paulesu et al. 1993). The more recent addition of the episodic buffer by Baddeley (2000) addresses some of the problems that arose from the original working memory model (Baddeley & Hitch 1974); specifically the inability for the integration of auditory and visuospatial information to produce a unified experience, and the lack of a connection between the working memory components and long-term memory.

It is from this model of working memory that we find the basis of cognitive load theory (CLT), an increasingly important theory in our understanding of the instructional design of educational interventions, specifically in medical education and SBET. CLT is built upon the main premise that cognitive resources are limited, i.e. working memory is of limited capacity, and thus in order to optimize learning we must design instructional materials with (the limitations of) human cognitive architecture in mind (Paas et al. 2003). CLT accepts the evidence from cognitive psychology that working memory can store no more than 5 to 9 items (Miller 1956), and can store information for no longer than a few seconds unless the information is actively rehearsed. These limitations of working memory are thought to apply only to the processing of new novel information obtained through sensory memory, whereas information from retrieved from long-term memory has no known limitations. The theory also draws upon the concept of schemas stored in long-term memory, which can be drawn into working memory. These schemas are thought to be of varying complexity and to contain the knowledge that is representative of human expertise, i.e. expertise exists within schemas and not in an abstract ability to deal with many novel mental elements that are not organized within long-term memory. Thus, expertise is viewed as a product of the combination of simple ideas into more complex ones in the development of a more and more elaborate schema of a particular task or skill. It is through the organization of knowledge that working memory load can be reduced as a highly complex schema can be retrieved into working memory and still represents only one
element within working memory. If the schema is developed to the point of automaticity, it may serve central executive functions, organizing the necessary information that needs to be processed in working memory for the execution of the task. In such circumstances where there exists a schema-based central executive, there are no limitations to working memory. This is best represented by an experienced physician making an accurate diagnosis by a single glance, whereas a novice without the necessary schema-based central executive would only be able to identify the component symptoms of the diagnosis in an unstructured manner (van Merriënboer & Sweller 2010).

Due to the limited nature of human cognitive architecture, CLT becomes most relevant when dealing with the acquisition of highly complex skills whereby learners are under ‘high cognitive load’. This acquisition of complex skills is characterized by the management of completely novel, unorganized pieces of potentially interacting information. These potential interactions result in a combinatorial explosion, as more elements of information are added to the mix the number of possible combinations of these elements grows exponentially. This would result in an incalculable number of interactions that would be far beyond the computational capabilities of working memory. Thus, in order to manage this degree of complexity, the number of informational elements that are processed must be limited to that within the capacity of working memory. According to CLT, this is the purpose of schemas, to help ‘chunk’ this information into manageable bits, incorporating these pieces of information into long-term memory or pre-existing schemas. Thus, allowing for these amalgamations of informational elements to be represented as a single workable element within working memory, decreasing cognitive load associated with the task at hand. As discussed earlier, the development of schemas may result in automation, which would free working memory capacity for other activities entirely due to the schema serving as the central executive within the working memory model, directing the processes within working memory without requiring to be contained within working memory itself. However, as automation requires large amounts of practice (arguably deliberate practice) and can only develop for aspects of a performance that may be represented as closed skills. This means that the performance of the specific skill is unaffected by the
environment and is thus the same across multiple scenarios (e.g. operation of tools). From this perspective, the goal of CLT would be to design instruction that would best encourage the development of schemas and the automation of schemas if at all possible.

Seeing that working memory serves as the gate keeper for all novel information, this means that it serves as the bottleneck of schema development, and thus, of learning and the eventual development of expertise. Accordingly, CLT is primarily concerned with how easily novel information is processed in working memory, or the amount of cognitive load imposed upon working memory by a specific context of learning. CLT theorizes that working memory load occurs in three forms:

1) Intrinsic load – load associated with the nature of the learning tasks themselves

2) Extraneous load – load associated with the manner of presentation of the learning tasks

3) Germane load – load associated with learning when dealing with intrinsic load (the formation of schemas)

Intrinsic load pertains to the innate properties of the to-be-learned skill or task and cannot be altered through modification of instructional interventions without changing the task itself. This would for example result from the simplification of the skill or due to the effects of learning itself. Intrinsic load is dependent upon the number of interacting elements that require simultaneous processing in working memory, which is dependent upon the extent of element interactivity, i.e. how readily or reluctantlly individual elements of the task can be learned in isolation, of the tasks or materials to be learned. An example of a task with low element interactivity would be learning a list of novel words (vocabulary), and an example of a task with high element interactivity would be learning grammar, which requires the concurrent processing of several words and their relationships to each other. The higher the element interactivity of a task, the more difficult the task and high the intrinsic cognitive load associated with it. That being said, through the formation of schemas, this cognitive load can be substantially reduced
through the formation of a schema that contains a large number of these interacting elements of
the task. This means that elemental interactivity can be effectively reduced through schema
formation, and that element interactivity varies depending upon expertise level (degree of
schema development).

Extraneous load differs from intrinsic load in that it is solely determined by the delivery
method of the material or task to be learned. An example of extraneous load would be when a
learner must integrate pieces of information from sources separated by space or time, or when a
learner must search for this information before they can complete the learning task. This may
also happen when a particular channel of information processing within working memory is
overloaded, such as overloading the visuospatial sketchpad by presenting information in a solely
visual manner (text & diagrams) as opposed to presenting some of this information through
spoken words and thus accessing the phonological loop component of working memory that
deals with auditory information. This overloading occurs due to the partial independence of these
components of working memory.

Finally germane load refers to the working memory resources that are devoted to the
learning of the task. For example, this would be the cognitive load associated with the formation
of schemas that ‘chunk’ the various interacting elements intrinsically associated with the task
(i.e. attributed to intrinsic load) based upon structural and surface similarities. This also occurs
when a pre-existing schema is elaborated upon by connecting it with new informational elements
from the novel task being learned.

It is through the manipulation of these three forms of load that learning can be optimized.
CLT assumes that extraneous and intrinsic cognitive loads are additive, and that whatever
remaining working memory capacity can be devoted toward germane load, i.e. learning. An
interesting corollary to this is that the existence of extraneous load is not necessary an impedance
to learning if the total cognitive load of the learning task (intrinsic + extraneous + germane) does
not exceed working memory capacity. Thus, reducing extraneous load may not always be
effective in optimizing germane load if there are already sufficient cognitive resources (i.e.
working memory) to deal with the task; this effect has been demonstrated for tasks with low element interactivity, and thus low intrinsic load (Carlson et al. 2003). The opposite is true when the task is complex, involving a high degree of element interactivity or high intrinsic load. In this case, it is likely that the high complexity task imposes a combined load from intrinsic and extraneous loads that may exceed working memory capacity, and thus making it difficult to induce germane load. By reducing extraneous load in this case, it will free up more cognitive resources to be devoted to intrinsic load and make it easier to facilitate the germane load required for learning. It is under these circumstances that the effective and efficient use of cognitive resources becomes paramount in ensuring learners are able to use their available cognitive resources for learning as opposed to paying heed to extraneous information about the task.

van Merriënboer & Sweller (2010) argue that the complex nature of clinical skills acquisition make the application of CLT to medical education highly relevant. This is particularly true due to the increasing call for more authentic training of clinical skills in an effect to integrate the training of the knowledge, skills, and attitudes deemed necessary for future performance as an independently practicing health professional (van Merriënboer et al. 2012). A series of instructional design recommendations for medical education training are proposed by van Merriënboer & Sweller (2010) based on principles of CLT:

“Reducing Extraneous Load

- **goal-free principle** – provide a non-specific goal for learners (e.g. ‘find as many explanations for these symptoms’ vs. ‘find the most probably explanation of these symptoms’)

- **worked example principle** – use worked examples that allow students to analyze and criticize (e.g.

- **completion principle** – use completion tasks that provide partial solutions for tasks for learners to finish
• *split attention principle* - use integrated source of information as opposed to presenting the same information several times or in different places

• *modality principle* – use a multimodal approach to engage all components of working memory

• *redundancy principle* – use a single source of information as opposed to multiple sources when the information can be provided independently in each

**Managing Intrinsic Load**

• *simple-to-complex strategy* – present a case of the task with low element interactivity and gradually increase element interactivity to full complexity

• *low-to-high-fidelity strategy* – present a case of the task with lower fidelity and gradually increase fidelity

**Optimizing germane load (by increasing intrinsic load)**

• *variability principle* – present a series of tasks with differences as observed in the real world as opposed to presenting a series of tasks that are similar

• *contextual interference principle* – opt for the presentation of tasks with higher contextual interference (e.g. random practice vs. blocked)

• *self-explanation principle* – enriched worked example or completion tasks where learners are prompted to self-explain the given information

**Dealing with the Expertise Reversal Effect**

• *completion strategy* – progress from worked examples to completion tasks with increasingly more information for the learner to complete
• **fading guidance strategy** – provide a steadily decreasing amount of guidance (i.e. scaffolding) across a series of tasks

• **integrated to non-integrated strategy (split attention)** – use integrated examples at first, then switch to non-integrated examples presenting information separately (e.g. text and visual information presented holistically first, then only presenting one or the other later in the task)

• **dual-to-single-mode strategy** – present information using two dual-mode presentations (auditory and visual) and transition to single-mode presentation (auditory only or visual only)”

These theories of motor and cognitive learning provide some insight into the development of clinical skills (e.g. phases of motor learning, Schmidt’s schema theory), and how these theories may work together through mental representations (schemas, representations of actions) and may be modulated through various forms of rehearsal (physical practice, mental imagery, observational practice, deliberate practice). As well as informs how the human cognitive architecture of our memory structures, the instructional design of materials, the nature of the task, and a learner’s prior knowledge (pre-existing schemas) can affect task performance and skill acquisition. With this understanding, we can now better appreciate how preparation in the absence of physical practice may be able to improve skill acquisition and training efficiency within SBET.

### 1.6.2 Traditional Reading Materials versus Observational Practice

As discussed earlier, there is a necessity for an initial cognitive representation, or representation of action before any progression in skill acquisition may take place. When placed in the context of preparing for SBET, any preparatory material must be able to generate mental representations of the action(s) to be learned without the aid of physical practice. Thus according to motor learning theory, for preparatory material to be effective for psychomotor skill acquisition, they must then be able to engage a learner in *mental imagery* or provide
opportunities to model the skill through observational practice (observational learning without the physical practice component); thus allowing the building of mental representation of the skill to be learned. According to Schmidt’s schema theory of motor control, it is from these mental representations of actions that a more elaborate motor ‘schema’ of a skill can be created, which contains generalized rules of a motor behaviour as well as the motor strategies and programs to reproduce the movement (Schmidt 1975). This would imply that varying modalities of preparation (e.g. text-based vs. video-based) for physical practice in simulation would result in differential understanding of the skill prior to simulation training. Specifically, modeling of the to-be-learned skill through a live demonstration or video-based instruction would likely facilitate observation practice and mental imagery, whereas, use of text-based materials may encourage some mental imagery but would not facilitate observational practice. Thus, although text-based instructional material may still provide a basic action representation, which can be further elaborated during physical practice, these instructional materials may not to lead to as robust an action representation as those materials that would facilitate both observational practice and mental imagery. One such example of this would be the use of video demonstrations of the skill that is to be learned in addition to providing instructional reading materials. This would theoretically lead to the formation of a much improved mental representation of action for the skill and thus would benefit to a larger extent from physical practice whereby elaboration of the schema may begin from a better developed representation of the skill.

From this theoretical perspective, it can be argued that WBL should employ the use of observational practice (e.g. by providing learners with an instructional video in which the skill to be learned is modeled) to optimize the formation of robust action representations in advance of physical practice, as this may promote more efficient refinement of the motor program during physical practice (e.g. during SBET). However, this is an oversimplification of psychomotor skill acquisition and observational practice. There are further nuances in how to best apply observational practice that can be drawn from observational learning processes described in Bandura’s social cognitive theory (Bandura 1986):
(1) Attention: Attention must be paid to the modeled actions for them to be learned.

(2) Retention: Observed actions must be stored as symbolic mental representations in memory to be retained and used in the future (mental representation of action).

(3) Production: The mental representation of the action must be performed.

(4) Motivation: The mental representations of the action will fade unless perceived consequences of performing the modeled behaviour are positive enough to encourage future performances.

Though production of the skill is prohibited during observational practice in the preparatory phase described above, the other three processes described by Bandura may readily be modulated through WBL to promote and improved observational practice; thus, theoretically leading to the formation of more robust mental representations. For example, providing more engaging material may improve attention and retention processes. One approach that has demonstrated this is the use of models that display variations in performances, allowing for the modeling of various strategies to adopt the motor skill further refining the action representations of a learner by providing multiple models of performance (Buchanan & Dean 2010).

Empirical research in observational learning has also demonstrated additional benefit of modeling variations in performance. A number of studies have shown that for novice learners, observing models that demonstrate practice under variable conditions (i.e. which model differences in performance of the skill in question or which utilized a ‘discovery’ model of performance) lead to better learning (in terms of retention and transfer of motor skill) when compared to observational practice under a constant or single strategy performance condition (Bird & Rikli 1983; Buchanan & Dean 2010). From a theoretical perspective, it is hypothesized that the variation in performance may facilitate the development of a more robust action representation by helping learners to select strategies for the movement in question (Buchanan & Dean, 2010). This work has implications for the design of WBL models of clinical skills (e.g. online videos), suggesting that by incorporating and drawing learner’s attention to variable
performances of the skill may enhance the potency of observational learning of the skill in question (Bird & Rikli 1983). This finding also follows the recommendations of Merriënboer & Sweller (2010) who suggest the incorporation of variability of practice, in this case observational practice, would lead the optimization of germane load; thus, enhancing learning.

1.6.3 Computer-Supported Collaborative Learning (CSCL)

A novel approach to the modification of observational practice and psychomotor skill acquisition is through the use of collaborative learning. When collaborative learning is combined with WBL, it is referred to as computer-supported collaborative learning (CSCL). The use of CSCL is in line with learner-centred, constructivist-based approaches to teaching learning that seek to create more powerful and engaging learning environments (Kirschner et al. 2004; Resta & Laferriere 2007). The theoretical basis for CSCL is predicated on cognitive theories that suggest that “cognitive processes necessary for deep learning and information retention occur in dialogues” (Van der Linder & Renshaw 2001; Kreijns et al. 2003). As such, CSCL represents an active learning technique in which collaboration is defined as “a learning process where two or more people work together to create meaning, explore a topic, or improve skills” (Harasim et al. 2007). Collaborative learning has demonstrated benefit in fostering deeper level learning, critical thinking, shared understanding, and long-term retention of learned material, by fostering social interaction which in turn promotes elaboration, questioning, rehearsal and elicitation of information presented to the learner (Garrison et al. 2001; Johnson & Johnson 1987; Kreijns et al. 2003). Empirical research further demonstrates that CSCL is particularly relevant to learning in the context of complex cognitive skills (such as problem-solving) and less applicable to simple skills (e.g. memorization tasks) (Kirschner et al. 2009a). It is argued that the mechanism of this result is based on the concept of cognitive load, as CSCL allows for learners to effectively increase their working memory capacity by distributing the load imposed by a complex task across the group, thereby freeing up the cognitive resources of each individual in the group to be put towards the development of more robust mental representations relating to the information presented, i.e. germane load (Kirschner et al. 2009a; Kirschner et al. 2009b). Thus, according to CLT, CSCL allows for the reduction of element interactivity of the task to be learned, effectively
reducing task complexity by allowing individuals within the group to focus on isolated elements (low element interactivity). Following this, as a group the learners may gradually deal with the full complexity of the task once an initial schema can be formed to reduce element interactivity (and thus intrinsic load). This ability to move from simple-to-complex supports the recommended strategy proposed by van Merriënboer & Sweller (2010), in this case it would reduce the likelihood of cognitively overloading learners. Alternatively, Kirschner (2001) notes a number of additional mechanisms to explain the observed benefit, as in CSCL:

“

- learning is active;
- the teacher plays the role of facilitator rather than instructor;
- teaching and learning are shared experiences;
- students must take responsibility for their learning;
- students are stimulated to reflect on their own assumptions and though processes.”

As yet, there is a paucity of research investigating the application CSCL to clinical psychomotor skills acquisition. Though it has been suggested by some that psychomotor skills are beyond the purview of WBL (Jolliffe et al. 2001), and thus CSCL by extension, there are at least three lines of evidence that suggest there may be a psychomotor substrate for these more ‘cognitively’ oriented educational interventions to act upon. Firstly, according to the Fitts and Posner (1967) three-stage theory of psychomotor learning, there exists a cognitive component to skill acquisition, at least in the earliest stages of learning, during which the initial action representation of a psychomotor skill is being developed. CSCL may play a critical role during this cognitive phase, in advance of physical practice. In addition, models of deliberate practice suggest that cognitive strategies focusing on improving psychomotor skills can lead to better learning (Barsuk et al. 2009; Barsuk et al. 2010). And finally, the observational practice literature describing the added benefit of variability in observed performance suggests that observers can deduce cognitive strategies for performance from watching a model (Shea et al. 2000; Black & Wright 2000). Again, CSCL may play an important role in stimulating reflection and selection of
such strategies that may enhance motor skill performance. Given these theoretical perspectives, further investigation of the role of CSCL in psychomotor skill acquisition is warranted.

1.6.4 Surgical Training vs. Clinical Training - Internal Jugular Vein (IJV) Central Venous Catheterization (CVC)

Within medical education, there are a variety of different procedures and skills that trainees must become competent in, which also varies depending upon the nature of the different clinical specialties. This is particularly true when surgical procedures are juxtaposed to more clinical procedures. Arguably the performance of complex surgical procedures and the acquisition of the necessary skills for competence within these procedures is highly dependent upon motor coordination and mental rotation and spatial temporal reasoning abilities (Wanzel et al. 2002; Keehner et al. 2004) and less reliant upon more cognitive clinical knowledge. It is this cognitive clinical knowledge that would be required of more clinical procedures such as diagnosing disease or recognizing appropriate treatments for conditions and the relevant contraindications of each, which would fall much more in line with the application of memory-based theories of learning (e.g. mental representations and schemas) (Norman 2005). Though there is clear overlap between the motor and cognitive aspects of skills, as outlined above throughout the literature, some clinical skills that would more amenable to educational interventions involving observational practice and/or CSCL than others. Should the critical elements of the skill be predominantly motor oriented, as in surgical skills training, there would certainly be difficulty in applying CSCL environments for learning. And should the critical elements of the skill lie predominantly in the cognitive domain (i.e. clinical procedures) there may certainly be a perceived benefit from a collaborative learning environment; however, this brings into the question of how benefit of observational learning. Thus, when deciding when and where to apply both CSCL and observational practice, it is important that the skill be appropriately complex in presenting novel elements in both the cognitive and motor realm of skill acquisition.
Internal jugular vein (IJV) central venous catheterization (CVC) is a skill that involves the insertion of a catheter into the superior vena cava through the IJV. Indications for the procedure include the delivery of caustic or critical medications and the measurement of central venous pressure. Contraindications include infection of the area overlying the target vein, and thrombosis of the target. Relative contraindications include coagulopathy, where caution must be exercised if CVC is to be performed. CVC insertion is a commonly performed skill by residents in the medical intensive care unit (MICU) during training. Traditional educational practices for CVC training involve bedside training on real patients with no standardized opportunities for deliberate practice or assessment (Duffy & Holmboe 2007). However, as the complications that arise from CVC are potentially life-threatening, which include infection, pneumothorax, arterial puncture, deep vein thrombosis, and bleeding (Barsuk et al. 2009a); it is vital that such avoidable complications be prevented. A series of studies by using simulation-based mastery learning models of training the CVC procedure to residents has demonstrated the benefit of simulation and mastery learning, a form of deliberate practice, in improving long term retention of the skill (Barsuk et al. 2010), decreasing complication rates from the procedure (Barsuk et al. 2009b) and other metrics of quality of performance and skill proficiency such as number of required needle passes to obtain access (Barsuk et al. 2009a). Most importantly, these studies in SBET for CVC demonstrate the link between effective simulation-based educational interventions for learning with positive clinical outcome measures.

Though the efficacy of this particular educational intervention of simulation-based mastery learning has demonstrated positive learning and clinical outcomes, little is done to advance our understanding the instructional design elements of the educational intervention that facilitated, or potentially impeded, learning. Learning to a mastery level of proficiency in CVC is an extremely difficult and complex task. In addition to requiring knowledge of the indications, contraindications, relevant anatomy, how to use the tools, and sterile technique; the technical component of the CVC involves roughly 27 specific steps as identified by Barsuk et al. (2009a). As well, these steps largely have some degree of interdependency, e.g. the insertion of the guidewire requires for the accurate placement of the cannulating needle which requires
appropriate anatomical landmarking prior to needle insertion. For a novice learner, the performance of the CVC requires the integration of novel clinical knowledge, such as anatomy, with novel complex psychomotor movements, which likely involve the use of novel tools as well. This learning situation that is presented is clearly very complex, involving a high degree of element interactivity, and thus a high intrinsic load. How we structure learning, be it through a model of deliberate practice or other means, is thus highly important in ensuring that learning is optimized when a novice is learning to perform CVC. CLT would suggest that we should pay particular attention to complex skills such as CVC.

An added incentive to improving training learning and training efficiency is the fact that simulation-based mastery learning requires a large investment in time on the part of faculty and learners themselves in order to achieve this level of mastery. Over 3 hours of physical training was spent in a SBET setting with individualized feedback provided for each learner likely from faculty educators (Barsuk et al. 2009a). As is a common occurrence in SBME studies, no cost metrics were provided from these studies of simulation-based mastery learning for CVC making it difficult to discuss the cost-effectiveness of training (Zendejas et al. 2013).
Chapter 2
Research Aims and Hypothesis

2.1. Purpose and Rationale

This ability for cognitive strategies (e.g. deliberate practice) to affect motor learning and for motor information (observational practice) to affect the cognitive learning speaks to the dual nature of psychomotor skills. This dual nature highlights why the study of complex clinical skill acquisition, which can consist of both tremendously complex motor and cognitive elements, is an ideal medium to study the role of these various preparatory modalities. Through the use of SBET, these clinical skills can be readily examined in a relatively safe and controlled environment when compared to real clinical settings.

The exploratory study described in this dissertation was designed to compare different preparatory WBL interventions for physical practice during a SBET workshop for IJV CVC. The CVC skill was chosen due to its high complexity both technically as a motor skill as well cognitively (including the number of steps in the procedure, the complex interactions between these procedural steps, and implications of deviations in performance on patient outcomes and successful completion of the procedure). The simulation training employed in this study utilized a mastery learning approach (Barsuk et al. 2009), whereby trainees practice to a pre-established level of proficiency in the skill. This model of training provides a unique opportunity to assess how different approaches to preparation in advance of simulation training contribute to the efficiency of learning in the simulated setting, as measured by the time required to reach competency (or mastery).

To compare and contrast the role of observational practice (including variability of modeled performance) and CSCL in simulation-based clinical skill acquisition, three preparatory interventions were developed to include additive preparatory activities, ranging from traditional reading materials (TM) on CVC, TM with the additional of observational practice activities including varying models of performance of CVC (OP), and TM plus OP with an added
collaborative learning element hosted through an online educational networking platform (OPEN). Educational networking is a term used to denote the application of ‘social networking’ technologies for the explicit purpose of learning, and is a form of CSCL. The effect on performance and learning during the physical practice in the SBET would be compared between the three interventions.

The preparatory Web-based OP and OPEN interventions were designed to address both the motor and cognitive components of the learning CVC, to provide general insights about how these modalities can be applied specifically to SBET, as well as to psychomotor skill acquisition in general, and helps identify potential avenues for future research. The design of each WBL intervention was informed by theories to optimize each particular theoretical approach to skill acquisition and learning. The OP intervention included the presentation of a video demonstration of an error free performance of the procedure by an expert as well as two additional performances that included variations on this procedure. From the theoretical review in the previous chapter this opportunity to model different variations of the task would likely improve the effectiveness of the OP and overall skill acquisition. These variations in practice were also further presented in the context of an error detection task to increase attention to the models of the performance as well as motivation – two aspects outlined by Bandura’s social learning theory to be essential to effective observational learning, and thus observational practice (Bandura 1986).

In the OPEN intervention, groups were sized accordingly to encourage optimal engagement and presentation of new ideas while providing a small enough group to encourage the formation of more meaningful relationships between participants. Participants received avatars and online usernames within their groups to encourage a sense of identity and allow for the possibility of greater group interactivity and development of more realistic relationships. As well, the collaborative learning tasks were kept as open-ended as possible to allow for greater interpretation and sharing of ideas and also to ensure the task presented was more complex and not mere memorization of the steps of the CVC procedure, which according to Kirschner et al. (2011) would likely render the effective cognitive load enhancing effects of CSCL ineffective.
These features were developed to work as best as possible for the CVC skill and have been noted as important aspects to facilitate the benefits of observational practice and CSCL (and collaborative learning in general). With relation to a more grand theory of skill and expertise development, these learning interventions would likely facilitate schema development in varying capacities. The rationale being that when compared to the TM group, the addition of observational practice, as seen in the OP intervention, and the addition of the observational practice and educational networking, as seen in the OPEN group, would provide superior schema development and learning, and thus better preparation prior to participating in physical practice during a SBET workshop in CVC and improved value and efficiency from the physical practice itself. Further details about each of the interventions are provided in the next section (Chapter 3 - Methods).

2.2. Research Questions and Hypothesis

The primary research question posed by this study is: “What is the effect of observational practice and CSCL as compared to traditional instructional materials on skill acquisition, retention, and time to competency during simulation training for clinical skills?” It is hypothesized that a significant improvement in learning, retention, and time to competency will be observed in those preparing with observational practice and CSCL as compared to those preparing through traditional reading materials. As well, it is anticipated that decreasing time to competency will be observed with the addition of each preparatory modality (e.g. TM → OP → OPEN). Two secondary research questions are also posed, related to participants’ perceptions and use of various preparatory activities:

“What are the perspectives of novice medical students on the use of various preparatory materials (e.g. lectures, videos, WBL, social networking etc…) for medical education training?” and “How do participants preparatory behaviours differ between those engaged in OP vs. OPEN?”
Chapter 3

Methodology

3.1. Overview of Study Design

This study utilized a prospective, three-armed experimental design to examine the effect of different preparatory educational materials on skill acquisition among medical undergraduates attending a one-on-one SBET workshop for IJV CVC. Participants were allocated to one of three intervention groups that differed in the nature of preparation in advance of clinical skills training: a Traditional Reading Material (TM) group; an Observational Practice (OP) group; and an Observational Practice and Educational Networking (OPEN) group. The study proceeded in three phases: a preparatory phase where each student attended a preparation session with instructional materials based on the intervention to which they were assigned; a physical practice phase where all participants attended a SBET Workshop conducted by an expert in CVC; and a retention phase where all participants returned to complete a retention test. All three phases of the study were completed over a period of 3 weeks, with approximately one week between each of the three sessions (Figure 1). Data collection was completed over a period of 2 months (July and August 2013).
Figure 1. Participant grouping and overall schematic of the study design from preparation, to physical training, to retention testing.
3.2. Participants, Recruitment and Group Assignment

Upon institutional ethics approval a total of 30 undergraduate medical students from the University of Toronto with no prior training or experience performing CVC were recruited into the study. Initial contact with potential participants was made via email through the office of the Vice Dean of Undergraduate Medical Education. Students interested in participating in the study were asked to contact the graduate student investigator via email to receive further information about the study and to arrange dates and times for participation. Further study information was sent to the students expressing interest, including an online scheduling survey with the available dates and times for each phase of the study. Recruitment into the study was contingent on participants scheduling a date and time for each of the three phases and was completed on a first-come first-serve basis. Written informed consent was obtained prior to the start of each participant’s preparation session.

After 30 participants confirmed dates and times for their three sessions, these individuals were anonymized through a specified subject number with no reference to their actual identities and randomized into one of the three arms of the study. A full randomization process could not be completed due to logistical constraints and the need to have participants in the OPEN group complete their preparation session at the same time to facilitate the educational networking portion of the intervention. As a result, a two-step pseudo-randomization method was used. First, to establish a cohort of participants for the OPEN arm of the study, the two preparation session dates with the largest number of participants registered were selected. From the participants who signed up for these dates, a blocked randomization method using a random number technique was used to assign a minimum of 10 participants to the OPEN group; the remaining participants were allocated to an ‘other’ group. Next, the remaining participants in the study, including those assigned to the ‘other’ group during the initial randomization step, were randomly assigned to either the TM or OP group, again using a blocked randomization method with a random number technique to ensure a balance of participants in each group.
3.3. Research Apparatus and Intervention Design

3.3.1. “Learning Central Venous Catheterization” Website and Materials

An online course was developed using the Moodle-based Observational Practice and Educational Networking (OPEN) platform (Grierson et al. 2012; Cheung et al. 2013; Rojas et al. 2012) to facilitate the preparation activities for both OP and OPEN groups. Participants were given a personalized account and could access this website with any internet-connected desktop or laptop computer. The website contained portable document file (PDF) versions of instructional handouts and articles describing the indications, anatomy and technique for performing CVC. In addition to these electronic reading materials, the website also hosted an instructional video demonstrating the CVC technique (Demo Video) and a custom developed video that facilitated a spot the difference activity. Participants were able to interact with the website through an interactive checklist and with each other through a collaborative discussion forum. Participants in each group only had access to the materials for their assigned group for the duration of the study (see 4.3.2). Instructions on the available preparatory materials and how to navigate the website were provided to participants on the main page of the course website (Figure 2).
Figure 2. Screenshot of the “Learning Central Venous Catheterization” course website as would be seen for participants in the OPEN group. The red circles highlight the differences that would not be seen by those in the OP group.

The demo video was created to demonstrate the skill of CVC as outlined by the task-specific checklist that was used to assess students at their SBET workshop session. During this instructional video, an expert in CVC performed the procedure using the IJV approach on the same part-task trainer participants would train on during their SBET Workshop. Text-based instructions for pertinent procedural steps were overlaid on the video and an audio recording of verbal instructions for the task was dubbed over top of the visual image (Figure 3).
The interactive checklist provided to participants included material from the task-specific checklist, CVC reading material, and video segments from the Demo Video. The interactive checklist was organized to allow participants to access further information about the particular steps of the procedure. This information was expandable or collapsible, allowing users to select specific steps of the procedure they wished to review further (Figure 4).
The spot the difference activity involved the use of two recorded performances of the CVC procedure on the part-task simulator. Each recorded performance was identical, with the exception of 25 differences that participants were asked to identify. These differences ranged from different but acceptable variations in practice (i.e. clinically irrelevant differences) to deviations in practice that had the potential to compromise patient safety or the completion of the procedure (clinically relevant differences). A list of all the embedded differences between these two videos is listed in Table 1; some variations between the videos may have been unintentional and were not included in the video.
<table>
<thead>
<tr>
<th>Part</th>
<th>Video A</th>
<th>Video B</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Consent</td>
<td>• Green sheet under patient</td>
<td>• No green sheet under patient</td>
</tr>
<tr>
<td>2. Patient Position</td>
<td>• Patient placed in slight Trendelenberg position</td>
<td>• Patient left in supine position</td>
</tr>
<tr>
<td>3. Operator</td>
<td>• Gown + Cap + Gloves + mask</td>
<td>• Gown + Gloves (No Cap and mask)</td>
</tr>
<tr>
<td></td>
<td>• White gloves</td>
<td>• Blue gloves</td>
</tr>
<tr>
<td></td>
<td>• Area cleaned starting outside inwards to the landmark</td>
<td>• Area cleaned from landmark outwards</td>
</tr>
<tr>
<td>4. Cleaning</td>
<td>• Cleaned with povidone-Iodine</td>
<td>• Cleaned with chlorohexidine</td>
</tr>
<tr>
<td></td>
<td>• Gown + Gloves (No Cap and mask)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• White gloves</td>
<td>• Blue gloves</td>
</tr>
<tr>
<td>5. Cleaning solution</td>
<td>• Area cleaned from landmark outwards</td>
<td>• Area cleaned from landmark outwards</td>
</tr>
<tr>
<td></td>
<td>• Cleaned with povidone-Iodine</td>
<td></td>
</tr>
<tr>
<td>6. Draping</td>
<td>• Off Centre – Redraping</td>
<td>• Draping centered</td>
</tr>
<tr>
<td>7. Equipment Check</td>
<td>• Large gauge needle sheath left off</td>
<td>• Large gauge needle sheath put back on</td>
</tr>
<tr>
<td></td>
<td>• Guidewire retracted</td>
<td>• Guidewire left out</td>
</tr>
<tr>
<td>8. Preparing catheter</td>
<td>• Normal Saline</td>
<td>• Heparinized Saline</td>
</tr>
<tr>
<td></td>
<td>• Air bubbles in last port</td>
<td>• No Air bubbles</td>
</tr>
<tr>
<td></td>
<td>• Brown port left open</td>
<td>• Brown port closed</td>
</tr>
<tr>
<td>9. Local Anesthetic needle</td>
<td>• Toward ipsilateral nipple</td>
<td>• Toward contralateral nipple</td>
</tr>
<tr>
<td></td>
<td>• Lateral to the landmark</td>
<td>• Medial to the landmark</td>
</tr>
<tr>
<td></td>
<td>• Touches glasses</td>
<td>• No aspiration (pull/push)</td>
</tr>
<tr>
<td></td>
<td>• Aspiration (pull/push)</td>
<td></td>
</tr>
<tr>
<td>10. Large gauge needle</td>
<td>• Toward ipsilateral nipple</td>
<td>• Toward contralateral nipple</td>
</tr>
<tr>
<td></td>
<td>• Lateral to landmark</td>
<td>• Medial to the landmark</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Guide wire</td>
<td>• Inserted to the 20cm mark</td>
<td>• Inserted to the 30cm mark</td>
</tr>
</tbody>
</table>
insertion

| 12. Dilator and incision | • No incision       | • Incision          |
|                          | • Dilator pushed 1-2cm | • Dilator pushed all the way in |

| 13. Catheter insertion   | • Guide wire in control | • Guide wire lost, not removed |
|                          | • Ports aspirated only  | • All ports aspirated and flushed |

| 14. Sharps               | • Clears 3 sharps, missing the suture needle | • Clears all 4 sharps |

| 15. CXR                  | • Not checked       | • Checked          |

Table 1. List the embedded differences in the spot the difference videos.

The clinical significance or lack of significance is discussed below. This information in addition to the list of the differences in the videos was provided to those in the OPEN group upon completion of the collaborative learning activity prior to their attendance at the SBET workshop; this list is provided below:

1. A green sheet or any sheet that can prevent soiling the bed sheets should be placed under the patient’s head and neck. This is important not so much for the procedure itself but for the following reasons:
   a. The nurses won’t be troubled to have the change the bed sheet that is either soiled by your cleaning solution or the patient’s blood
   b. Changing bed sheet is not only time consuming for your nursing colleagues but also poses problems for critically ill patients, for example accidental extubation during movement of patient

2. A slight Trendelenberg position helps with
   a. Prevention of air embolism during catheter insertion
   b. Allows filling of the internal jugular vein to facilitate catheterization
3. Donning a face mask and surgical cap is essential during the procedure for reduction of infectious complications of the central line.

4. The color of the gloves does not matter as long as they are sterile. This is **NOT** clinically significant.

5. You should always clean from the point of entry outwards as doing it the other way around would compromise sterilization principles.

6. Cleaning with chlorhexidine for central line insertion has been shown in a meta-analysis in 2002 to be superior to povidone iodine in reducing the risk of central line infection.

7. Redraping can breach sterility.

8. During equipment check, the large gauge needle sheath should be left off after positioning to prevent needle stick injury.

9. The guidewire should be retracted when preparing the guidewire prior insertion to facilitate the procedure. This is clinically **NOT** significant.

10. You can use either normal saline or heparinized saline to prime the central catheter. Hence this is **NOT** clinically significant. There is a risk of flushing heparinized saline into the vein which can result in (1) coagulopathy and (2) this uncommon but potentially fatal syndrome called HIT: Heparin Induced Thrombocytopenia. I would personally prefer normal saline for the above reasons but there is no evidence to favor one over the other.

11. When priming the central catheter with saline, make sure no air bubbles are preset within the line to reduce the risk of air embolism.

12. The brown port should be left open to facilitate the procedure as the guidewire is anticipated to exit through the brown port. However, this is **NOT** clinically significant.

13. The local anaesthetic needle, when used to locate the IJV, should be pointed towards the ipsilateral nipple and lateral to the carotid pulsation.

14. You should not touch any non sterile site during the procedure. In video A, the operator touches his spectacles during the procedure which is a breach of sterility.
15. When anaesthetizing the deeper structures, you should always aspirate before administering local anaesthetic to prevent inadvertently administering lidocaine intravenously.

16. The large gauge needle should be inserted lateral to the carotid pulsation and towards the ipsilateral nipple.

17. The guidewire should not be inserted too deep as this may result in arrhythmias.

18. An incision can be made to facilitate the insertion of the dilator if required. This may not be required in some patients. This is NOT clinically significant.

19. The dilator should be pushed in about 1-2 cm to dilate the track in the skin and subcutaneous tissue. There is no need to insert the dilator all the way in and risk injuring the vein.

20. In video A, the operator has lost control of the guidewire and failed to remove the guidewire during the procedure. This may result in the serious complication of wire embolism. The corrective measure for this complication would be an endovascular procedure to “fish out” the wire, failing which would require a surgical operation to remove the guidewire!

21. In video B, after the central catheter was inserted, the ports were aspirated and not flushed subsequently. Aspiration without flushing would result in the patient’s blood being left within the catheter. This would cause clotting within and render the catheter useless.

22. In Video A, the suture needle was not cleared, putting your nurse and the cleaner at risk of a needle stick injury.

23. You should always check the CXR for proper placement of the central catheter as well as to rule out complications such as a pneumothorax.

As part of the spot the difference activity participants were asked to view each of the videos in parallel and answer two questions:

1) “Identify as many differences as you can between Video A and Video B”
2) “Of these differences, which are clinically relevant and why?”

The screenshot in Figure 5 demonstrates the layout of the website activity as viewed by the participants and the screenshot in Figure 6 demonstrates the mirroring nature of the videos (same camera angle for each of the steps aligned by time), as well as some of the differences.

Figure 5. A screenshot of the video spot the difference activity from the OPEN website.
Figure 6. A screenshot of a paused portion of Video A and B of the spot the difference activity demonstrating the synchronicity of the videos in both time and camera angle. In addition, some differences between the performances can be noted from this segment of the videos – with respect to Video B differing from video A 1) No headcap is worn, 2) Gloves are blue, 3) a box is located on the end of the table, and 4) the patient is not placed in Trendelenburg position (not elevated).
The educational networking portion of the website consisted of a discussion forum where participants could interact with their peers in a collaborative online environment. Participants were asked to complete a collaborative learning activity on this portion of the website, which involved reviewing and discussing their answers to the spot the difference activity with the rest of the group, followed by expert debriefing of their discussion (Figure 7).

![Figure 7. A screenshot of the collaborative learning activity discussion forum and the instructions provided for the participants in the OPEN group.](image)

3.3.2. Intervention Group Design

Each of the three intervention groups were provided with a varying amount of preparatory material. The materials provided to each of the groups were designed to be additive; a base level of preparatory material (i.e. the electronic reading materials) were provided to all groups, the instructional video and spot the difference video was provided to the OP and OPEN groups, and
finally the opportunity for educational networking through the collaborative learning activity was only provided to the OPEN group.

The specific materials provided to each group was as follows:

1) The TM group received electronic reading materials only, in the form of Portable Document Files (PDF) consisting of:

   a. An article on CVC technique from the New England Journal of Medicine (Graham et al. 2007);

   b. An in-house CVC instructional guide created by Dr. Jansen Koh (a practicing intensive care physician considered an expert in CVC), with images of the simulator to be used during the SBET Workshop (Appendix A);

   c. A task-specific checklist that students would be scored on during their SBET Workshop (Appendix B).

2) The OP group received these same reading materials, as well as the instructional video and the spot the difference activity described above, which were designed to facilitate observational practice of the CVC skill.

3) The OPEN group received the reading materials, instructional video and spot the difference activity, and additionally had the opportunity to engage in ‘educational networking’ with the other participants assigned to this group through the collaborative learning activity. To facilitate this collaborative learning phase, participants responses to the spot the difference activity were posted on the website to allow them to review, discuss, and debate their answers with their peers. Participants were informed that this would occur during the preparatory session. The collaborative learning activity consisted of a discussion forum with instructions for participants to discuss the variations in the spot the difference activity to decide which were clinically relevant, and to decide as a group on which three variations were most
clinically relevant (see Figure 8). Following the completion of the collaborative learning activity, participants in the OPEN group received feedback and a debriefing on their discussion from an expert in CVC, as well as a complete list of the differences embedded within the spot the difference activity.

Due to the nature of the educational intervention, participants could not be blinded to their group and were made aware of their grouping during their preparation session.
Figure 8. Intervention groups – This figure outlines the differences in the preparatory materials received for the TM, OP, and OPEN groups. The OP group received the same materials as the TM group with the addition of a Demo Video and the spot the difference Activity. The OPEN group received the same materials as the OP group with the addition of the collaborative learning activity.
3.4. Study Protocol

3.4.1. Preparation Session

In the first phase of the study, participants in each group attended a scheduled preparation session. During the session, participants were seated at a workstation with a desktop computer, briefed on the study, and written informed consent was obtained. Following this, a preparation session survey and pre-intervention MCQ test (Appendix C) were administered prior to review of any preparatory materials. Upon completion of the survey and MCQ test, depending on their group, participants were briefed on their preparatory materials. The TM group had access to a folder on the desktop containing the TM PDFs. The OP and OPEN groups received a guided tour of the “Learning Central Venous Catheterization” course (each of which contained the preparatory materials pertaining to that group, as described in 4.3.2) where they were asked to select a username, avatar, and shown how to navigate through the website. Participants were then asked to review all their respective preparatory materials to their satisfaction before leaving the laboratory.

After leaving the laboratory, all participants were granted access to their preparatory materials (in accordance with their group assignment) for review in advance of their physical practice session one week later. Those in the TM group were emailed PDF copies of their preparatory materials whereas participants in the OP and OPEN groups had access to their preparatory materials through their personal logins on the “Learning Central Venous Catheterization” website. Those in the OPEN group were also instructed to participate in the collaborative learning activity, and were informed that participation in the activity was required in order to attend the SBET Workshop; no minimum or maximum degree of participation in the activity was defined. Upon completion of the collaborative learning activity, a debriefing to their discussion along with answers to the spot the difference Activity were made available through the OPEN website.
3.4.2. SBET Workshop and Retention Test

In the second and third phases of the study, participants attended a simulation-based workshop for CVC and completed a simulation-based retention test of the CVC procedure respectively.

The SBET workshop was led by an expert in CVC blinded to group allocation. During the workshop, participants were taught the landmark technique on a Generation I Central Venous Access Simulator (Blue Phantom©). After administration of a post-intervention MCQ and a second survey (which varied based on group assignment) (Appendix D), the SBET Workshop proceeded in exactly the same manner for all groups: all participants viewed a modified version of the New England Journal of Medicine CVC instructional video, edited to remove any reference to the use of ultrasound. Following this, participants were provided a demonstration of the procedure on the simulator in the same setting they would be tested in. After the live demonstration, participants were provided a copy of the task-specific checklist to view and were allowed to ask questions.

Once participants felt ready, they began their physical practice by attempting repeated trials of the CVC procedure. During practice trials, all necessary tools were organized for all participants in the mock procedure room, and reset after each trial. Participants were not given feedback during practice trials, however between each trial they were allowed to view their checklist assessment and were given feedback on any errors made in the previous trial.

Trials were stopped if:

i. a participant successfully completed the procedure,

ii. if they failed to locate the IJV within 5 minutes or required more than 5 needle pass attempts with the local anesthetic needle,

iii. if they required more than 2 needle pass attempts with the large cannulating needle
iv. if an arterial puncture occurred with the large cannulating needle.

Following a ‘mastery learning’ paradigm (Barsuk et al. 2009), the physical practice continued until each participant achieved competency, which was defined as the ability to perform the procedure twice in a row with no errors or missed steps according to the checklist. Performance on the trials was assessed via direct observation from an expert.

After the SBET Workshop, participants were asked not to review any materials on CVC prior to their scheduled retention test. The retention test session was scheduled approximately one week after the SBET Workshop and consisted of one final survey (Appendix E) prior to a single trial in which the participant attempted to perform an IJV CVC, in an identical setting to the workshop. All workshop and retention test trials were video-recorded to facilitate expert review of participants’ performance. Video data were edited to remove identifiable features of participants before being scored by the second reviewer.

3.4.3. Assessments

All participants completed three surveys prior to the start of each of the three experimental phases (Appendix C, D, & E respectively) to obtain demographic data, perceptions on online learning and application of social networking to medical education (Educational Networking), perceived workshop readiness, impressions of the OPEN platform (for the OP and OPEN groups), and preparation behavior. Additional survey questions probed the types of educational activities that participants most commonly engaged in, which activities they found to be most fun and engaging, and their perceptions on the effectiveness of WBL vs. live demonstration in clinical skills training. All survey questions presented a selection of response options for participants to choose from (see Appendices for specific categorizations).

Pre and post preparation intervention MCQs were also administered at the start of the preparation session and again at the start of the SBET workshop, to test changes in participants knowledge with respect to the CVC procedure. These MCQs were developed by an expert in
CVC and piloted with two novices in CVC to ensure appropriate difficulty and sensitivity to differences in knowledge before and after preparation.

To assess participants’ performance of CVC during physical practice and during the retention test, three categories of performance measures were employed: expert-based measures and time-based measures, and total number of trials required to achieve competency. Following a mastery learning paradigm, competency was defined as achieving a perfect score on two consecutive trials on a modified version a validated checklist for IJV CVC (Barsuk et al. 2009). An expert in CVC scored live performances using the checklist to determine when the competency point had been reached for each participant. To generate the time to competency metric, during the SBET workshop all trials were timed and the total time spent on task was summated to generate a time to competency metric. In addition, the number of trials required to achieve competency was recorded as the ‘trials to competency’ metric.

Expert based metrics were employed on the first trial (pre-test) and final trial (post-test) of the SBET workshop, as well as during the retention test. Specifically, the aforementioned task-specific checklist and a Global Rating Scale (GRS) adopted by Ma et al. (2012) from the Objective Structured Assessment of Technical Skills (OSATS) (Martin et al. 1997) were scored by two experts in CVC. The first expert led the SBET workshop and scored live performances; this rater was blinded to group allocation, but not to the study phase (i.e. pre-test, post-test or retention-test). To overcome this potential source of bias, a second trained expert blinded to both group allocation and study phase reviewed video-recordings of each of these performances in a randomized manner and rated participants using both the checklist and GRS.

Throughout the study, website activity was monitored to observe number of logins, pages visited, character counts, word counts and overall activity on the spot the difference activity (OP and OPEN groups) and collaborative learning activity (OPEN group only).

3.5. Data Analysis

All statistical analyses were conducted using SPSS version 21.0 (IBM Corp, Armonk, NJ).
3.5.1. Demographic and survey data

Demographic data and responses collected from the surveys administered to participants at the outset, before the SBET workshop, and at the retention test were analyzed using descriptive statistics. The mean (SEM) or frequency of responses (expressed as the percentage of participants indicating each response) to each response category in each survey question was calculated, the results of which are presented in Chapter 4. The time between the preparation session and the SBET workshop, as well as the time between the workshop and retention test was recorded for each participant and analyzed using a one-way Analysis of Variance (ANOVA) to determine if there were significant differences in the time between study phases (i.e. from preparation to training, and between training and retention) for the three study groups.

3.5.2. MCQ data

A mixed 3x2 repeated measures ANOVA was used to analyze the MCQ data, with group (TM, OP or OPEN) as the between subjects factor and trial (pre vs. post) as the within-subjects repeated measure, to determine if there was a significant learning effect (based on the main effect across trials), a significant difference in performance between the preparation groups (based on the main effect across groups), and whether there was a significant group x trial interaction. A threshold of significance was set at $\alpha = 0.05$ (two-tailed) for all main effects and interactions. Based on the results of the overall F-test, no further post-hoc pairwise testing was conducted.

3.5.3. CVC performance data

The intraclass correlation (ICC) was calculated to determine the reliability of checklist and GRS assessments between the two expert raters. All performance data, including participants scores on the procedural checklist, GRS, and time to competency (total time spent training before achieving the aforementioned competency threshold), were also interrogated using the Shapiro-Wilks test for normality. As all data were normally distributed, further analyses were carried out using ANOVA.
Specifically, a mixed 3x3 repeated measures ANOVA was used to analyze the checklist and GRS data, with group (TM, OP or OPEN) as the between subjects factor and trial (pre-test, post-test, and retention-test) as the within-subjects repeated measure, to determine if there was a significant learning effect (based on the main effect across trials), a significant difference in performance between the preparation groups (based on the main effect across groups), and whether there was a significant group x trial interaction. A threshold of significance was set at $\alpha = 0.05$ (two-tailed) for all main effects and interactions. Based on the results of the overall F-test, no further post-hoc pairwise testing was conducted.

For the time and number of trials to competency measures, a one-way ANOVA was conducted to determine if significant differences between the three interventions (TM, OP and OPEN). Given the small sample size, a power calculation was also conducted (G*Power statistical software) to determine the observed power in the study. Finally, as the ANOVA represents an omnibus test to determine the differences between the three treatment arms, a linear trend analysis was also conducted to test the hypothesis that a significant trend in decreasing time to competency would be observed with the addition of each preparation modality (e.g. TM $\rightarrow$ OP $\rightarrow$ OPEN). As the trend under investigation was between intervention arms, the difference in the ‘amount’ of preparation available to participants in each group cannot be assumed to be the same. As such, a non-parametric trend analysis test, the Jonckheere-Terpstra Trend Test, was used. As the hypothesis being tested was that a significant linear trend of decreasing time to competency would be observed with the addition of each preparation modality, a significance threshold for the linear trend was set at $\alpha < 0.05$ (one-tailed).

3.5.4. Website activity data

Finally, the website activity and survey data were further analyzed to determine if any significant differences existed between preparatory behaviour between the groups. Specifically, with respect to preparatory behaviour, the proportion of participants who reported that they usually review instructional materials prior a clinical skills training session was compared with the proportion of participants in the study who did in fact review the preparatory materials in
advance of the SBET workshop using an independent samples Student t-test ($\alpha < 0.05$, two-tailed). In addition, the proportion of participants who accessed the preparatory materials in advance of the SBET session, as well as the average self-reported time spent reviewing these materials, was compared between the three intervention groups using a one-way ANOVA ($\alpha < 0.05$, two-tailed). Finally, the total time spent on the website, as well as the time spent and number of words entered on the spot the difference activity in the OP and OPEN groups were compared using an independent samples Student’s t-test ($\alpha < 0.05$, two-tailed).
Chapter 4
Results

4.1. Demographics and Survey Results

The mean age of the participants was 24.2 years old with 13 males and 17 females.\(^1\) All students were entering their second (16), third (11), or fourth (3) year of medical undergraduate studies. The TM, OP, and OPEN groups had 10, 9, and 11 participants in each respectively. Five participants had seen a central line procedure performed on a patient, but none had received any formal training on the procedure or any procedure involving the Seldinger technique (technique using a guidewire to gain access to blood vessels and hollow organs). Demographic data is summarized in Table 1.

Only one participant did not complete the SBET workshop (i.e. was unable to train to competency) and was removed from performance analysis. The average time between the preparation and SBET workshop did not differ significantly between the three groups (\(F_{(2,26)} = 2.994; p<0.068\)) with the mean and range of time between preparation and simulation training being 7.2 (1-13), 6.7 (5-9), and 9.6 (7-14) days in the TM, OP and OPEN groups respectively. Similarly, there was no significant difference in the the time between physical practice and the retention test (\(F_{(2,26)} = 2.200; p<0.131\)), with the mean and range of time between simulation training and retention test being 9.8 (6-17), 12.2 (5-16), and 8.8 (6-14) days in the TM, OP and OPEN groups respectively.

\(^1\) Two subjects failed to provide their age.
4.1.1. General Perspectives and Use of Web-Based Learning and Educational Networking

All participants (100%) said that they used WBL for medical education. Of those with a smartphone (27 of 30, 90%) and tablet (12 of 30, 40%), 81.5% (22 of 27) and 91.7% (11 of 12), used these technologies for medical education respectively. Of the listed learning activities participants engaged in for their medical education, 37.8% involved WBL, which included a) online videos (including lectures), b) online reading materials (including research articles), c) online educational networking, d) smartphone applications, and e) tablet applications. 49.2% of the listed learning activities represented what were classified as traditional learning methods, which included, from most cited to least cited, a) lectures, b) textbooks, c) tutorials, d) study groups, e) printed research articles, and f) self-assessment exercises (tied with printed research articles). The remaining 13% of responses consisted of more hands on education through either a) SBET or b) conferences/workshops.

The three most common learning activities for medical education, from most cited to least cited, were a) lectures, b) online videos, and c) online reading materials (tied with online videos). The responses were split 54.4%, 44.4% and 1.1% across traditional, WBL, and hands on educational methods (conferences/workshops) respectively. The three most fun and engaging learning activities included, from most cited to least cited, online videos (including lectures), SBET, and study groups. Responses were split 42.7%, 34%, and 23.3% across traditional, WBL, and hands on educational methods respectively.

With respect to psychomotor skill acquisition and modeling, all participants (100%) felt that viewing a demonstration prior to trying a clinical skill would be beneficial. Only 4 students felt that both a live and video demonstration would be equally beneficial whereas 26 felt they were not. Of these 26 students, 21 felt a live demonstration would be superior for learning and 5 felt that a video demonstration would be superior for learning. These results and those regarding WBL are also summarized in Table 1.
<table>
<thead>
<tr>
<th>Demographics</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Males / Females</td>
<td>13 (43.3) / 17 (57.7)</td>
</tr>
<tr>
<td>Year 1</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Year 2</td>
<td>16 (53.7)</td>
</tr>
<tr>
<td>Year 3</td>
<td>11 (36.7)</td>
</tr>
<tr>
<td>Year 4</td>
<td>3 (10)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Use of web-based learning in medical education</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Laptop/Personal computers</td>
<td>30 / 30 (100)</td>
</tr>
<tr>
<td>Tablet devices</td>
<td>11 / 12 (91.7)</td>
</tr>
<tr>
<td>Smartphones</td>
<td>22 / 27 (81.5)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Use of traditional learning methods vs web-based learning</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning activities in medical education</td>
<td></td>
</tr>
<tr>
<td>Traditional*</td>
<td>121 / 246 (49.2)</td>
</tr>
<tr>
<td>Web-based learning**</td>
<td>93 / 246 (37.8)</td>
</tr>
<tr>
<td>Workshops***</td>
<td>32 / 246 (13.0)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Top 3 usual learning activities in medical education</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Lectures</td>
<td>23 / 90 (25.6)</td>
</tr>
<tr>
<td>Online videos</td>
<td>17 / 90 (18.9)</td>
</tr>
<tr>
<td>Online reading materials</td>
<td>17 / 90 (18.9)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Top 3 Most fun and engaging learning activities in medical education</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Online videos</td>
<td>23 / 150 (15.3)</td>
</tr>
<tr>
<td>Simulation based activities</td>
<td>21 / 150 (14.0)</td>
</tr>
<tr>
<td>Study groups</td>
<td>20 / 150 (13.3)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Demonstration for psychomotor skills learning is important</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>No difference between live and video demonstration</td>
<td>4 / 30 (13.3)</td>
</tr>
<tr>
<td>Live better than video demonstration</td>
<td>21 / 26 (80.8)</td>
</tr>
<tr>
<td>Video better than live demonstration</td>
<td>5 / 26 (19.2)</td>
</tr>
</tbody>
</table>

* textbooks, printed articles, study groups, lectures, tutorials, self assessment exercises
** Online reading materials, online videos, online education networking, smartphones applications, tablet device applications, podcasts
*** Workshops (including simulation based activities), conferences

Table 1. Summary table of WBL perspectives and use characteristics of undergraduate medical students
All but two participants (28 of 30, 93.3%) engaged online in social networking. Of these participants 100% used Facebook, 71.4% of which did so on a daily basis. On average, participants spent a self-reported time of approximately 4.2 (±1.0) hours a week on the Facebook and other social networking websites. It was found that 35.7% of participants (10 of 28) used these social networking technologies for medical education, spending an average of approximately 1.9 (± 0.7) hours a week doing so with 100% (10 of 10) finding it to be useful for their medical education. Participants were split on whether they felt that social networking would be useful for learning CVC, with 14 responding ‘Yes’ (46.7%) vs. 16 ‘No’ (53.3%). Participants overwhelmingly felt that remaining anonymous for social networking was important for encouraging participation (25 of 29, 86.2%, 1 non-responder). This social networking data is summarized in Table 2.
<table>
<thead>
<tr>
<th>Use of computer-based social networking in general</th>
<th>28 / 30 (93.3)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Platform</strong></td>
<td>Facebook</td>
</tr>
<tr>
<td><strong>Average no. of hours a week</strong></td>
<td>4.2 ± 1.0</td>
</tr>
<tr>
<td><strong>Daily Use</strong></td>
<td>20 / 28 (71.4)</td>
</tr>
<tr>
<td>Use of computer-based social networking for medical education</td>
<td>10 / 28 (35.7)</td>
</tr>
<tr>
<td><strong>Platform</strong></td>
<td>Facebook</td>
</tr>
<tr>
<td><strong>Average no. of hours a week</strong></td>
<td>1.9 ± 0.7</td>
</tr>
<tr>
<td><strong>Find it useful for education</strong></td>
<td>10 / 10 (100)</td>
</tr>
<tr>
<td>Feel anonymity would encourage participation in educational networking</td>
<td>25 / 29 (86.2)</td>
</tr>
<tr>
<td>Utility of computer-based social networking for learning psychomotor skill (useful for learning CVC)</td>
<td>14 / 30 (46.7)</td>
</tr>
</tbody>
</table>

Table 2. Summary table of social networking and CSCL perspectives and use characteristics of undergraduate medical students
4.2. MCQ Data

The average pretest/post-test MCQ scores for the TM, OP, and OPEN groups were 7.60 (±0.82)/11.10 (±0.605), 7.33 (±0.65)/ 11.11 (±0.351), and 6.1 (±0.48)/ 11.70 (±0.300), respectively. A two-way mixed repeated measures ANOVA between group across pre and post MCQ scores show significant learning effects in all participants ($F_{(1, 28)} = 97.3; p = 0.00$), and a non-significant effect for group ($F_{(2, 27)} = 1.428; p = 0.257$).

4.3. CVC Performance Data

4.3.1. Inter-Rater Reliability

Intraclass correlation (ICC) was calculated between the two reviewers for both checklist and GRS assessment scores; values of 0.999 and 0.821 were found respectively, demonstrating excellent inter-rater reliability.

4.3.2. Expert-based Metrics

The average checklist score and GRS score for the initial SBET Workshop trial (pre-test), final SBET Workshop trial (post-test), and retention test for each group are summarized in Table 3.
<table>
<thead>
<tr>
<th>Trial</th>
<th>Initial</th>
<th>Final</th>
<th>Retention Test</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group</strong></td>
<td>TM</td>
<td>OP</td>
<td>OPEN</td>
</tr>
<tr>
<td><strong>Checklist Score</strong></td>
<td>16.8 (±2.3)</td>
<td>17.2 (±2.5)</td>
<td>20.1 (±2.5)</td>
</tr>
<tr>
<td><strong>GRS Score</strong></td>
<td>16.0 (±1.1)</td>
<td>17.8 (±0.95)</td>
<td>16.8 (±2.0)</td>
</tr>
</tbody>
</table>

Table 3. Summary of mean checklist score and GRS score during the initial and final trials of the SBET workshop and the retention test trial – values are represented as means (±SEM) for TM, OP, and OPEN groups.
The mixes 3x3 ANOVA for checklist score and GRS measures demonstrate a significant main effect for trial in all groups ($F_{(2,52)} = 35.3, p < 0.001$; $F_{(2,52)} = 102.3, p < 0.001$ for checklist and GRS respectively), indicating that participants performance in CVC improved with physical practice. Although a marginally higher mean checklist and GRS score was observed in the OPEN group at retention, the overall main effect for group was non-significant ($F_{(4,52)} = 0.349, p = 0.843$; $F_{(4,52)} = 0.229, p = 0.921$ for checklist and GRS respectively). These data are shown in Figures 1 and 2.
Figure 1. Mean checklist scores for the initial and final SBET Workshop trials, and Retention Test trials. Error bars represent the standard error of the mean.
Figure 2. Mean GRS scores for the initial and final SBET Workshop trials, and Retention Test trials. Error bars represent the standard error of the mean.
4.3.3. Time and Number of Trials to Competency

The average time to competency for participants in the TM, OP, and OPEN groups were 62.3 (±7.5), 51.5 (±4.5), 47.1 (±4.5) minutes respectively. A one-way ANOVA showed no significant difference between the groups ($F_{(2, 27)} = 1.898; p = 0.170$). However, non-parametric trend analysis revealed a significant linear trend of decreasing time required to attain competency ($J-T$ Statistic = -1.840, $p = 0.033$) with each additional preparation modality (i.e. TM vs. OP vs. OPEN). These results are summarized in Figure 3.
Figure 3. Mean time to competency in minutes vs. group. Error bars represent the standard error of the mean, * denotes a significant linear trend (p<0.05) of decreasing time to competency across TM, OP, and OPEN groups respectively.
As well, the average number of trials required to reach competency during the SBET Workshop were 5.30 (±0.54), 4.33 (±0.47), and 4.30 (±0.40) for the TM, OP, and OPEN groups respectively. Although the trend in the data appeared similar to the time-to-competency metric, the one-way ANOVA showed no significant difference between the groups ($F_{(2, 27)} = 1.469; p = 0.249$). In this case the trend analysis also failed to demonstrate a significant linear trend of decreasing number of trials required to attain competency across the three groups ($J-T$ Statistic = -1.337, $p = 0.091$). These results are summarized in Figure 4 below.
Figure 4. Mean number of trials to reach competency vs. group. Error bars represent the standard error of the mean.
4.4. Preparation Behaviour and Website Activity

Overall, 19 of 30 participants reviewed the material prior to attending the SBET Workshop, a significantly higher proportion compared to the 4 of 30 that said they usually prepare prior to attending a learning session ($t = -5.113, p = < 0.0001$).

In terms of additional review of preparatory materials after the initial preparation session, 6 of 10, 4 of 9, and 9 of 11 said they reviewed materials in the TM, OP, and OPEN groups respectively (participation in the collaborative learning activity was not counted as review of material for the OPEN group). No significant difference was found between the groups ($F_{(2, 27)} = 1.527, p = 0.235$). Of those who reviewed materials in each group, the average self-reported time spent on review was 46.6 ($\pm 16.5$), 57.5 ($\pm 14.4$), and 42.8 ($\pm 11.4$) for the TM, OP, and OPEN groups respectively; no significant difference was found between groups ($F_{(2, 16)} = 0.241, p = 0.788$).

All students (30/30, 100%) felt that the preparation they did would help them learn to perform CVC more quickly and all (30/30, 100%) felt that they would be less comfortable in the workshop if they had no preparation.

The total time spent on the OPEN website during the initial preparation session did not differ significantly between the OP and OPEN group ($t = -1.558, p = 0.138$). A significant difference was found between OP and OPEN groups in terms of the amount of time spent on the spot the difference task ($t = 3.075, p = 0.007$) and number of words entered on this activity ($t = 2.192, p = 0.044$) in their responses, with the OPEN group spending more time and entering more words than the OP group. A summary of the preparatory behaviours of the OP and OPEN groups on this activity are summarized in Table 4.
<table>
<thead>
<tr>
<th>Measure</th>
<th>OP (mean, SE)</th>
<th>OPEN (mean, SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time spent on activity</td>
<td>1264 (172)</td>
<td>2289 (264)</td>
</tr>
<tr>
<td>(seconds)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of words*</td>
<td>215 (15)</td>
<td>277 (22)</td>
</tr>
</tbody>
</table>

Table 4. Differences in preparatory behaviour on the spot the difference activity between OP and OPEN groups. Summary of mean checklist score and GRS score during the initial and final trials of the SBET workshop and the retention test trial. * denotes a statistically significant difference between the two groups at the $\alpha = 0.05$ level.

Those in the OP and OPEN group all reported that they felt the website was easy to use (20/20, 100%) and if given the opportunity, would use such a website for learning clinical skills in the future (20/20, 100%). With regards to the spot the difference activity, all but 2 participants (18/20, 90%) reported it to be fun and engaging, and all but 1 participant reported it to be beneficial in addition to the instructional video for learning to perform CVC (19/20, 95%). When asked to rank the materials they felt most helped in their preparation for the workshop, 14/20 (70%) choose the instructional video (top ranked activity), 5/20 (25%) the reading materials, and 1/20 (5%) the interactive checklist. No participants in the OPEN group ranked the collaborative learning activity first. Ranking the material in terms of fun and engagement, 6/9 (66.6%) of participants in the OP group ranked the spot the difference activity first, and 3/9 (33.3%) ranked the instructional video first. In the OPEN group, the instructional video was ranked first most often (6/11, 54.5%), followed by the spot the difference activity (3/11, 27.3%), and finally the collaborative learning activity (2/11, 18.2%). When asked if any of the preparatory materials were not useful, 3 participants in the OP group cited the spot the difference activity (3/9, 33.3%), and 1 cited the reading materials (1/9, 11.1%). In the OPEN group, there were 7 activities cited from 5 participants that were felt to be not useful in their preparation, with 4 responses for the collaborative learning activity (4/11, 36.4%), 2 responses for the interactive checklist (2/11, 18.2%), and 1 response for the expert debriefing of the discussion (1/11, 9.1%).
Assessing only those engaged in the collaborative learning activity (OPEN group), 3 of 11 participants (27.3%) found the activity to be fun and engaging and 1 of 11 participants (9.1%) found the activity to be stressful. All 11 (100%) felt they were provided with adequate time to engage in discussion and 6/11 (54.5%) felt that it was important that their real identity remained hidden for the online discussion. When asked if they would prefer an expert be present during the discussion, 7/11 (63.6%) responded ‘Yes’. Participation in the collaborative learning activity was seen the form of visits and posts from all participants in the OPEN group. A screenshot of the discussion within the collaborative learning activity forum is shown in Figure 5.
Figure 5. Screenshot of the collaborative learning activity discussion forum participants in the OPEN group participated in.
The expert debriefing provided to participants in the OPEN group for the collaborative learning activity is provided below:

**Group Discussion 1:**

It was mention that if the guidewire wasn’t removed from the catheter, it would not have been possible to flush the catheter. Actually, even with the guidewire within the catheter, it would be possible to aspirate blood from and flush saline through all the ports of the catheter, even the brown one where the guidewire is within. This complication did, unfortunately occur in my institution several years ago and the critically ill patient had to undergo a radiological procedure to fish out the guidewire which was thankfully successful. Otherwise, the patient would have to undergo an operation to remove the wire.

I agree with the “top errors” that were narrowed down but the comments that there generally are no “top” errors is important in adopting an attitude that all clinically significant errors are errors that should not be committed as these leads to lower success rates and higher complication rates. Hence for the simulation workshop, we decided that all participants have to score a perfect score to “pass” the skill station.

If there are any queries or further questions, please make a note and we can have a discussion on these during the third appointment where we will also review your answers to the MCQs.
Group Discussion 2:

To summarize, the “top errors” that were identified by the group were

1. Failure to maintain sterility
2. Failure for Trendelenberg position
3. Guidewire not removed
4. Mechanical complications such as wrong insertions depth of dilator, guidewire.
5. Failure to review CXR

I agree with the “top errors” that were narrowed down. It was really great to see the discussion on clinically relevant “top” errors. There are no right or wrong answers. In reality, there are generally no “top” errors and every step is important. Adopting the attitude that all clinically significant errors are errors and should not be committed, is the right way to go as any clinically significant error leads to lower success rates and higher complication rates. Hence for the simulation workshop, we decided that all participants have to score a perfect score of 28 points in two consecutive tries in order to “pass” the skills station.

It was great that one member, Prof Wiley, gave references to support his/her decision! Let me pose these questions to the group for thought:

1. On the Trendelenberg position,
   a. It is supposed to prevent air embolism. Any idea how this position prevents air embolism? In other words, if I were to do the procedure in a reverse Trendelenberg position, will air embolism definitely occur?
   b. Are there contraindications to Trendelenberg positions for CVC? If yes, how do we perform the procedures on these patients?

2. As for guidewire embolism,
   a. No official data exists because it’s a rather uncommon error but more importantly
   b. The data can be found in the “Out of Court” hospital settlements data. These are cases where clinical errors are the obvious fault of the doctors and the hospital & medical insurance lawyer know there’s no way to defend these
errors. So it’s settled out of court and wire embolism is one of those types of errors.

c. Rather than understand what complications can occur with a wire embolism, if it were to unfortunately occur, what are the corrective steps to retrieve this wire in the patient? The first thing of course is to come clean with the error as the guidewire will be very visible on the CXR! Next step is to get your interventional radiology colleague and beg them to “fish it out” via endovascular techniques. If this option is not possible or failed, then it’s best to start calling your cardiothoracic surgeon for a vascular operation! As you can see, the corrective actions have immense implications for a critically ill patient. So always, please be mindful of the guidewire and never lose track of it!

3. With regards to CXR, is a CXR always necessary post CVC insertion?
   a. It is in most institutions especially in the States and Canada. However, this may not be the case in certain European & North American centers.
   b. This is because these centers that do not “conform” to the traditional practice of CXR actually use other means to check placement as well as rule out complications.
   c. The use of bedside ultrasound scan as point of care testing has emerged recently and will become, in my opinion, the new standard of care once training and funding issues can be resolved. Hence these centers have intensivists or ERs doctors who can perform bedside USS to check position of catheters and rule out complications.
   d. The size of a portable USS machine is now the size of an iPhone and cost about $7-10K! So it’s a matter of time before it replaces the stethoscope! This is what I think will happen soon and we can discuss about this more at the workshop if you are interested.
I will leave you guys to think about question 1 and we can discuss the answers more during the retention test day, i.e., the 3rd session.

If there are any queries or further questions, please make a note and we can have a discussion on these during the third appointment where we will also review your answers to the MCQs.
Chapter 5  
Discussion and Conclusion

This study examined the role of web-based observational practice and collaborative learning in preparing novice learners for simulation training in CVC. This following chapter will discuss the main results of the study and their implications for SBME. The first topic of this section explores the results from survey data about the general perceptions and practices around WBL, social networking, and CSCL. These results suggest that medical undergraduates are receptive to the use of WBL for clinical skills training and recognize the value of observational practice to support physical training. Next, the significant linear trend seen for improved learning efficiency in the OP and OPEN preparation intervention groups is discussed. Implications for SBET pre-training and potential theoretical explanations underpinning this finding will be explored with relation to other corroborating study results such as the potential role collaboration played in augmenting learner perceptions and use of preparation materials. In the final section, study limitations and directions for future research will be explored.

5.1. General Perceptions and Practices Around WBL, Social Networking, and CSCL

The initial demographic survey study aimed to assess the current penetration of WBL and CSCL amongst undergraduate medical students, their perceptions on using these tools for clinical (psychomotor) skill training, and their general educational preferences prior to any study manipulation. The results show that all surveyed medical undergraduate students used WBL in some form to support their medical education. It was found that 10 of the total 28 students, who reported to use social networking, also used social networking specifically for the purposes of supporting their medical education (CSCL or educational networking). Although CSCL was not used as extensively as WBL, nearly half of the participants recognized the potential utility of online collaborative learning for learning clinical skills (i.e. CVC), and nearly all participants
reported to use social networking in the personal lives, with two-thirds reporting daily use. This supports other work citing the increasingly large role of WBL in health professional education (Johnson et al. 2007; Kamin et al. 2006). This also emphasizes that undergraduate medical students have both the access to WBL and CSCL technologies, often across multiple devices (laptops/personal computers, smartphones, and tablets), as well as the technical know-how to engage with them in a meaningful manner to support their medical education.

More interestingly, participants reported online videos, simulation-based activities, and study groups to be the most fun and engaging instructional materials in their education; activities that are amenable to WBL and were captured within the additive educational interventions of the OP and OPEN group preparations. All participants also recognized the utility of technical skill demonstration prior to psychomotor skills training (30/30), and to a lesser extent, the potential of social networking to facilitate clinical skill acquisition (CVC skill acquisition) (14/30). These results show that learners will likely be receptive to the use of WBL in combination with simulation, particularly if engaging educational activities such as online videos and potentially collaborative learning opportunities are provided. This is informative to the design of WBL and SBET interventions for undergraduate medical students; these types of educational materials should be kept in mind when seeking to establish higher levels of learner engagement and active learning, and by extension, improving learning outcomes. Clearly, these results suggest WBL is an educational medium that medical students enjoy engaging with and that these learners will likely be receptive to the idea of applying both WBL and CSCL to facilitate preparation for SBET.

However, it is important that we approach the use of WBL cautiously. Despite the popularity of WBL in both its use and study, Cook et al. (2010) point out that WBL in medical education is poorly characterized and cannot be considered a panacea due to the broad range of instructional approaches that the term WBL encompasses. We cannot simply expect to apply ‘WBL’, or even ‘CSCL’ for that matter, to simulation and expect to gain meaningful insights into when, how, and why these interventions lead to specific outcomes. A degree of mindfulness is required in order for us build these interventions upon sound pedagogical theory, for us to be able to both test
potential mechanisms of action and apply these to WBL and SBME optimally. In the previously cited meta-analysis of WBL in medical education by Cook et al. (2010), there were no studies assessing the use of WBL as a means to prepare learners for SBET and few studies comparing the efficacy of different instructional design elements of WBL. Thus, although there are obvious opportunities for WBL to be used to augment SBET, and theoretical frameworks that would suggest the potential for improved learning, as yet there is a lack of empirical data supporting the use of WBL in preparation for simulation and how best this can be achieved (Cook et al. 2010).

5.2. Preparation Affects Efficiency of Learning

Checklist and GRS performance scores showed significant learning effects in all groups, however no significant differences between groups from pre-test, to post-test, and retention test were observed. This finding is not surprising, given that participants were trained using a mastery learning approach where they were trained until they reached a specified level of competency. With this in mind, the far more important and sensitive measure to assess the effect of the varying preparatory interventions becomes the amount of physical practice time required to achieve competency; thus, comparing the differences in the efficiency of learning between the group interventions. The main finding with regards to performance indicates a linear trend for decreasing time to competency for those engaged with OP and OPEN in addition to TM preparatory materials. Though the one-way ANOVA comparing the mean time to competency between the preparatory groups yielded a non-significant difference, there was a significant linear trend showing improved learning efficiency (decrease in time to achieve competency) in groups preparing with the addition of observational practice opportunities (OP) and the addition of both observational practice and collaborative learning opportunities (OPEN) to the traditional reading materials (TM). That is, participants in the OP group attained competency faster than those in the TM group, and those in the OPEN group attained competency faster than those in both the OP and TM groups. This result suggests there is an important role that different types of preparation play in improving the efficiency of learning during actual physical practice of psychomotor skills, in this case CVC in simulation.
This being said, one of the reasons group differences in the ANOVA were not observed may be due to the study being underpowered to detect a significant difference with the study sample size. A post-hoc power analysis (using the G*Power statistical software) revealed that the study had a Cohen’s $f$ effect size of 0.38, and thus with 30 participants the study had a beta value of 39.4%, suggesting the study was not sufficiently powered to detect a significant difference between groups on CVC performance. A post-hoc sample size calculation suggests that with this effect size, a sample size of 72 subjects (24 per group) would have been required to observe a significant difference. However, due to logistical barriers no further data could be collected after this power analysis was completed. Also, being that this study is exploratory and is the first known study to examine the impact of varying formats of web-based preparation on psychomotor skill acquisition during SBET, there were no similar WBL interventions with outcomes to conduct an appropriate power analysis a priori and thus the study was originally powered according to other simulation studies in the literature dealing with similar technical skills (Brydges et al. 2010). The observation that the current study was underpowered substantiates the claims made by others that when comparing instructional designs ‘head-to-head’ in WBL or SBME, there will likely be a reduction in the effect sizes observed and as a result larger sample sizes will be required to power future educational studies of this nature (Cook et al. 2011).

An alternate explanation for the lack of a significant difference observed in the ANOVA is that all groups did in fact receive some opportunity for OP, given that participants in all three groups reviewed an instructional video and received a live expert demonstration prior during the SBET workshop. While this was done to reflect a more ‘realistic’ way in which simulation workshops are conducted, the author acknowledges that this may have reduced the magnitude of the effect of the manipulation across the three groups. However, despite this likely reduction in the effect size for the interventions in question, the fact that a significant linear trend was observed speaks to the potential strength of the underlying effect of OP and CSCL.
Overall the findings support the hypothesis that anticipated that learning of CVC during physical practice would be facilitated in participants receiving more elaborate preparation through exposure to observational practice and educational networking. This advantage from preparation would theoretically result in the formation of more robust schemas of the CVC skill, and by extension, when entering the initial practice conditions these learners should have a continued advantage whereby the effective complexity of the task has been reduced (decreased intrinsic load). The effect of this advantage is hypothesized to be seen in an observed time-savings during physical practice to the predefined level of competency as seen in the significant linear trend. Contrary to the hypothesized improvements to retention, no such effect was observed, likely due to the reasons discussed earlier in this section. Figure 1 outlines this concept of schema development from preparation and physical practice.
Figure 1. The hypothetical progression of schema development for CVC throughout the study - Learners receiving OP or OPEN preparation would be thought to have more elaborate schemas for CVC upon entering the SBET workshop. At the end of the workshop however, both groups should be trained to competency thus exhibit minimal differences in their performances and potentially schemas. At the retention test, there may be lingering benefits to the OP and OPEN group due to their initial advantage from preparation though this was not detected in any of the metrics.
The finding for improved learning efficiency (as evidenced by the significant trend to lower time to competency) with the addition of opportunities for observational practice and collaborative learning have implications for the way we design both SBET and integrate this instructional tool with WBL and other curricular instruction in medical education. This underlines how important it may be for us to think about SBET beyond just the physical simulators, simulation centres, or other physical locations where training takes place. The results also demonstrate how preparation for SBET may leverage WBL, extending learning beyond the physical and temporal boundaries of what has been traditionally thought of as simulation.

### 5.3. Theoretical Insights and Implications

It should be first noted that this study was not designed to test specific theoretical factors of the various components of the OP and OPEN preparatory interventions and their contributions to the observed significant trend for improvement in learning efficiency. However, there are still insights that can be drawn by applying knowledge from existing theoretical frameworks around psychomotor skill acquisition and collaborative learning to the study results. Observational practice and collaborative learning likely improved learning efficiency by developing more robust action representations as discussed in Chapter 1. The generation of a more elaborate action representation during WBL preparation, could have provided a learning advantage once physical practice commenced at the SBET workshop. This benefit, however, is likely not simply attributed to the mere knowledge or understanding of the steps pertaining to the skill; we can see from the post MCQ scores that there was no significant difference in MCQ scores between the groups. Rather an explanation that would be supported from motor learning theory would be that there was improvement in efficiency of motor schema development in CVC skill during physical practice, which would be attributed to the existence of a more robust action representation at the beginning of the physical practice for participants in the with exposure to preparatory observational practice and collaborative learning opportunities. Thus, even though the participants may ‘know’ the same amount of information pertaining to the steps of the skills, their actual action representations may have been affected by the opportunity for OP in the
preparation materials. This is supported by literature in observational learning that demonstrates OP with physical practice is more beneficial than physical practice alone (Ashford et al. 2006).

5.3.1. Early and Late Mediation of Observational Practice Benefits

The potential impact of OP in the interventions used in this study may have been augmented by the variations in CVC performance presented to learners during the spot the difference activity. Aside from simply improving the attention, retention, and motivation of participants observing the modeled performances – all of which are mechanisms proposed by Bandura (1986) to improve observational practice – the spot the difference videos may have also allowed for the refinement of action representations for the CVC skill by presenting variations in the models of performance presented to learners (Bird & Rikli 1983; Buchanan & Dean 2010). The potential benefit of this activity may lie not only in the opportunity for learners to observe a variety of ways in which CVC was performed, but because the task itself asks participants to attend specifically to these differences and think deeply about the relevance of the observed variations, it may also encourage learners to more deeply process the useful strategies modeled in the performances and to consider some of the reasons for why the variations may have been employed.

How this benefit from observational practice and variation of practice is manifested may be supported by research investigating the mirror neuron system, which describes how observed actions can illicit similar patterns of cortical activation within the brain of the observer as would be seen in the execution of the same behaviour (Rizzolatti & Craighero 2004). It is suggested that the benefits to learning from observational practice may be due to the priming of the motor system during this activation of the mirror neuron system (early mediation) (Vogt 2002; Vogt & Thomaschke 2007). Alternatively it has been argued that the benefits are more strategic in nature (late mediation), as demonstrated in perceptual error detection improvements observed after observational practice (Black and Wright 2000; Black et al. 2005). This idea that observational practice can lead to the development of cognitive strategies is supported particularly for novel motor skills (Maslovat et al. 2010), where it has been suggested that mirror neuron activation is
significantly reduced or non-existent when observers view models of behaviour they themselves do not typically perform (Calvo-Merino et al. 2005; Calvo-Merino et al. 2006). This may mean that when novel movements are viewed where no previous motor programs can be drawn from, the mirror neuron system and the learning enhancement due to priming effects of the motor cortex may not come into play.

With respect to the learning of the CVC skill by the novice participants, it is likely that some components of the skill were already contained within a repertoire of motor programs – potentially providing a substrate for the effects of priming to take place – but also that there were novel aspects of the skill they would have never had experience with. Thus, a more cognitive or strategic benefit to observational practice would arguably be more important for these novel aspects of the CVC skill. This is interesting as it was anecdotally noted by the experimenters that participants most commonly had difficulty with the handling of the tools used to complete the procedure (such as needles, syringes and guidewires), which were likely largely ‘novel’ to the learners. For example, locating the internal jugular vein with the anesthetic needle and syringe involved understanding its handling (e.g. how best to hold and withdraw on the syringe), movement (how to effectively apply force to advance the needle), and the haptic feedback associated with moving through various tissues, all of which were clearly novel for all participants. If we view the learning of a complex clinical skill like CVC as a combination of discrete motor actions that must be formed into a more holistic action representation of the whole procedure, it would be interesting to see how observational practice could be improved if we purposefully embedded variations in CVC performance that model strategies for handing these difficult, but ‘critical’ components of the task. Or to put it alternatively, an interesting line of inquiry that arises from the current study would aim to elucidate the effect of preparatory OP material that is purposefully designed to impart cognitive strategies for learners on how to approach physical training during the SBET portion of skills training. As well, it could be particularly beneficial for learning if these variations in the modeled performances were to be developed around the specific errors participants were noted to have made (e.g. in the handling of tools).
5.3.2. Effects of Collaborative Interactivity on Observational Practice

The observed linear trend for improved learning efficiency extends beyond that of the benefits of preparatory observational practice, suggesting additive and potentially synergistic effects of the collaborative learning activity for those in the OPEN group. Similar to the specific mechanistic contributions of preparatory OP discussed in the previous section, from this study the mechanism by which the CSCL intervention contributed to the observed decrease in competency cannot be elucidated. However, theoretical inferences about the effects of the OPEN preparation and CSCL can be made based on the results observed from the study. Specifically when comparing data about the preparation behaviour of the OP and OPEN groups, an interesting finding is the difference in how participants in the two groups approached the spot the difference activity. There was a significant increase in the amount of time spent on the task during the preparation session, as well as the number of words used in the responses of participants in the OPEN group, compared to those in the OP group. This result suggests an increased level of motivation or engagement with the spot the difference activity among members of the OPEN group. Given they were provided with explicit instructions that their responses to this activity would be posted on the website for others to review and discuss, the observed difference may in turn reflect some sense of social accountability among participants in the OPEN group. The notion of taking responsibility for one’s own learning is a key aspect of CSCL, as described by Kirschner (2001), and may account for the differences in time to competency observed between the OP and OPEN groups. The observed effect may also reflect an affective component to the intervention, as the knowledge of being able to work as a group toward a high complexity task may improve self-efficacy (or group-efficacy), further altering the way that learners interact with learning materials (Kirschner et al. 2011). Thus this change in approach to utilization of the preparatory materials due to the introduction of the collaborative learning activity may play a role in the trend for observed learning benefits.

In addition to increased engagement with the materials, the decreased time to competency in the OPEN group may be related to other proposed mechanisms of CSCL, namely that engaging in collaborative learning leads to deeper level processing, critical thinking,
understanding that is shared amongst the group, and overall retention of the material (Garrison et al. 2001; Johnson & Johnson 1999). All of these mechanisms of action for CSCL likely worked synergistically with the mechanisms at play in observational practice (Bandura 1986).

However, the magnitude of the difference between the OP and OPEN groups with respect to time to competence was much smaller than the difference between the TM and OP groups, suggesting the additive impact of CSCL to OP was not as great as the effect of adding OP to traditional preparatory activities. This muted effect may have resulted from a sub-optimal CSCL environment; the collaborative learning activity seen in this CSCL intervention was somewhat contrived in its approach to producing social interaction, which has been identified as the key element in facilitating the learning benefits of CSCL (Gilbert & Moore 1998; Gunawardena 1995; Gunawardena et al. 1997; Liaw & Huang 2000; Northup 2001; Wagner 1994; Wagner 1997). Participants in this study were given a highly structured way to socially interact, with a strict limit to time and minimal expectations of engagement. Thus, the potential learning benefit that could be expected from engaging in truly socially interactive collaborative learning was likely blunted. Furthermore, for ethical reasons all participants were anonymized and did not have the opportunity to develop social relationships in advance of the educational networking activity, which would have limited the sense of trust participants had with other members of the group. In order for CSCL to work optimally, trust, a sense of social belonging and closeness with the group are required. Additionally, to truly facilitate the sharing of ideas, real relationships need to be forged between individuals that share a sense of community and a common goal (Rouke 2000). In the WBL intervention applied to the OPEN group preparation, social interaction was certainly encouraged (i.e. through the use of avatars and profile pages), but due to the limited level of control over social interaction, it was decided that the collaborative component of the OPEN preparatory activity be structured and controlled to ensure a base level of interaction – focusing on the cognitive processes related to the learning activity itself. Clearly, according to Rouke (2000), this type of environment did not allow for more intimate social relationships to be formed and the obvious focus on the material to be learned with little emphasis on social interaction outside of this helped control the interaction, but also restrained
its potential.

How exactly this social interaction improves learning in these CSCL environments may likely be due to the advantages proposed by Kirschner (2009a), who argues that collaboration offers the advantages of an increase in effective working memory (group working memory), thus freeing up cognitive processing power within individuals that can be devoted to schema development – described within the theoretical frame of Cognitive Load Theory (van Merriënboer et al. 2010). Similar to the previous sections discussion on observational practice, this idea of producing improved mental representations of the knowledge or skill are paralleled; likely, resulting in a synergistic effect of having collaborative learning oriented around observational practice. However, it is important to appreciate the complexity that exists between the interactions of all the components of these environments. The addition of the collaborative learning activity with other materials such as the spot the difference activity make for very complex interactions that affect level of engagement and social interaction in addition to level of processing and observational practice. Teasing apart how these pieces contributed to the finding of improved learning efficiency will be difficult and is beyond the scope of this study. It should be noted that the full potential of these theorized benefits of collaborative learning explained by cognitive Load Theory might only apply once the criteria of social interaction are met. Thus, as discussed by Kreijns et al. (2003), the focus of future studies and designs of CSCL environments should seek to avoid the pitfalls of social interaction. Namely, if we seek to assess the effects of collaborative learning on psychomotor skill acquisition, we must not take social interaction for granted, and not restrict social interaction to the cognitive processes underlying the to-be-learned material/skill. This would suggest that the effect of the collaborative learning activity was likely not as powerful an intervention, contributing to the lack of a significant difference being found in the group comparison for time to competency.

5.4. Learner Perceptions on Preparation Activities

Participants in all groups felt that preparation was useful for their learning and would be less comfortable entering the SBET workshop without preparation. This suggests that learners
recognized the complexity of the CVC skill and appreciated the opportunity to offload at least some of the training prior to the workshop. Interestingly, compared to the 4/30 participants who reported to typically prepare prior to a learning session, 19/30 were found to have reviewed their preparatory materials again following their initial in-lab preparation session. This may suggest that WBL encourages preparation amongst those who would not normally engage in such behaviour, but also that students were excited to engage in the SBET workshop for CVC training and make the most of their experience. The latter of which would support the demographic survey data showing simulation training as one of the top three most fun and engaging instructional methods reported. In addition, the added emphasis on preparation due to the nature of the study might have encouraged participants to prepare prior to attending their scheduled SBET workshop.

For participants who were given access to the online learning platform (OP & OPEN groups), all reported the website to be easy to use and that if given the opportunity they would use it for learn it for other clinical skills as well. This supports our initial demographic survey data, which suggested that participants would be receptive to WBL use as well as be capable of navigating through the online platform. Results regarding specific WBL materials they enjoyed most or found most useful varied and are less informative, however do lend some credence to the idea that those engaged within the OP and OPEN groups had different interpretations of the materials, perhaps due to the additive effects of the different preparatory interventions (TM vs. TM+OP vs. TM+OP+EN).

Some of these survey results suggest future improvements that may be adapted to WBL interventions involving observational practice and/or CSCL activities. Specifically the use of the collaborative learning was not perceived as valuable, or as fun and engaging, as it potentially could have been. Future design of interventions will likely need to address this concern through increasing the perceived value, perhaps by focusing the materials on more nuances of the skill and variations that pertain to the difficulties that novices were more likely to encounter, or by increasing the social interactivity of the environment (Kreijns et al. 2003). As well, the inclusion of features such as more immediate feedback from the spot the difference answers and the
presence of an expert during discussions were recommended from participants. These alterations may improve the overall experience and use of the collaborative learning activity, and the utility of the spot the difference activity.

5.5. Summary, Limitations, and Future Directions

The results of this study demonstrate the ability for different preparatory approaches to affect the efficiency of skill acquisition of CVC in novice learners. As well, the additive nature of the preparatory interventions allows for some insights to be garnered from the potential contributions of these additional preparation materials, namely opportunities to engage in observational practice and collaborative learning.

The theoretical perspectives on observational practice and collaborative learning discussed demonstrate the similarities between contemporary theories of motor and cognitive learning. In the context of learning to perform a complex psychomotor skill involving a large cognitive and motor component, the use of observational practice and CSCL may act synergistically, producing learning benefits which may account for the observed trend for increasing efficiency of learning for those in the OP and OPEN groups observed in the current study. Though this study cannot speak to the exact mechanisms of action for the improvements in learning efficiency, insights from the results suggest that there is a clear interaction when using collaborative learning to augment observational practice activities (i.e. spot the difference activity). These effects may relate to a number of theoretical constructs such as action representation improvement, reduced cognitive load, and altered affective aspects of cognition such as motivation and confidence (self-efficacy vs. group-efficacy). Further studies will be required to elucidate the specific contributing factors to the observed improvements to learning efficiency as well as the interactions observed between the various elements. Regardless, the results of this study provides some evidence to support the use of CSCL environments to improve clinical skill acquisition, and how CSCL may enhance the learning (formation of schemas or representations of actions) when combined with opportunities to engage in observational learning.
The immediate implication of the current study for SBME is highlighting of the need for more thoughtful investigation into how we use preparation to enhance learning outcomes, as there is indeed a contribution to learning in simulation from different preparatory approaches. Further work must be done to refine and control preparatory interventions in order to both optimize and understand the effects of observational practice, collaborative learning, timing effects of preparation (such as how long before a SBET session should preparation be given and if the preparation should it be massed or distributed in nature), and other questions about the instructional design surrounding the use of preparation to enhance SBET specifically related to the CLT. These proposed lines of research will support the notion that we need to move beyond research that seeks to prove the effectiveness of simulation and WBL (Cook et al. 2008; Haji et al. 2013). Such research will work towards clarifying why specific instructional interventions work and how we can improve the efficiency of simulation training, in order to also improve its cost-effectiveness. Furthermore, this line of inquiry specifically targeted at the use of preparation will help inform best practices for curricular integration, specifically how we can engage with SBME, WBL, and CSCL instructional approaches in tandem to improve medical education training programs. These questions of how to apply these different educational modalities with simulation will be especially important as the medical education field moves more and more towards a CBME model of training.

With regards to the main finding of this study, it is important to note that the significant linear trend for increased efficiency of physical training across the groups (from TM to OP to OPEN) is seen despite several limitations of the study design. Firstly, the fact that much the benefit observed from the observational practice opportunities during preparation for the OP and OPEN group may have been washed out since the opportunity for the TM group to engage in observational practice was provided during the SBET workshop where all groups (including the TM group) the New England Journal of Medicine CVC instructional video as well as a live demonstration. As well, the small sample size likely led to the study being underpowered as demonstrated by the power analysis in section 5.2. Lastly, the OP and OPEN interventions were likely far from optimized to take full advantage of the learning benefits possible from the
suggested literature around observational practice and collaborative learning. For example should the demonstrational videos or the spot the difference activity be designed to focus on the commonly encountered problems novices face when learning the skill it would be anticipated that there be enhanced learning from the observational practice material. And with regards to the collaborative learning activity, the development of a more socially interactive CSCL environment would likely act synergistically with the observational practice components of the preparation to improve learning and likely learning efficiency during physical training. Future studies may benefit from leveraging the use of existing relationships within medical education courses, and engage in a more longitudinal study design that would further facilitate the development of true relationships built upon trust and a sense of community and common goal, all which are thought to enhance social interactivity in CSCL and thus improve learning (Rouke 2000). Should these limitations be addressed in the future, the study interventions may result in better preparation of learners, with the potential for larger associated effect sizes.

The future directions from this work should firstly seek to address these limitations of this current study particularly with regards to the sample size, and refinement of the preparatory interventions. Once the effects related to observational practice and CSCL are corroborated, research that aims to tease apart different aspects of observational practice and collaborative learning and their associated effect on training efficiency may be pursued. Some important research questions that could be assessed in future studies include how these preparatory interventions fair in a non-mastery learning SBET setting, thus allowing potential differences in performances to be observed in the checklist and GRS performance metrics for pre-test, post-test, and retention tests. Such experiments would further help elucidate the contributions of different preparatory materials to skill acquisition, and potentially further the concept of cost-effective training through preparation if particular forms of preparation lead to better retention (and potentially transfer) when physical practice time is controlled. And lastly, the effect of these preparatory approaches on skill transfer would be another interesting area of study. Either examining transfer to IJV CVC in a different context (e.g. modified simulator or new environment) or perhaps even different clinical/psychomotor techniques such as a femoral CVC
or chest tube insertion, which also employ the Seldinger technique. The results from this transfer might help to illuminate differences that result from the potentially deeper understanding that underlies learning as a result of the different approaches to preparation and training. As well, this would further support the connection between the cognitive and motor components of clinical skills, providing a potential argument for the integration of these aspects in future training curricula.

Moving away from the application of WBL and CSCL solely for preparation is also another interesting option to explore within a program of research. The use of these various instructional approaches in a more longitudinal manner (prior to SBET, during SBET, and after SBET) would help provide valuable insights on the use of these technologies across various skills and better inform the design of curriculum that would seek to integrate CSCL, WBL, and SBET – essentially SAET. As well, further lines of research could be explored to examine the role of these instructional approaches towards skill retention and maintenance or even helping facilitate deliberate practice through an educational network of peer reviewers that could provide feedback on performances.

5.6. Conclusions

This dissertation represents an initial exploration of the use of preparatory collaborative WBL to augment psychomotor skills acquisition for SBET. This study demonstrates how WBL technologies (specifically online videos and CSCL environments) may be leveraged to successfully augment complex real-world psychomotor skills acquisition, in this case SBET for CVC training using a mastery learning approach.

With the shift towards CBME fast approaching, and with the recognition of SBME’s role in facilitating assessment and training for CBME, the optimization of how we use simulation is important and will become increasingly so. The results from this study demonstrate the potential utility in application of web-based and collaborative learning instructional approaches to psychomotor skills acquisition, specifically for improving learning efficiency. Though the study
design limits the theoretical conclusions that can be drawn, importantly for SBME, this study demonstrates that preparation for physical practice can play an important role in improving both the quality and cost-effectiveness of simulation. Suggesting that this is a worthwhile area of study that where further research is warranted. As well, the results from this study make an argument for the role of integrating various instructional approaches with SBME, in particular the use of WBL with SBET, to improve learning efficiency and potentially outcomes. As preparation is a largely neglected aspect of SBME instructional design, the integration of WBL and SBET through preparatory approaches may be one means of addressing this gap. Further research is required to clarify the instructional design questions about how to best use web-based preparation to optimize SBET.
References


Miller, G. A. (1956). The magical number seven, plus or minus two: some limits on our capacity for processing information. *Psychological review, 63*(2), 81.


Rourke, L. (2000, May). Operationalizing social interaction in computer conferencing. In *Proceedings of the 16th annual conference of the Canadian Association for Distance Education*.


Sidhu, R. S., Park, J., Brydges, R., MacRae, H. M., & Dubrowski, A. (2007). Laboratory-based vascular anastomosis training: a randomized controlled trial evaluating the effects of bench model fidelity and level of training on skill acquisition. *Journal of vascular surgery, 45*(2), 343-349.


Appendices

Appendix A: “In-house” CVC instructional handout

Reading Material

Central Venous Catheterization (CVC) of the Internal Jugular Vein (IJV)

Central venous catheterization is an important clinical skill to master. More than 5 million central catheters are inserted in the United States with an associated complication rate of 15%. Simulation based education has been shown to be effective in training learners to be competent in this skill. The more you practice, the more proficient you will be in this skill as it has been shown that doctors who perform more than 50 CVC have complication rates lower compared to those who have performed less. This article serves to explain the steps you should go through when performing this procedure. The illustrations include both real patients and those from our mannequin to better prepare you for the upcoming workshop.

1. **Obtaining informed consent from the patient.** As in all procedures, the following 6 points should be covered:
   a. You have to explain why you are doing this procedure, i.e. indications.
      These include
      i. Delivery of caustic and critical medications
      ii. Parenteral nutrition
      iii. Measurement of central venous pressure
      iv. Measurement of the ScvO2 (oxygen saturation of venous blood in the superior vena cava)
   b. Contraindications should be addressed and includes:
      i. Thrombosis of the target vein
      ii. Infection over the area of the target vein
      iii. Coagulopathy – this is a relative contraindication and increases the risk of bleeding
   c. Explain the procedure to the patient
   d. Explain the risks involved and these are:
      i. Mechanical complications
         1. Arterial puncture – 3%
         2. Pneumothorax – 0.2%
         3. Wire embolism < 0.1%
ii. Infectious complication – 8.6 per 1000 catheter days
iii. Thrombotic complications – 3 per 1000 catheter days
e. Explain the corrective actions should these complications occur
   i. If accidental puncture of the common carotid artery occurs,
      1. This can be corrected by applying pressure on the common carotid artery
   ii. A chest tube may be required if a pneumothorax occurred
   iii. A radiological procedure or an operation may be required should a wire embolism occurs
   iv. Infectious and thrombotic complications
      1. Explain that strict adherence to infectious control practice will minimize this complication
      2. Explain that catheter will be removed as soon as it is no longer required to reduce both these complications
f. Explain that this procedure may be unsuccessful and that another site may have to be chosen for central venous catheterization

2. After obtaining consent, place the patient in a slight **Trendelenberg position**
   a. The patient is in a Trendelenberg position when he is supine on a surface that is inclined at 45 degrees, with the head in the lower position. For CVC, insertion, a slight degree of Trendelenberg is required, i.e. 15-30 degrees. This is necessary to prevent air embolism during the procedure as well as to ensure adequate filling of the internal jugular vein.
   b. Important to note that this position may not be possible in certain groups of patients. The Trendelenberg position may result in a raise intracranial pressure in patient with an intracranial haemorrhage or a head injury. Similarly for a patient with conditions resulting in raised intraocular pressure. This position is also often poorly tolerated by the patient with congestive cardiac failure.

Trendelenberg Position
3. Next **surface mark the point of entry** for your needle. It is important to note where you intend to insert your needle as this would determine where you clean, how you drape and where to administer the local anaesthetic. This is a crucial step in determining successful cannulation of the IJV.
   a. The point of entry for the right IJV CVC is the apex of the triangle on the right side of the neck that is formed by
      i. The superior border of the right clavicle
      ii. The lateral border of the sternal head of the sternocleidomastoid muscle
      iii. The medial border of the clavicular head of the sternocleidomastoid muscle.
   b. The point of entry at the apex of the triangle is just lateral to the carotid pulse
      i. In about 92% of patients, the IJV is found anterior-lateral to the common carotid artery.
      ii. The other 8% of patients have variations in anatomy which accounts for failure to cannulate the IJV using this landmark technique.
c. It is important to note the head of the patient should be facing left, slightly off the midline, as extreme rotation of the head to the left may alter the relative position of the right IJV to the common carotid artery.

4. Make sure you wear a cap, face mask, sterile gown and sterile gloves

5. Clean the site of entry
   a. Starting from the site of entry identified in step 3, clean in a circular fashion from the site outwards, ensuring that you clean the area up to the mastoid of the ear superiorly, the clavicle inferiorly and the midline of the neck anteriorly.
   b. Use chlorhexidine as the cleaning agent rather than povidone iodine as this has been shown to result in a lower infectious rate for CVC insertions.
6. **Drape** the patient with a sterile drape, covering a wide area, but ensuring that the point of entry surfaced mark in step 3 is exposed and accessible. This step should be done once only as re-draping the patient with the same drape may break sterility. If after draping the patient and you realize that the point of entry is covered or inaccessible, remove the drape and use a fresh drape.

7. Prepare your **equipment**
   a. 25G needle with a 5 ml syringe and 1% lidocaine for local anaesthetic
   
   b. The CVC needle and syringe provided in the set
      i. Ensure that the bevel of the needle is aligned with the numbering of the syringe
c. Guidewire
   i. The distal end of the guidewire is curved to prevent vessel injury
   ii. Withdraw the distal end of the guidewire as shown to facilitate the procedure
   iii. The guidewire is marked along its length with black stripes. 1 stripe corresponds to the 10cm mark, 2 stripes to the 20cm mark and 3 stripes to the 30 cm mark.
d. Dilator

e. Blade
f. CVC catheter
   i. Remove all port hubs of the triple lumen catheter
   ii. Flush every port with normal saline and clamp all ports after flushing
   iii. Replace all the port hubs except the brown port hub
   iv. Note that there are markings on the CVC catheter with a 15 cm mark for reference.

   g. Sterile normal saline
   h. Stitch (3/0 silk), needle holder and scissors
i. Dressing

j. Sharp Box

8. Administer *local anaesthetic* (LA) with 1% lidocaine using the 25G needle
   a. Start at the point of entry that was identified in step 3
   b. Make a wheal (a small bump beneath the skin) around the area with a single poke
   c. Remove the needle completely
9. Administer the **LA to the deeper structures** and use this same needle to **locate the IJV**
   a. The IJV is about 1-2 cm beneath the skin
   b. Insert the 25G needle again
      i. at the point of entry identified in step 3
      ii. just lateral to the pulsation of the common carotid artery
      iii. at about 30 degree angle to the patient’s neck
      iv. ensure that the needle is pointed towards the ipsilateral nipple.
   c. As you administer LA to the deeper structure, ensure you aspirate before pushing in LA to prevent inadvertent administration of the LA directly into the IJV. Therefore, as you insert, do an aspirate-push manoeuvre repeatedly to anaesthetized the deeper structures till you withdraw venous blood from the IJV.
   d. Once blood is withdrawn, you have reached the IJV and do not push any LA. Make a note of the position, depth and angle of the needle before withdrawing it completely.
   e. Apply some gauze as some bleeding is anticipated.
10. Next, use the **CVC needle** and syringe and cannulate the IJV using the exact position, angle and depth that was identified by the 25G needle as above.
   a. Once blood is aspirated, ensure that smooth aspiration of blood is possible
   b. Remove the syringe
   c. A smooth flow of venous blood from the CVC needle is anticipated
   d. If bright red pulsatile blood is obtained, you have cannulated the carotid artery. Remove the needle at once and apply firm pressure with a
dressing onto the carotid artery for about 10 mins to prevent hematoma formation.

e. Other ways of knowing that you have cannulated the internal jugular vein and not the carotid artery include:

   i. The plunger of the syringe is never pushed upwards spontaneously by the force of the venous blood; if this happens, you are in the carotid artery

   ii. You can connect the catheter to a pressure transducer and check for presence of a venous pressure waveform rather than an arterial waveform

   iii. You can also obtain a blood sample from the catheter and a concomitant blood sample simultaneously from the radial artery and the oxygen saturations of both sample should be different, with the venous sample having a lower oxygen saturation.

11. Insert the **guidewire** to a depth of about 12-15 cm

   a. Use the markers on the guidewire so that you know how deep you have inserted the guidewire

   b. Stop when you see 2 black stripes on the guidewire which corresponds to the 20 cm mark.

   c. Inserting the guidewire too deep may result in arrhythmias and pericardial injury and tamponade

   d. You should be able to insert the guidewire smoothly. If not, do not force the guidewire in. Remove the guidewire and reposition the CVC needle so that venous blood can be aspirated smoothly.

12. After inserting the guidewire, **remove the CVC needle**, leaving the guidewire in place within the IJV.

13. Insert the **dilator** over the guidewire.

14. Use the blade to make a **small incision** at the point of entry just before the dilator enters the skin

15. Dilate the skin and subcutaneous tissue with the dilator over the guidewire.

   Insert the dilator by about 1-2 cm. This is to ensure smooth passage of the CVC catheter later. It is important to note that you should be confident that you are in the internal jugular vein and not in the carotid artery as dilating the carotid artery can lead to serious consequences. If there’s any doubt, do not proceed with dilation and ask for help.

16. Remove the dilator, leaving the guidewire in place within the IJV.

17. Next, **insert the CVC** catheter over the guidewire
a. As you insert the CVC catheter over the guidewire, ensure you have control of the guidewire (holding onto the guidewire) always.
b. Unclamp the brown port to allow the guidewire to exit the CVC catheter
c. Once the guidewire has exited the CVC catheter via the brown port and you have control of the guidewire, insert the CVC catheter to a depth of 15 cm.
d. It is important you have control of the guidewire at all times to prevent wire embolism.
e. Once the catheter is inserted to a depth of 15cm, remove the entire guidewire.
f. Make sure you can aspirate blood from all ports and flush the ports with normal saline, ensuring no air bubbles are present. Replace all port hubs.

18. **Secure** the CVC catheter with sutures using 3/0 silk
19. Apply **dressing**
20. Dispose all **sharps** in the sharp box.
21. Order a **CXR**
22. **Review** the CXR to ensure proper placement of the CVC catheter
   a. The CVC catheter should be within the superior vena cava (SVC)
   b. The tip of the catheter should be above the carina on the CXR
   c. The CVC catheter should also be parallel to the SVC and should not be abutting the wall of the SVC
   d. If malpositioning occurs, this must be rectified by adjusting the CVC catheter, ensuring that sterility is maintained.
   e. Also look for complications of CVC such as pneumothorax and hemothorax.

You will be assessed based on a validated rating scale as below. To complete the simulation workshop, you need to achieve a perfect score of 28 marks in two consecutive attempts. The rating scale is:

1. Informed consent: must do all (Indications, risks, procedures)
2. Place patient in slight Trendelenberg position
3. Surface mark point of entry
4. Resident gets in sterile gown, gloves, mask & cap
5. Area is cleaned with chlorhexidine
6. Area is draped in usual sterile fashion
7. Flush the ports of the catheter with sterile saline
8. Clamp each port
9. Remove the brown port hub
10. The skin is anesthetized with lignocaine in a small wheal
11. Deeper structures anesthetized, aspirating before each push
12. Localizes the vein with this needle
13. Using the large needle, cannulate the vein while aspirating
14. Remove the syringe from the needle
15. Advance the guidewire into the vein no more than 12-15 cm
16. Mention to nick the skin with a blade
17. Advance the dilator over the guidewire and remove dilator
18. Advance the catheter over the guidewire
19. Never let go or lose track of the guidewire
20. Once catheter is inserted, remove guidewire in its entirety
21. Advance catheter to approximately 14-16 cm on the right side
22. Ensure that blood can be aspirated from each port and flushed
23. Secure the catheter in place
24. Place dressing in place
25. Maintain sterile technique
26. Clear Sharps in sharp box
27. Order a CXR
28. Review CXR for proper placement of central line
Appendix B: Task-specific checklist and GRS for CVC

**IJV Central Line Checklist via Landmark Technique**

Subject Number/ Initials: ________________  Attempt no.: ________

<table>
<thead>
<tr>
<th>Action</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: Done Correctly  B: Done Incorrectly  C: Not done</td>
<td></td>
</tr>
<tr>
<td>Time required: ________</td>
<td></td>
</tr>
<tr>
<td>A: Scores 1 point  B or C: Score 0 point  Total score: ________</td>
<td></td>
</tr>
</tbody>
</table>

Rate your self-confidence in setting an IJV CVC via landmark technique from 0-10, 0 being ‘Not confident at all’ to 10, ‘Very confident’.  ________

<table>
<thead>
<tr>
<th>Action</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Informed consent: must do all (Indications, risks, procedures)</td>
<td>A</td>
</tr>
<tr>
<td>2. Place patient in slight Trendenlenberg position</td>
<td>A</td>
</tr>
<tr>
<td>3. Surface mark point of entry</td>
<td>A</td>
</tr>
<tr>
<td>4. Resident gets in sterile gown, gloves, mask &amp; cap</td>
<td>A</td>
</tr>
<tr>
<td>5. Area is cleaned with chlorhexidine</td>
<td>A</td>
</tr>
<tr>
<td>6. Area is draped in usual sterile fashion</td>
<td>A</td>
</tr>
<tr>
<td>7. Flush the ports of the catheter with sterile saline</td>
<td>A</td>
</tr>
<tr>
<td>8. Clamp each port</td>
<td>A</td>
</tr>
<tr>
<td>9. Remove the brown port hub</td>
<td>A</td>
</tr>
<tr>
<td>10. The skin is anesthetized with lignocaine in a small wheal</td>
<td>A</td>
</tr>
<tr>
<td>11. Deeper structures anesthetized, aspirating before each push</td>
<td>A</td>
</tr>
<tr>
<td>12. Localizes the vein with this needle*</td>
<td>A</td>
</tr>
<tr>
<td>a. No of attempts required ______</td>
<td></td>
</tr>
<tr>
<td>b. Time required before locating the vein ______</td>
<td></td>
</tr>
<tr>
<td>13. Using the large needle, cannulate the vein while aspirating **</td>
<td>A</td>
</tr>
<tr>
<td>a. Arterial puncture occurred</td>
<td>Yes/No</td>
</tr>
<tr>
<td>b. No of attempts required ______</td>
<td></td>
</tr>
<tr>
<td>c. Time required before cannulation ______</td>
<td></td>
</tr>
<tr>
<td>14. Remove the syringe from the needle</td>
<td>A</td>
</tr>
<tr>
<td>15. Advance the guidewire into the vein no more than 12-15cm</td>
<td>A</td>
</tr>
<tr>
<td>16. Mention to nick the skin with a blade</td>
<td>A</td>
</tr>
<tr>
<td>17. Advance the dilator over the guidewire and remove dilator</td>
<td>A</td>
</tr>
<tr>
<td>18. Advance the catheter over the guidewire</td>
<td>A</td>
</tr>
<tr>
<td>19. Never let go or lose track of the guidewire</td>
<td>A</td>
</tr>
<tr>
<td>20. Once catheter is inserted, remove guidewire in its entirety</td>
<td>A</td>
</tr>
<tr>
<td>21. Advance catheter to approximately 14-16 cm on the right side</td>
<td>A</td>
</tr>
<tr>
<td>22. Ensure that blood can be aspirated from each port and flushed</td>
<td>A</td>
</tr>
<tr>
<td>23. Secure the catheter in place</td>
<td>A</td>
</tr>
<tr>
<td>24. (Mention) Place dressing in place</td>
<td>A</td>
</tr>
</tbody>
</table>
25. Maintain sterile technique
26. Clear Sharps in sharp box
27. Order a CXR
28. Review CXR for proper placement of central line

*if item 11a. > 5 times or 11b. > 5mins, the procedure is halted and items 12-27 are marked “C”
**if item 12a. occurs OR 12b. >2 occurs, then the procedure is halted and items 13-27 are marked “C”

What are the steps you found difficult in this CVC practical exercise? ______________________________
<table>
<thead>
<tr>
<th>Please rate the following areas:</th>
<th>Not competent to perform independently</th>
<th>Borderline competence to perform independently</th>
<th>Competent to perform independently</th>
<th>Above average competence to perform independently</th>
<th>NA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appropriate preparation of instruments pre-procedure</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Appropriate analgesia</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Specific components of technical ability:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time and Motion</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Many unnecessary moves</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Instrument handling</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Repeatedly makes tentative and awkward moves</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Flow of procedure and forward planning</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequently stopped or needed to discuss next move</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Knowledge of instruments</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequently used an inappropriate instrument</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Aseptic technique</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seeks help where appropriate</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>OVERALL ABILITY TO PERFORM PROCEDURE</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
</tbody>
</table>
Appendix C: Pre-intervention survey and MCQ

The Role of Online Collaborative Learning in Simulation-Based Training of Clinical Skills: Survey 1

Date:_________                     Subject No:_________

Demographic Data

Name: _____________________________      Age: ___________________

Medical Student Year (as of Sept 2012): _______________    Sex : Male/Female

Baseline Data

1. Have you had any educational experience with central line insertion?    Yes / No
   a. If so, what was it and how long ago was this experience?
      Circle all that are applicable
      Months ago
      •  Reading materials
      •  Video
      •  Lecture
      •  Tutorial
      •  Practice on a training model
      •  Performed on a patient
      •  Seen it performed on a model
      •  Seen it performed on a patient
      What type? (IJ, SC, Femoral)

2. Have you ever done a procedure requiring the Seldinger* technique?    Yes / No
   a. If yes, how long ago (months) was this
   b. If yes, was this on a model or a person
   c. If yes, what was this procedure

3. Have you ever seen a procedure requiring the Seldinger* technique?    Yes / No
   a. If yes, how long ago (months) was this?
   b. If yes, where was this done (IJ, SC or femoral)?
   c. If yes, was this on a model or a person?

4. One a scale of 1-5, how motivated are you to learn CVC from this ‘course’? (Circle one)

<table>
<thead>
<tr>
<th>Not motivated at all</th>
<th>Not so motivated</th>
<th>Motivated</th>
<th>Very motivated</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>
5. Do you feel it would be beneficial to watch a demonstration of a clinical skill before trying it yourself?  
   Yes / No 
   a. Do you think a live or a video-based demonstration are equally beneficial?  
      Yes / No 
      a. If no, which do you feel is better?  
         Live / Video 

6. Do you use online learning technologies for your medical education?  
   Yes / No 
   a. If yes, how often do you use online learning? 
      Daily  A few times a week  A few times a month  Less than a few times a month 
      b. Do you find online learning fun and engaging?  
         Yes / No 
      c. Do you find it easy to use?  
         Yes / No 

7. Are you engaged in social networking (e.g. Facebook, Twitter...)?  
   Yes / No 
   a. If yes, please specify which ones  
   ________________________________________________________________  
   b. How frequently? (Circle one) 
      Daily  A few times a week  A few times a month  Less than a few times a month 
      c. How much do you use this (hours/week or hours/month [specify]) _______ 

8. Have you used social networking for learning purposes?  
   Yes / No 
   a. If yes, how frequently? (Circle one) 
      Daily  A few times a week  A few times a month  Less than a few times a month 
      b. How much do you use this (hours/week or month [specify]) _______ 
      c. Do you find it useful to your education?  
         Yes / No 
      d. Do you feel that being anonymous in an online network would encourage participation?  
         Yes / No 

9. Do you think social networking would be useful for learning CVC?  
   Yes / No 

10. Which are the ways you usually learn from in medical education? (Please circle all that are relevant). 
   a. Textbooks 
   b. Printed research articles 
   c. Online reading material (including research articles) 
   d. Online videos (including lectures) 
   e. Online educational networking (social networking for education) 
   f. Study groups
g. Lectures
h. Tutorials
i. Simulation-based education
j. Smartphone applications
k. iPad (or similar tablet devices) applications
l. Conferences/Workshops
m. Self assessment exercises (e.g. MCQs for the USMLE)
n. Podcasts
o. Other(s) (Please specify) _____________________

11. Please circle the top 3 ways you usually learn from in medical education.
   a. Textbooks
   b. Printed research articles
   c. Online reading material (including research articles)
   d. Online videos (including lectures)
   e. Online educational networking (social networking for education)
   f. Study groups
   g. Lectures
   h. Tutorials
   i. Simulation-based education
   j. Smartphone applications
   k. iPad (or similar tablet devices) applications
   l. Conferences/Workshops
   m. Self assessment exercises (e.g. MCQs for the USMLE)
   n. Podcasts
   o. Other(s) (Please specify) _____________________

12. Please rank the top 5 ways of learning you find most fun and engaging (please circle all that is relevant).
   a. Textbooks
   b. Printed research articles
   c. Online reading material (including research articles)
   d. Online videos (including lectures)
   e. Online educational networking (social networking for education)
   f. Study groups
   g. Lectures
   h. Tutorials
   i. Simulation-based education
   j. Smartphone applications
   k. iPad (or similar tablet devices) applications
   l. Conferences/Workshops
   m. Self assessment exercises (e.g. MCQs for the USMLE)
   n. Podcasts
   o. Other(s) (Please specify) _____________________

13. Do you have a smartphone? 
   a. Yes / No
   b. Please specify (apple, android, others)_______________
a. Do you use your phone to supplement your medical education?  Yes / No

14. Do you have a tablet device?  Yes / No
   a. If yes, please specify (iPad, Windows based, Kindle)________________
   b. Do you use this device for medical education?  Yes / No

If you have any other comments that you would like to give with regards to enhancing your learning experience in medical school currently, please let us know:

__________________________________________________________________________
__________________________________________________________________________

Pre-preparation MCQ:

1. The following are indications for a central venous catheterizations EXCEPT
   a. Delivery of caustic and critical medications
   b. Measurement of central venous pressure
   c. Measurement of SvO2
   d. Parenteral nutrition

2. The following patients may pose difficulties in central line insertion EXCEPT:
   a. Patient who is coagulopathic
   b. Patient who is obese
   c. Patient who is restless
   d. Patient with a large larynx

3. If there is presence of a skin rash over the intended site of insertion of the central line, you should:
   a. Proceed with the procedure maintaining strict aseptic technique at all times
   b. Choose a different site for the central line
   c. Apply steroid and antibiotic cream to the rash before proceeding with the procedure
   d. Explain to the patient during consent taking that there is a high risk of infection and once consent is obtained, proceed with the procedure

4. You must wear the following for central venous catheterizations except
   a. Sterile gown
   b. Sterile cap
   c. Sterile gloves
   d. Face mask

5. With regards to draping the patient, which of the following is true:
   a. You should drape the patient first and then clean the site within the drape
   b. Draping should cover as wide an area as possible, leaving the site of interest exposed and accessible
   c. If you have drape the patient such that the site of interest is not properly centered or accessible, you should adjust the drapes till it is placed satisfactorily before proceeding
d. Draping is not essential as long as the area of interest is adequately cleaned

6. The patient should be placed in which position for central venous catheterizations:
   a. Fowler position
   b. Trendelenberg position
   c. Reverse Trendelenberg position
   d. Rose position

7. Which of the following is true with regards to surface marking the internal jugular vein
   a. The common carotid artery is medial to the internal jugular vein
   b. The internal jugular vein can only be accessed at the apex of the triangle formed by the clavicle and the 2 heads of the sternocleidomastoid muscle
   c. The internal jugular vein is found lateral and anterior to the common carotid artery 99% of the time
   d. The external jugular vein can be used as a landmark for the internal jugular vein

8. Inserting the local anaesthetic needle to locate the IJV includes the following EXCEPT:
   a. It should be inserted lateral to the common carotid artery pulsation
   b. It should be angled at about 30 degrees to the skin of the patient
   c. It should point towards the contralateral nipple
   d. It should be inserted at the apex of the triangle bounded by the clavicle and the 2 heads of the sternocleidomastoid muscle

9. The dilator should be inserted to a depth of:
   a. 1-2 cm
   b. 12-15 cm
   c. 25-30 cm
   d. The entire length of the dilator

10. With regards to sharps management, you should do the following
    a. Count the number of sharps you have and make sure you inform your nursing assistant the number of sharps that is to be cleared
    b. Dispose all used sharps and keep the sharps that were not used
    c. Make sure you recap all the sharps first before disposing
    d. Clear all sharps yourself

11. The proper placement of a right IJV central venous line on the CXR includes the following except:
    a. Tip of the catheter above the carina
    b. Tip of the catheter within the right atrium for more accurate central venous pressure
    c. Within and parallel to the walls of the superior vena cava
    d. Not abutting the walls of the superior vena cava

12. It has been shown that doctors who perform more than ___ CVC have less complications compared to those who have done less than this.
    a. 10
    b. 25
    c. 50
    d. 100

13. The Trendelenberg position may be detrimental to the following patients EXCEPT:
    a. The patient with a haemorrhagic stroke
    b. The patient with raised intraocular pressure
c. The patient with congestive cardiac failure
d. The patient with severe sepsis from a pneumonia

14. A central line should not be set in a patient who is:
   a. Awake
   b. Mechanically ventilated
   c. Sedated and paralysed
   d. None of the above

15. The risk of arterial puncture during central line insertion is greatest for this site:
   a. Right Internal Jugular Vein
   b. Left Subclavian Vein
   c. Right Femoral Vein
   d. Left Internal Jugular Vein
Appendix D: Post-intervention survey and post-preparation MCQ

TM Group:

The Role of Online Collaborative Learning in Simulation-Based Training of Clinical Skills: Survey 2

Date: ______________ Subject No: ______________

1. With regards to your learning in general, do you normally (Circle One)
   a. Read/Prepare before coming for a learning session such as a lecture.
   b. Read after attending a learning session
   c. Read before and after a learning session
   d. Just attend the session and not do any preparation or post reading

2. Do you feel that the preparatory materials were useful in teaching you to perform CVC? (i.e. with them, you feel like you would be better able to perform a CVC – circle one)
   Not Useful At All Somewhat Useful Useful Very Useful

3. Do you feel that after going through the preparation you will be able to learn the skill at the workshop faster?
   Not at all Somewhat Faster Faster Much Faster

4. Did you review any of the materials after the preparation session? Yes / No
   a. If yes, how much time did you spend in total (specify mins/hrs)? __________
   b. When was the last time you reviewed these materials? (Specify date) __________
   c. Did you print the reading materials? Yes/No
      i. If yes, estimate what percentage of time did you spend reviewing the reading materials from the printouts vs. reviewing from your computer?
         Printout viewing Computer viewing
         _____ % + _____ % = 100%

5. Did you use any other resources to help you prepare for this workshop? Yes/No
   a. If yes, what resources did you use? And how much time did you spend (specify mins/hrs)? ______________________________

6. How confident do you feel in placing a central venous catheterization on a simulated mannequin successfully? (on a scale of 0-10, with 0 being no confidence at all and 10 being very confident)
   __________________

7. Do you feel you would be as comfortable in the workshop if you had NO preparation?
   Much Less Comfortable Less Comfortable Just As Comfortable

8. Do you feel you would be more comfortable in the workshop if you had preparation through reading materials and an instructional video?
   No difference More Comfortable Much More Comfortable

9. Do you feel you would be as comfortable in the workshop if you ONLY had preparation WITH an instructional video but WITHOUT the reading materials?
10. Do you think an additional component of having an instructional video would
   a. Improve my learning experience \(\text{Yes / No}\)
   b. Enable me to learn CVC skill faster at the workshop \(\text{Yes / No}\)
   c. Be a waste of time; no added benefit for preparing for the workshop \(\text{Yes / No}\)

11. Do you think an additional component of having to evaluate error videos on central line insertion would
   a. Improve my learning experience \(\text{Yes / No}\)
   b. Enable me to learn CVC skill faster at the workshop \(\text{Yes / No}\)
   c. Be a waste of time; no added benefit for preparing for the workshop \(\text{Yes / No}\)

12. Do you think an additional component of online discussion with your fellow peers on the error videos would
   a. Improve my learning experience \(\text{Yes / No}\)
   b. Enable me to learn CVC skill faster at the workshop \(\text{Yes / No}\)
   c. Be a waste of time; no added benefit for preparing for the workshop \(\text{Yes / No}\)

If you have any other comments about your preparation for this workshop, please write them below.

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

OP Group:

The Role of Online Collaborative Learning in Simulation-Based Training of Clinical Skills: Survey 2

Date: _____________ Subject No:_____________

1. With regards to your learning in general, do you normally (Circle One)
   a. Read/Prepare before coming for a learning session such as a lecture.
   b. Read after attending a learning session
   c. Read before and after a learning session
   d. Just attend the session and not do any preparation or post reading

2. Do you feel that the preparatory materials were useful in teaching you to perform CVC? (i.e. with them, you feel like you would be better able to perform a CVC – circle one)

Not Useful At All Somewhat Useful Useful Very Useful
3. Do you feel that after going through the preparation you will be able to learn the skill at the workshop faster?

Not at all  Somewhat Faster  Faster  Much Faster

4. Did you review any of the materials after the preparation session?  Yes / No
   a. If yes, how much time did you spend in total (specify mins/hrs)?  
   b. Which materials did you review on your own after the session (circle all the relevant ones)? Estimate the percentage of time spent on each of the materials.
      i. Reading materials (including checklist)  
      ii. Instructional video  
      iii. Interactive Checklist/Reading Material  
      iv. “Spot the difference” activity or videos  
   c. When was the last time you reviewed these materials? (Specify date)  
   d. Did you print the reading materials?  Yes / No
      i. If yes, estimate what percentage of time did you spend reviewing the reading materials from the printouts vs. reviewing from your computer?
         Printout viewing  +  Computer viewing  = 100%

5. Did you use any other resources to help you prepare for this workshop?  Yes / No
   a. If yes, what resources did you use? And how much time did you spend (specify mins/hrs)?

6. Did you find the website easy to use?

   Not Easy  Somewhat Easy  Easy  Very Easy

7. Would you use such a website for learning other clinical procedures?  Yes/No

8. List the things you liked about the website.
   a.  
   b.  
   c.  
   d.  
   e.  

9. List the things you would improve about the website.
   a.  
   b.  
   c.  
   d.  
   e.  

10. Did you find the Spot the Difference activity a useful learning experience? (Circle one)

   Not Useful At All  Somewhat Useful  Useful  Very Useful
   a. Did you find it fun and engaging?  Yes / No
b. Did you feel it would be more fun and engaging if you did it with a group of peers (at the same time)?
   Yes / No

c. Do you feel watching these variations in performances in addition to the instructional video were beneficial to learning to perform CVC? (Circle one).

Not Beneficial at all  Somewhat Beneficial  Beneficial  Very Beneficial

11. To the best of your ability, rank the preparatory materials in order of how well you feel they prepared you to perform CVC (1 being most important, 4 being the least important):
   a. Reading materials (including checklist) ____
   b. Instructional video _____
   c. Interactive Checklist/Reading Material ____
   d. “Spot the difference” activity _____

12. To the best of your ability, rank the preparatory materials in order of how fun and engaging they were (1 being the most fun and engaging, 4 being the least):
   a. Reading materials (including checklist) ____
   b. Instructional video _____
   c. Interactive Checklist/Reading Material ____
   d. “Spot the difference” activity _____

13. Did you feel any of the preparatory materials were NOT useful in preparing you for performing a central line insertion (and could be omitted)? (Circle all that apply)
   i. Reading materials (including checklist)
   ii. Instructional video
   iii. Interactive Checklist/Reading Material
   iv. “Spot the difference” activity
   b. Of the items you felt were not useful, do you think they could be modified in such a way that would make them more useful?

14. How confident do you feel in placing a central venous catheterization on a simulated mannequin successfully? (on a scale of 0-10, with 0 being no confidence at all and 10 being very confident)
   ______________

15. Do you feel you would be as comfortable in the workshop if you had NO preparation?
   Much Less Comfortable  Less Comfortable  Just As Comfortable

16. Do you feel you would be as comfortable in the workshop if you ONLY had preparation through reading materials?
   Much Less Comfortable  Less Comfortable  Just As Comfortable

17. Do you feel you would be as comfortable in the workshop if you ONLY had preparation through reading materials and an instructional video?
18. Do you feel you would be as comfortable in the workshop if you ONLY had preparation through an *instructional video*?

Much Less Comfortable  Less Comfortable  Just As Comfortable

19. Do you think the addition of online discussion with your peers on error videos would (i.e. a collaborative online activity; for example: coming up with a list of differences for the Spot the Difference activity)
   a. Improve my learning experience  Yes / No
   b. Enable me to learn CVC skill faster at the workshop  Yes / No
   c. Be a waste of time; no added benefit for preparing for the workshop  Yes / No

If you have any other comments about your preparation for this workshop, please write them below.

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

OPEN Group:

The Role of Online Collaborative Learning in Simulation-Based Training of Clinical Skills: Survey 2

Date: _____________  Subject No:_____________

1. With regards to your learning in general, do you normally (Circle One)
   a. Read/Prepare before coming for a learning session such as a lecture.
   b. Read after attending a learning session
   c. Read before and after a learning session
   d. Just attend the session and not do any preparation or post reading

2. Do you feel that the preparatory materials were useful in teaching you to perform CVC? (i.e. with them, you feel like you would be better able to perform a CVC – circle one)

Not Useful At All  Somewhat Useful  Useful  Very Useful

3. Do you feel that after going through the preparation you will be able to learn the skill at the workshop faster?

Not at all  Somewhat Faster  Faster  Much Faster

4. Did you review any of the materials after the preparation session?  Yes / No
   a. If yes, how much time did you spend in total (Specify mins/hrs)?  ________
   b. Which materials did you review on your own after the session (circle all the relevant ones)? Estimate the percentage of time spent on each of the materials.
      i. Reading materials (including checklist)  _____________%
ii. Instructional video

iii. Interactive Checklist/Reading Material

iv. “Spot the difference” activity

v. “Spot the difference” answers from your peers

vi. Collaborative Learning Discussion forum

vii. Expert debriefing of the “Spot the difference” activity

c. When was the last time you reviewed these materials? (Specify date)

d. Did you print the reading materials? Yes / No

i. If yes, estimate what percentage of time did you spend reviewing the reading materials from the printouts vs. reviewing from your computer? Printout viewing + Computer viewing = 100%

5. Did you use any other resources to help you prepare for this workshop? Yes / No

a. If yes, what resources did you use? And how much time did you spend (specify mins/hrs)?

6. Did you find the website easy to use? Not Easy Somewhat Easy Easy Very Easy

7. Would you use such a website for learning other clinical procedures? Yes / No

8. List the things you liked about the website.

a. ____________________________

b. ____________________________

c. ____________________________

d. ____________________________

e. ____________________________

9. List the things you would improve about the website.

a. ____________________________

b. ____________________________

c. ____________________________

d. ____________________________

e. ____________________________

10. Did you find the Spot the Difference activity to be useful learning experience? (Circle one)

Not Useful At All Somewhat Useful Useful Very Useful

a. Did you find it fun and engaging? Yes / No

b. Did you feel it would be more fun and engaging if you did it with a group of peers (at the same time)? Yes / No

c. Do you feel watching these variations in performances in addition to the instructional video were beneficial to learning to perform CVC? (Circle one).

Not Beneficial at all Somewhat Beneficial Beneficial Very Beneficial

11. Did you find it a useful learning experience to engage in the collaborative learning activity (i.e. online discussion) with your peers? (Circle one)

Not Useful At All Somewhat Useful Useful Very Useful
a. Did you find it fun and engaging? 
   Yes/No

b. Did you find this stressful? 
   Yes/No

c. Do you feel the time provided to engage in discussion was adequate? 
   Yes/No
   i. If no, was it too (Circle): short  long
   ii. How long would you have preferred (in days)? _____

d. Was it important that your real identity remained hidden for the online interaction? 
   Yes/No
   i. If no, do you think the discussion would be improved if you knew who your peers were? 
   Yes/No

e. Would you prefer that an expert was present during the discussion? 
   Yes/No
   Please discuss why.

12. To the best of your ability, rank the preparatory materials in order of how well you feel they prepared you to perform CVC (1 being most important, 7 being the least important):
   a. Reading materials (including checklist) _____
   b. Instructional video _____
   c. Interactive Checklist/Reading Material _____
   d. “Spot the difference” activity _____
   e. “Spot the difference” answers from your peers _____
   f. Collaborative Learning Discussion forum _____
   g. Expert debriefing of the “Spot the difference” activity _____

13. To the best of your ability, rank the preparatory materials in order of how fun and engaging they were (1 being the most fun and engaging, 7 being the least):
   a. Reading materials (including checklist) _____
   b. Instructional video _____
   c. Interactive Checklist/Reading Material _____
   d. “Spot the difference” activity _____
   e. “Spot the difference” answers from your peers _____
   f. Collaborative Learning Discussion forum _____
   g. Expert debriefing of the “Spot the difference” activity _____

14. Did you feel any of the preparatory materials were NOT useful in preparing you for performing a central line insertion (and could be omitted)? (Circle all that apply)
   i. Reading materials (including checklist)
   ii. Instructional video
   iii. Interactive Checklist/Reading Material
   iv. “Spot the difference” activity
   v. “Spot the difference” answers from your peers
   vi. Collaborative Learning Discussion forum
   vii. Expert debriefing of the “Spot the difference” activity

   b. Of the items you felt were not useful, do you think they could be modified in such a way that would make them more useful?
15. How confident do you feel in placing a central venous catheterization on a simulated mannequin successfully? (on a scale of 0-10, with 0 being no confidence at all and 10 being very confident)

16. Do you feel you would be as comfortable in the workshop if you had NO preparation?

<table>
<thead>
<tr>
<th>Much Less Comfortable</th>
<th>Less Comfortable</th>
<th>Just As Comfortable</th>
</tr>
</thead>
</table>

17. Do you feel you would be as comfortable in the workshop if you ONLY had preparation through reading materials?

<table>
<thead>
<tr>
<th>Much Less Comfortable</th>
<th>Less Comfortable</th>
<th>Just As Comfortable</th>
</tr>
</thead>
</table>

18. Do you feel you would be as comfortable in the workshop if you ONLY had preparation through reading materials and an instructional video?

<table>
<thead>
<tr>
<th>Much Less Comfortable</th>
<th>Less Comfortable</th>
<th>Just As Comfortable</th>
</tr>
</thead>
</table>

19. Do you feel you would be as comfortable in the workshop if you ONLY had preparation through an instructional video?

<table>
<thead>
<tr>
<th>Much Less Comfortable</th>
<th>Less Comfortable</th>
<th>Just As Comfortable</th>
</tr>
</thead>
</table>

If you have any other comments about your prep for this workshop, please write them below.

________________________________________________________________________________________________________________

Post-preparation MCQ:

1. With regards to complications of central venous catheterization of the IJV, which of the following statement is true:
   a. Overall complications can be as high as 15%  
   b. Thrombotic complications will not occur if strict aseptic technique is adhered to  
   c. Wire embolism is a common complication that is easy to rectify  
   d. If an accidental arterial puncture occurs, you should stop the procedure on that side and set the catheter on the contralateral side.

2. While inserting the central venous line, you aspirate air into the central line needle. This could mean that you have:
   a. Caused an arterial puncture  
   b. A successful cannulation but air is within the internal jugular vein  
   c. Caused a pneumothorax  
   d. Caused a thrombosis to occur in the internal jugular vein
3. The best solution for cleaning the site for central venous catheterizations is
   a. Povidone iodine
   b. Normal saline
   c. Chlorhexidine
   d. Heprinized saline
4. The following can be used for local anaesthetic
   a. Midazolam
   b. Succinylcholine
   c. Diazepam
   d. Lidocaine
5. The guidewire should be inserted to a maximum depth of:
   a. 1-2 cm
   b. 12-15 cm
   c. 25-30 cm
   d. The entire length of the guidewire
6. With regards to the central venous catheter, the following is FALSE:
   a. Infectious complication rate increases with additional lumens/ports
   b. A 7F single lumen catheter is not as good as a 7F triple lumen catheter for fluid boluses in a
      resuscitation
   c. A 16 cm catheter can be used for central venous catheterization of the IJV
   d. The central venous catheter should be removed as soon as possible once it is no longer required
7. You would ask your nurse to prepare which suture material for securing the central line:
   a. 1/0 Silk
   b. 3/0 Silk
   c. 10/0 Silk
   d. 10/0 Prolene
8. The following are potential breach of sterile technique EXCEPT:
   a. Redraping the patient several times with the same drape
   b. Touching your sterile gown accidentally with your sterile gloved hands
   c. Adjusting your face mask with your sterile gloved hands halfway through the procedure
   d. Not wearing face mask and cap
9. The following are reasons for a slight Trendelenberg position for CVC insertion EXCEPT:
   a. Preventing air embolism
   b. Engorgement of the neck veins for easier insertion
   c. Especially useful for CVC in a septic shock patient
   d. For patient’s comfort
10. The Trendelenberg position is most likely to post difficulty in which patient:
    a. The patient with septic shock
    b. The patient with cardiogenic shock
    c. The patient with anaphylactic shock
    d. The patient with haemorrhagic shock
11. The distal end of the guidewire is curved so that:
    a. It helps prevent vessel injury
    b. It helps prevent arrhythmia
    c. It helps prevent infectious complications
d. It is for aesthetic reason

12. The following can be used as an indication that you have cannulated the internal jugular vein EXCEPT:
   a. Slow ooze of dark blood occurs on removal of the syringe
   b. The plunger of the syringe is pushed by the force of the blood
   c. The presence of a central venous pressure waveform when connected to a pressure transducer
   d. A significant low blood saturation compared to an arterial sample of the same patient

13. On reviewing the CXR, you realize that the tip of the catheter is below the carina and abutting the wall of the vessel. This could mean the following EXCEPT:
   a. The catheter could be in the right atrium
   b. There is an increased risk for arrhythmias
   c. There is a risk for pericardial tamponade
   d. There is an increased risk of a pneumothorax

14. Which of the following statements are true:
   a. Central lines are required in all patients in the intensive care unit
   b. Central lines are more efficient at fluid resuscitation compared to peripheral venous catheters
   c. Central lines must not be placed in the patient who has coagulopathy
   d. Central lines with multiple ports could result in a higher rate of infection compared to central lines with a single port

15. The risk of infection for central lines is greatest for this site:
   a. Right Internal Jugular Vein
   b. Left Subclavian Vein
   c. Right Femoral Vein
   d. Left Internal Jugular Vein
Appendix E: Post-training survey

The Role of Online Collaborative Learning in Simulation-Based Training of Clinical Skills: Survey 3

Date:_____________  Subject No:_____________

1. Did you find that the learning activities achieved its objectives of
   a. Increasing knowledge of central line insertion
      Did not achieve  Somewhat achieve  Achieved
   b. Improving your technical skills of central line insertion on a mannequin
      Did not achieve  Somewhat achieve  Achieved
   c. Improving comfort level of performing central line insertion on real patients
      Did not achieve  Somewhat achieve  Achieved
      Improving your technical skills of central line insertion on a real patient
      Did not achieve  Somewhat achieve  Achieved

2. How much do you feel the following activities contributed to your KNOWLEDGE about central line insertion?
   a. Preparation Phase
      No contribution  Some contribution  Significant contribution
   b. Simulation Workshop
      No contribution  Some contribution  Significant contribution
   c. Retention Test and Feedback
      No contribution  Some Contribution  Significant Contribution

3. How much do you feel the following activities contribute to your SKILL of central line insertion?
   a. Preparation Phase
      No contribution  Some contribution  Significant contribution
   b. Simulation Workshop
      No contribution  Some contribution  Significant contribution
   c. Retention Test and Feedback
      No contribution  Some Contribution  Significant Contribution

4. With regards to knowledge building and facts, do you think (circle)
   a. Simulation workshop was equivalent/better/worse as compared to attending all 3 components (Preparation + Simulation + Retention Test & Feedback)
   b. Simulation workshop + Retention Test & Feedback are equivalent/better/worse as compared to all 3 components.
   c. Simulation workshop + Preparation are equivalent/better/worse as compared to all 3 components

5. With regards to skills acquisition, do you think (circle)
   a. Simulation workshop was equivalent/better/worse as compared to attending all 3 components (Preparation + Simulation + Retention Test & Feedback)
b. Simulation workshop + Retention Test & Feedback are equivalent/better/worse as compared to all 3 components.
c. Simulation workshop + Preparation are equivalent/better/worse as compared to all 3 components.

6. Do you feel that your preparation helped you in performing a central line during your simulation-based education workshop? Yes / No
   (If yes please answer the following; if no, skip and go to the next question)
   a. If you were to create a preparatory website for CVC, what do you think are the optimal materials for online preparatory materials that would help you perform a central line better and faster in the simulation workshop? (Circle all relevant items and then rank, with 1 being most relevant)
      i. General reading material on central line insertion (e.g. textbook passage)
      ii. Specific instructional reading material on central line insertion
      iii. Video describing central line insertion (like the NEJM video)
      iv. Step-by-step video demonstration by an expert
      v. Video demonstration of how to handle the various equipment used in central line insertion, such as the syringes, catheter, the guidewire
      vi. Video demonstration of how to perform steps that are commonly found to be difficult, such as using the one-hand technique for syringe manipulation and locating the IJV
      vii. Video demonstration of common errors by novice learners
      viii. “Spot the error” video activity with feedback just prior to the simulation workshop
      ix. “Spot the error” video activity with immediate feedback online
      x. Interactive checklist for central line insertion with links to relevant portion of the reading materials and video demonstration
      xi. Self assessment test (e.g. MCQ with answers and feedback during the simulation workshop)
      xii. Self assessment test with immediate feedback online
      xiii. Online group discussion on the “how” and “why” of central line insertion without an expert
      xiv. Online group discussion forum on the “how” and “why” of central line insertion led by an expert?
      xv. Online group discussion on the “how” and “why” of central line insertion with an expert (asynchronous: ie expert and participants log in comments anytime of the day at their convenience)
      xvi. Online group discussion on the “how” and “why” of central line insertion with an expert (synchronous: ie expert and participants log in all at the same time and have an active discussion)
      xvii. A general discussion forum for questions and answers about central line insertion (or specific prep materials) moderated by an expert
   b. Do you feel you would be more inclined to use the preparatory materials if they were made available online than if they were offline? Yes / No
   c. How long would you want to have this preparatory material made available to you before the workshop? (state no. of days in advance) _______days
d. Is it beneficial to have this preparatory material available to you after the workshop?  
   Yes / No

7. If it was not compulsory to go through the preparatory materials prior to the workshop, how likely are you to prepare for the workshop if preparatory material were made available to you through the website?  
   Unlikely Likely Very Likely

8. With regards to the simulation-based training, which method of training do you feel you would have learned best from? (Assuming you have only 1 hr to achieve all 28 steps) (Circle only one)
   a. Familiarization with the equipment and performing perceived difficult steps before proceeding to do the entire procedure with feedback... (circle one below)
      i. after each attempt
      ii. immediate feedback
   b. Repeated practice of the entire procedure, self-learning during the procedure and feedback given after the each attempt on the difficult steps and correction of errors (similar to this workshop)
   c. Repeated practice of the entire procedure but with halting in between the procedure for immediate feedback for difficult steps and correction of errors.

9. Do you feel video demonstration and live demonstration are equally beneficial for acquiring clinical skill in a procedure such as CVC?  
   Yes / No
   a. If no, which is more beneficial?  
      Video / Live