Online versus Face-to-Face: Development, Refinement, Implementation, and Evaluation of an Online Intravenous Pump Emulator, Including Outcomes for Clinical Practice for Nursing Students

Doctor of Philosophy

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Abstract

Preparing undergraduate nursing students for the nursing profession via distance education has created the challenge of finding innovative ways to teach clinical skills online. As intravenous (IV) pump devices are commonly used in clinical settings, gaining competence in their use is of particular importance for nursing students. The purpose of the present research was to develop, refine, implement and evaluate an online IV pump emulator (IVPE) modelled on the actual IV pumps used in on-campus nursing laboratories, with the specific aim of evaluating student's learning outcomes along with their perceptions of device use. Using a quasi-experimental design method including a longitudinal element, the implementation and evaluation was undertaken among undergraduate nursing students using the online IVPE, an actual IV pump, or a combination of the two. In Stage 1, a prototype online IVPE was developed and evaluated using Remote Access Laboratory (RAL) technology. In Stage 2, the prototype online IVPE underwent preliminary evaluation by first year undergraduate nursing students ($n = 20$) to assess its functionality, perceptions of use, and equivalence in learning outcomes compared to nursing students using an actual IV pump. In Stage 3, a more comprehensive mixed-methods evaluation was conducted with refined methods and an improved version of the online IVPE. A larger sample of first year undergraduate nursing students ($n = 179$) was divided into online only, on-campus only and online + on-campus user groups. In the final stage, retention of competency in actual IV pump use was evaluated among a sub-sample of Stage 3 participants ($n = 102$) as they progressed into the next year of their program. No significant differences in learning outcomes were found between the online only and on-campus only groups, thus demonstrating equivalency of the online technology with the traditional face-to-face training with an actual IV pump in a simulated laboratory. Significantly better learning outcomes were evident among the combined group, who trained with both forms of the IV pump, compared to the online only and on-campus only groups. At the 26-week follow-up testing period, the combined group showed superior learning outcomes on some activities and completed the activities on the actual IV pump faster than the other two groups. A high percentage of participants, regardless of group, reported feeling confident using the actual IV pump. In summary, the online IVPE was shown to produce equivalent learning outcomes to traditional training methods, and superior learning outcomes when used in conjunction with face-to-face training; thereby contributing to more competent nurses responsible for the preparation and administration of IV infusions. Recommendations on the viability of including the IVPE as an online resource in undergraduate nursing programs locally and internationally are provided.

Certification of Dissertation

I certify that the ideas, experimental work, results, analyses, software, and conclusions reported in this dissertation are entirely my own effort, except where otherwise acknowledged. I also certify that the work is original and has not been previously submitted for any other award, except where otherwise acknowledged.

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Victoria R Terry Date

ENDORSEMENT

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Associate Professor Clint Moloney Date

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Dr Leslie Bowtell Date

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Dedication

My husband, Peter

and

My son, Finn

Love always,

Dr Pump

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List of Abbreviations

AAT	Assessment Activity Tool
ACSQHC	Australian Commission on Safety and Quality in Health Care
CPR	Cardio-Pulmonary Resuscitation
ECG	Electrocardiogram
HWA	Health Workforce Australia
HMI	Human-Machine Interface
IM	Intramuscular
IV	Intravenous
IVPE	Intravenous Pump Emulator
LMS	Learning Management System
NQC	National Quality Council
NMBA	Nursing and Midwifery Board of Australia
ONL	Online participants
ONC	On-campus participants
ONL + ONC	Online and On-campus participants
OSCE	Objective Structured Clinical Assessment
PLC	Programmable Logic Controller
RAAT	Revised Activity Assessment Tool
RAL	Remote Access Laboratory
RN	Registered Nurse
SCADA	Supervisory Control and Data Acquisition
SDT	Self-Determination Theory
SL	Second Life
USQ	University of Southern Queensland
UTS	University of Technology Sydney
VTBI	Volume To Be Infused

Chapter 1

Introduction

1.1 Background

A shift in the education of nurses came about in the 1960s due to professional unrest about wages and conditions as the role of the nurse became increasingly demanding and complex (Russell, 2005). A decade later, in the 1970s, it was reported that technology was advancing in hospitals, and nurses were more exposed to and more accountable to patient care, including operating new equipment and devices (Russell, 2005). Along with more demanding working conditions, more complex health problems, and advances in health care delivery, came the need for nurses to be more professionally accepted and better educated. As a result, the transfer of nursing education from hospitals to higher education institutions was achieved throughout Australia by 1993 (Francis, 1999; Russell, 2005). University programs emphasised the delivery of quality, current, and meaningful education to nursing students, incorporating the principles of patient-centred care, evidence-based practice, team work and collaboration, quality improvement, safety, and technology (Cronenwett et al., 2007).

These factors provided the background and laid the foundations for the present research. If a nursing student on a clinical practicum were to negotiate a complex health care issue using unfamiliar equipment, patient safety could be compromised. Therefore, exposing undergraduate nursing students to new technologies, advanced equipment and skills, before introducing them to acute clinical environments formed the rationale for this research. In addition, the introduction of an external/off-campus program for nurses created a clinical skills “hands-on” challenge that further compounded the need for exposure to, and mastery of, technology. Discovering ways to effectively deliver clinical skills to external students in order to promote patient safety was a priority requiring immediate and further investigation.

Feedback from facilitators, preceptors and registered nurses from the profession showed that nursing students on medical and surgical placements were inadequately equipped with clinical reasoning skills and competency with clinical equipment and procedures (Cottrell & Donaldson 2013). This type of feedback, despite making educators feel ineffective was welcomed as it created the realisatiodaily n that it was time for a fresh approach to lift standards towards producing more competent nurses. Furthermore, it directed future education practices to take specific focus on building skills through the scaffolding of learning. Patients' lives depend on it. In 2011 at an Australian regional university, the course examiner for one of the most influential courses in a nursing degree, *Medications Theory and Practice,* following discussions with clinical staff, determined that the external offering for nursing students included minimal exposure to clinical equipment prior to their first clinical practicum. This sparked the need to seek effective and innovative ways to offer exposure of common clinical equipment to the external cohort of students. The realisation of a need to create effective resources using online technology provided impetus for the present research (Hadar, 2013).

Around this time, the Remote Access Laboratories (RAL) and robotic experimentation were brought to the attention of nursing academics by a team of engineers who were exploring ways to implement their technology into other disciplines. During late 2011, RAL was becoming a significant technological pathway for delivery of education at the university. From discussions between nursing and engineering academics emerged the idea of transforming clinical equipment from simulated laboratories to the online learning space for nursing students. Fundamental to this transition was the assurance and commitment (to the external nursing students) to deliver accessible, meaningful, evidence-based and high quality educational clinical resources online.

With this in mind, a team of nursing academics sought to extend the concept of RAL from robotic laboratory experiments to practical nursing activities and skills. A range of clinical equipment used by nursing students in the simulated laboratories was reviewed by the team. Procedures and skills from day-to-day learning and teaching activities were also reviewed, some of which were considered to have potential to be offered to all students through RAL. Of the clinical equipment with which nursing students practice frequently (repeatedly testing their knowledge, skills and clinical reasoning) the IV infusion pump was chosen as a prime candidate for inclusion in RAL. The IV pump is a common device used on a daily basis by nurses when caring for patients in health facilities all around the world. The use of IV pumps to deliver volumes of fluid is indicated in many health scenarios from mild dehydration to lifesaving fluid replacement situations. IV pumps are used for infants, children and adults to infuse blood products, medications, and therapies associated with the treatment of thousands of disease and conditions. It is essential that nurses are competent in the use of IV pump devices (Tollefson, 2012), which is why the education and training of IV pumps for student nurses is so integral in their program of tertiary study.

Next, a mapping exercise was undertaken whereby a series of questions about the steps involved in commencing an IV infusion via an IV pump were presented to nursing educators and students. These steps included turning on the IV pump, responding to the start-up default setting, inserting the IV tubing, setting the rate and volume to be infused, starting the IV pump, changing the set rate and volumes, troubleshooting, responding to alarms, and turning off the IV pump. Gathering this information was designed to assist the engineers in their preliminary investigation in understanding the functions of an IV pump, thus allowing them to determine the viability of the experiment.

The transferability of an IV pump operation to the online environment was initially examined using robotic technology through RAL, which marked the start of the different stages of research, highlighted later in this chapter. Changes to traditional educational delivery requires different pedagogical approaches that will effectively enable the design, facilitation and assessment of content knowledge including the ability to support the students and their technical skills (Redmond, 2011).

1.2 Rationale for the Research

The program of research was undertaken with the primary aim of improving the safety and effectiveness of health care delivery by nursing students. The increasing demand for university nursing students to have access to online educational resources necessitated the development and evaluation of innovative technologies capable of producing the required learning outcomes (Harder, 2013). More specifically, university education offered by distance to nursing students should simulate, as far as possible, the realities of a hospital ward and ensure that graduates are competent in skills and techniques fundamental to their professional practice (Mancuso-Murphy, 2007). With the emphasis on delivering quality and safe health care, comes the expectation that nursing students receive a sound education formulated on evidence-based practices, however a program is delivered.

The present research aimed to elicit evidence that an online IV pump could produce equivalent or improved learning outcomes, using a systematic and evidence-based approach. This is primarily to determine whether an online IV pump could be considered as a viable tool to deliver best practice education to undergraduate nursing students. The Joanna Briggs Institute (JBI) model of evidence-based health care, is an Australian model that describes a process of drawing evidence from health care innovations and activities, and applying it to practice (Lockwood, Aromataris & Munn, 2014; Pearson, Wiechula & Lockwood, 2005). This model was considered in the process of designing the present research and when the various stages were developed and undertaken. FAME is the acronym used in the model, representing the concepts of Feasibility, Appropriateness, Meaningfulness and Effectiveness. Feasibility (i.e., the extent to which an activity is practical and practicable), appropriateness (i.e., the extent to which an intervention is apt in a situation), meaningfulness (i.e., the extent to which an intervention is positively experienced) and effectiveness (i.e., the extent to which an intervention achieves the intended effect) of the online IVPE had to be established to provide a credible evidence base to support its use in clinical practice. Pearson and colleagues (2005) argued that if these concepts are demonstrated through well-designed research, then the evidence is credible. Having established the central research question of whether computer-assisted online technology provides an equivalent educational experience to the traditional face-to-face approach, an appropriate research design was developed to evaluate the outcomes in relation to credible clinical performance (Nagy, Mills, Waters, & Birks, 2010).

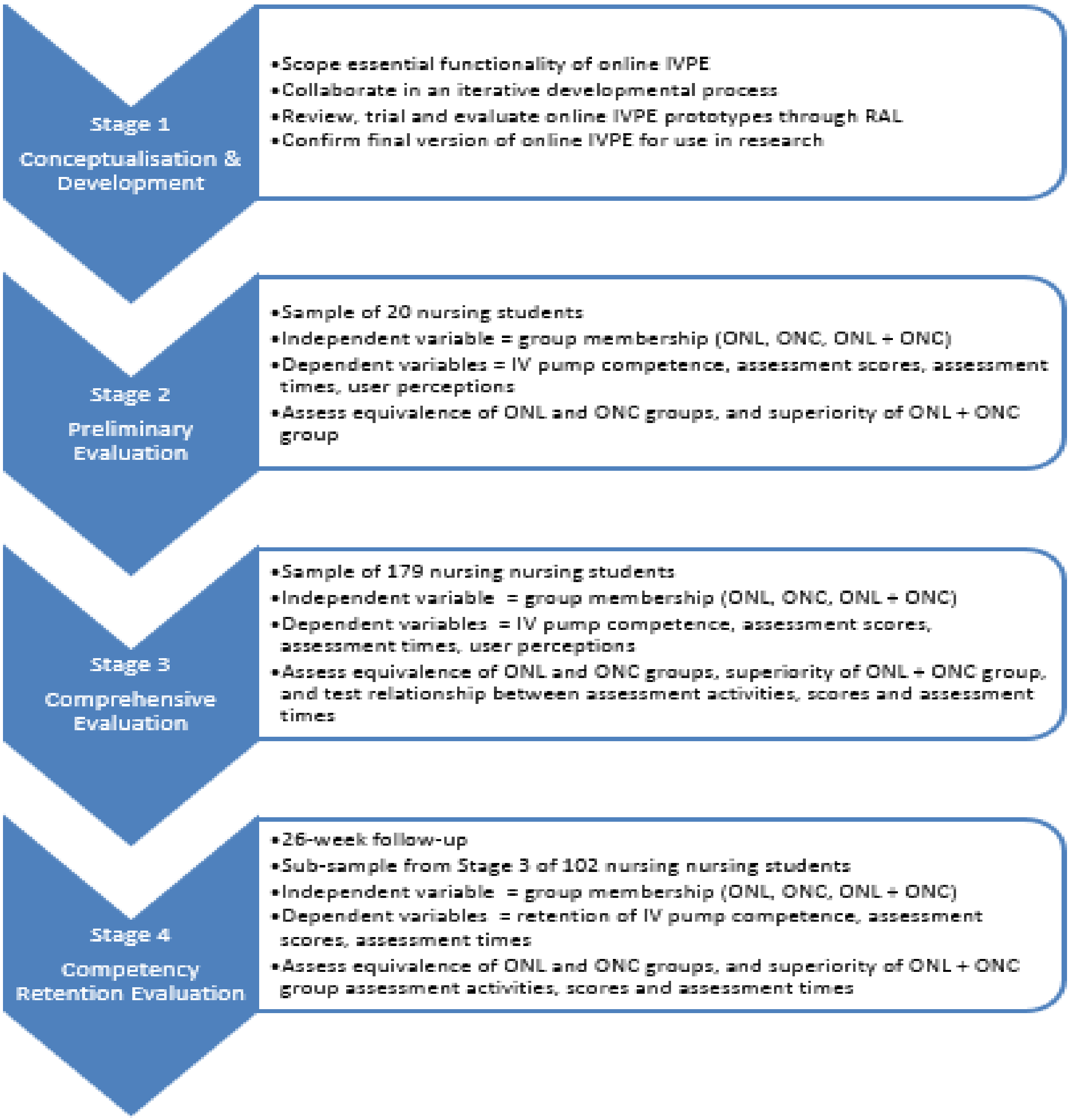
1.3 Structure of the Thesis

The thesis is divided into seven chapters. This introductory chapter provides an overview of the subject matter and an outline of the research stages and processes. Chapter 2 contains a detailed literature review, including the theoretical and conceptual underpinnings of the research. It is followed sequentially by the four stages of research reported in Chapters 3, 4, 5, and 6. Chapter 7 presents a general discussion of the findings.

1.4 Stages of the Research

The program of research had four stages (see Figure 1.1). Stage 1 involved the collaborative design of the online IVPE using a RAL platform. Stage 2 was a preliminary evaluation of the online IVPE to test its equivalence to an actual IV pump. Also in this stage was the assessment of traditional face-to-face instruction in developing competence in the use of an actual IV pump compared to online instruction. User perceptions of the online IVPE were also assessed and evaluated. Results from this stage of the research informed the refinement of features of the online IVPE that supported the learning outcomes for nursing students both externally and on-campus, and helped to refine the research methodology for the next stage of the research. Stage 3 was a comprehensive evaluation of a refined online IVPE using revised methods, with a new, larger cohort of first year Bachelor of Nursing students. Stage 4 assessed the retention of competency in using the actual IV pump by a sub-group of the same cohort of nursing student participants used in Stage 3, as they progressed through into the second year of their program.

For Stages 2 and 3 a quasi-experimental research design was used, and for Stage 4 a longitudinal element was added to the methodology. This research design is both readily applicable to clinical nursing practice and appropriate for a between-group comparison (Nagy et al., 2010) to evaluate the equivalence of an online educational resource to the traditional face-to-face training of undergraduate nursing students.



Note. RAL = Remote Access Laboratory; IV = Intravenous, IVPE = Intravenous Pump Emulator; ONL = Online Group, ONC = On-campus Group, ONL + ONC = Online + On-campus Group.

Figure 1.1. Stages of research.

Outcome variables were assessed using both direct and indirect methods. The direct method of assessment was designed to provide evidence of competence gained in using clinical equipment and the extent to which the required competence was retained over time. The indirect measures took the form of surveys to assess user perceptions of the training, features of the technology used, and level of confidence in using the equipment and technology.

1.5 Ethics

The program of research received ethics approval from the University of Southern Queensland (USQ) Human Ethics Committee on 30/7/2012 - HREC Approval Number: H12REA154 (see Appendix A). The key ethical issues in the research were that the participants were well informed and provided with a Plain Language Statement with the offer to keep a copy for their records. Participant consent was voluntary and obtained throughout all stages of research. The participants could not be involved in the research unless they were 18 years of age or over and could withdraw at any time with no adverse effects. The consent process was deemed to be ethical.

It was assessed that there were no foreseeable risks associated with the research other than a small time imposition of up to 1 hour for some participants involved in Stages 3 and 4. The participants were well informed that the research would not impact on their assessment of the course of study in any way. The results of the research are available to the participants through the Study Desk Learning Management System and storage of electronic and raw data is compliant with University ethical regulations.

Minor amendments were submitted and approved on 12/10/2012 - HREC Approval Number: H12REA154.1 (see Appendix B) with further amendments submitted for Stages 3 and 4 which were approved by the USQ Human Ethics Committee on 04/09/2013 - HREC Approval Number: H12REA154.2 (see Appendix

C). The information for participants and participant consent form for Stage 2 can be located in Appendix D.

1.6 Preface

The education of nursing students in universities has traditionally been a very "hands-on" process, delivered in on-campus simulated hospital wards using manikins as patients and a range of other simulated and clinical equipment. The move to online and distance education and the flexible delivery of teaching has meant that health care educators have had to explore innovative teaching delivery methods (Mancuso-Murphy, 2007). Core components of any undergraduate nursing program are to teach the required clinical knowledge and to effectively develop the necessary clinical skills. Undergraduate nursing students in external programs have no daily access to the physical resources available to their on-campus counterparts. Therefore, to support their educational experience, it is incumbent on academic and other teaching staff to source, develop, design and implement a variety of resources to supplement the face-to-face teaching. Training nursing students in the use of clinical equipment using online tools is increasingly necessary, but prior to implementing such initiatives, it is essential that a substantive evidence-base for the equivalence of online simulation with traditional teaching methods be established (Pearson et al., 2005).

Online technology designed for nurse education purposes may also have benefits for those already working in the profession. Kenny (2002) reported that many nurses, especially older or more mature nurses, describe being anxious about using technology in a clinical environment. Furthermore, several barriers to engagement with digital technology by nursing professionals have been highlighted (Eley, Fallon, Soar, Buikstra, & Hegney, 2009). Such barriers included workload demands, access to computers at work and lack of support for adopting technology in the workplace (Eley, et al., 2009). There is no doubt that computers and technology have become more common in health care administration, but work demands on ward nurses may be an ongoing barrier to their use. A recent study comparing nurse educators from a tertiary teaching institution to clinical staff working in a hospital setting found that the university educators reported superior knowledge and skill about clinical evidence-based practice (Upton, Scurlock-Evans, Williamson, Rouse, & Upton, 2015), suggesting that even experienced nursing professionals may derive benefit from competency development opportunities afforded by the same online educational technologies and resources used by students.

One of the most compelling reasons for implementing technology-assisted simulated learning into nurse education was put forward by Messmer (2008) who promoted the education of nurses using advanced technologies as a solution to an escalating number of patient deaths resulting from iatrogenic factors (i.e., illness caused by medical treatment). In Australia, statistics indicate that iatrogenic hospital death tolls are equivalent to two jumbo jet disasters annually, and that being a patient in an Australian hospital places already sick individuals at increased risk (Messmer, 2008). In critical incidents requiring rapid decision-making and actions, often utilising clinical equipment and medications, patient outcomes are improved by targeting ways in which nurses can learn to deliver care under controlled and safe conditions (Messmer, 2008). Further, technology-assisted simulation is viewed as an appropriate way to prepare nursing students to perform competently in all clinical situations, but particularly in stressful scenarios (Messmer, 2008).

More recent and compelling evidence in a health workforce review commissioned by the World Health Organization (WHO) found that students studying in the health professions gain knowledge and skills through online and offline eLearning as well as, or better than, through traditional training. The WHO has expressed the firm view that millions of students worldwide could be educated and become qualified doctors and nurses through electronic learning which, in the review, was found to be just as effective as traditional educational means (Al-Shorbaji, Atun, Car, Majeed, & Wheeler, 2015).

Developments in the use of RAL have expanded the potential for providing undergraduate nursing students with exposure to interactive online technology and virtual clinical scenarios. A RAL system allows university students, regardless of location, to actively engage in learning activities, especially those involving simulated equipment or experimentation, without requiring on-campus attendance. The educational experience that is facilitated by RAL is characterised by accessibility to information with a supported personalised approach to learning (McLoughlin & Lee, 2010) and hence provides an appropriate platform for the development of clinical skills from off-site locations.

With the underlying technology now well established, health-related disciplines are moving rapidly to embrace the potential to develop essential competencies for health professionals in online environments that offers geographical flexibility. Such an approach has potential benefits for learners, especially in maintaining life-study balance and developing competencies at a rate appropriate to the individual. More importantly, from a patient safety perspective, the development of clinical competencies to a high standard through the use of online virtual environments is clearly advantageous prior to allowing the treatment of actual patients by novice practitioners. The medical profession has enthusiastically embraced the development of surgical skills using virtual operating technology (Bric, Connolly, Kastenmeier, Goldblatt, & Gould, 2014; Kim, Choi, Park, & Park, 2014; Schreuder, Wolswijk, Zweemer, Schijven, & Verheijen, 2012) and the nursing profession has used remote technology to, for example, teach insulin administration and wound care (Sampsel, Bharwani, Mehling, & Smith, 2011).

The present program of applied research targeted the development, using remote-access technology, of clinical competence of undergraduate nursing students in the use of IV pump equipment, which is a fundamental requirement for all nursing professionals. The critical importance of effective training in the use of IV equipment by nurses was highlighted in a 1993 legal case in which systemic deficiencies in nurse training, rather than incompetence on the part of the inexperienced nurse involved, were blamed for a medication error using an IV infusion device that led to the death of a patient in Scotland (Dimond, 1994). On its own, this tragedy provides a compelling rationale for the need for further research into innovative strategies to develop clinical competence among those in preparation for a career in nursing.

1.7 Research Aims

The overall aim of the research was to design, refine, implement, and evaluate an online IVPE for the purpose of supporting online education of undergraduate nursing students. This included providing an authentic learning experience for nursing students to access, utilise, and practice with an online version of an IV pump. More specifically, the research provided information regarding the equivalence, benefits or negatives for online nurse education compared to traditional methods of face-to-face teaching and learning. In addition, the learning outcomes of the nursing students who were instructed and practiced solely online, solely face-to-face or with both methods, were compared.

In Stage 3, there was also an aim to determine whether participants from the different groups performed better on specific activities and functions with the actual IV pump. A further aim was to establish perceptions of useability and functionality of the online IVPE, including accessing the program via RAL, gauging student interest and motivation in accessing a unique online teaching tool in order to evaluate and refine the online IVPE protocols and assessment activities. Finally, in Stage 4, there was the aim to evaluate the retention of competency using the actual IV pump after 26 weeks of no exposure to the equipment. These research aims will be discussed more specifically where they align with the various stages of the research project.

Chapter 2

Review of Literature

This chapter includes a detailed review of the literature relevant to the present research. The search procedures encompassed peer-reviewed literature sourced from databases including MEDLINE, PubMed, Google Scholar, and CINAHL, accessed via the EBSCO Host platform. The keywords searched were specific to nursing education, namely: medication errors, intravenous and IV medication errors, face-to-face education, online education, distance education, blended education, clinical skills, simulation, emulation, remote access laboratories, robotics, virtual and second life technology, information technology in nursing, competency of skills, objective structured clinical assessment (OSCE), confidence, clinical reasoning, and retention of skills.

Despite the paucity of research on the specific topic of computerised or online IV infusion pump programs, closely associated topics were critically evaluated for strengths and limitations. The review of literature is structured to first address research related to the safe medication administration by nurses, especially in the area of IV medications and infusion pumps. Current learning and teaching practices for undergraduate nursing students and education delivery trends will then be explored. Such topics include traditional face-to-face education, simulation practices, flexible and blended programs of study and specific assessment methods used currently in undergraduate nursing education; some which are the same methods used in the current research.

Specific areas of online education will be discussed in detail. Particular attention is given to the practices in relation to teaching clinical skills to nursing students through computer-assisted means including digital, virtual and remote delivery practices in distance education. The literature review will also explore the assessment of competency of clinical skills in nursing education, levels of confidence, and the retention of knowledge and clinical skills by nursing students and students from other health-related disciplines. The theoretical and conceptual foundations to which the research is linked are outlined, and finally some significant terms that appear throughout the research are defined in context for the reader.

2.1 Medication Administration by Nurses in Hospitals: Errors and Safety

As medication administration is fundamental to nursing practice (Ehsani et al., 2013), this section will address medication errors by nurses and issues surrounding breaches of safe practice. Both Australian and international hospital environments are explored. Strategies to prevent such errors, looking specifically at the administration of IV medications through infusion pump devices are reviewed, and strategies for promoting safer practice amongst undergraduate nursing students are suggested. There is a plethora of international literature about medication administration errors in hospitals by nurses including the causes and the many programs and strategies for error prevention and safer practice. However, there is a distinct lack of literature addressing specific educational technology tools and resources designed to prevent IV medication and infusion errors occurring.

Medication errors have serious direct and indirect results. Direct results include patient harm including death, suspension or loss of registration for the nurse, as well as increased health care costs as a result of patient injury whereas, indirect results might include harm to nurses in terms of professional and personal status, confidence, and integrity (Anderson & Townsend, 2010). The most current statistics available for the number of medication errors in Australian hospitals are reported in the 2013 Australian Commission on Safety and Quality in Health Care Review

(ACSQHC), which identified that during the period 2011-2012, among total hospital admissions of approximately 9 million nationally, 5–10% of patients were subjected to a medication administration error occurring either on admission or during their hospital stay (ACSQHC, 2013). Although alarming to consider that hundreds of thousands of patients incur a medication error while in hospital, some comfort can be derived from the fact that the incidence has not increased from the previous review in 2010. On the other hand, even though the rate of medication errors has not increased, the situation is not improving either. Therefore, there is a need for more effective strategies to be implemented to reduce these statistics.

There are numerous definitions in the literature but, essentially, a medication error can be defined as a preventable medication event that may cause or lead to patient harm and can occur at any time during the medicating process: prescribing, supplying, preparing, administering, monitoring, or documenting (ACSQHC, 2013). Since its establishment in 2006, the ACSQHC has been committed to reducing error and harm in the delivery of medications in the national health care system. Ensuring safety and quality in the use of medications is a priority of numerous initiatives in both the private and public health sectors. Achieving lasting improvements in the delivery of health care to patients is inherent in all aspects of these initiatives, including ongoing education for all clinicians involved in the medicating process (ACSQHC, 2013).

Several factors contribute to medication errors and these are well documented in the literature. Transcription errors, personal issues, work interruptions and distractions, fatigue, and poor communication have all been implicated as key factors in causing medication errors (ACSQHC, 2013; Brady, Malone & Fleming, 2009; Speroni, Fisher, Dennis, & Daniel, 2013). Attention and knowledge deficits during prescribing, dispensing and administration have also been identified as factors contributing to medication errors by nurses (Nichols, Copeland, Craib, Hopkins, & Bruce, 2008; Niemann et al., 2015; Westbrook, Rob, Woods, & Parry, 2011). Other studies have identified additional causes, including nurses not adhering to policy guidelines in medication administration, such as identifying the "5 rights" resulting in errors (Kim & Bates, 2013) and misreading medication vial labels due to poor eyesight and/or poor lighting (Jones, 2014). Nursing inexperience has also been shown to be a contributing factor to medication errors (Brady et al., 2009; Ehsani et al., 2013; Pang, Kong, deClifford, Lamp, & Leung, 2011).

2.2 Intravenous Medication Administration Errors

As well as working with oral medications, the preparation and administration of intravenous or IV medications is also a normal part of a nurse's day in acute hospital wards or other healthcare facilities. Given the indications and actions of the types of IV medications used in the contemporary treatment of medical conditions, any dosage or administration error could cause harm, and potentially serious harm or even patient death (Barras et al., 2013; Husch et al., 2005). This is supported by the ACSQHC (2013) report, which provides statistical evidence that IV medications have a higher risk and severity of error than other medication administrations.

There is sufficient research evidence of the occurrence of IV medication errors made by nurses in hospitals to warrant concern. For example, in 2001, research into medication practices in a paediatric hospital reported IV medication errors occurred with 54% of patients (Kaushal et al., 2001) and data collected for a similar study of 100 hospitals reported that 61% of serious medication errors related to IV medications (Bates, Vanderveen, Seger, Yamaga, & Rothschild, 2005). In addition, and even more alarmingly, a study of medications delivered via IV infusion pumps, reported that mistakes were made by nurses in 69.9% of cases (Husch et al., 2005).

Many factors have been documented as contributors to IV medication errors. A significant number of IV medication errors are related to skill and knowledge deficits (Hicks & Becker, 2006; Taxis & Barber, 2003; Wright, 2012). It has also been noted that IV medication errors, especially more severe errors, are less prevalent among nurses with more clinical experience in the workplace (Pang et al., 2011; Roughead, Semple, & Rosenfeld, 2013; Westbrook et al., 2011). Nevertheless, a disturbing statistic from Pang et al. (2011) showed that, in an Australian hospital, clinical errors in IV medications amounted to 70% of all infusions administered. Of these, 92% involved either incorrect solutions, incorrect rate and volumes, and/or incompatibilities with other fluid solutions and medications, some resulting in serious reactions and extended hospital stays for patients. It was reported that nursing inexperience was a factor in the majority of these errors (Pang et al., 2011).

2.3 Intravenous Medication Administration Devices

Throughout hospitals nationally and internationally, various types of IV infusion pumps are in use. Basic volumetric IV pumps are used predominantly for IV fluid administration but can also be used for delivering IV medication infusions, whereby the nurse programs a dose or rate and a specific volume to be infused (Taxis & Barber, 2003). Smart pumps on the other hand, are used more specifically for IV medications such as narcotics and chemotherapy drugs, and have information appropriate to acceptable doses and delivery rates pre-programmed into the IV pump's memory to prevent an overdose or dangerous doses being programmed into the device (Pang et al., 2011). Smart pump technology may seem to hold the key to reducing the number of errors with IV infusions, although some studies do not support this notion.

As far back as 2004, the National Patient Safety Agency in the United Kingdom (UK) called for standardisation of infusion device equipment and/or the introduction of smart pumps or computer programs to reduce IV medication errors. Smart pumps are widely used in the United States of America (USA) and include the programmable software to reduce the incidence of errors which, in some recent studies have been perceived to be very successful (Gerhart, O'Shea, & Muller, 2013). Iacovides et al. (2014) concurred that, when used properly, these devices contribute to the prevention of IV medication errors and essentially guarantee patient safety. Pang and colleagues extended their research on IV infusions, finding that the introduction of smart pumps and anti-dose error software resulted in far fewer medication errors (Pang et al., 2011). However, Cummings and McGowan (2011) reported that smart pumps do not prevent all programming and administration errors; a finding that is also supported by Husch and colleagues, whose research on the smart pump found that nurses were still programming incorrect rates and volumes (Husch et al., 2005). Even with technology-assisted devices, it is evident nurses must still adopt professional judgment and clinical reasoning, as well as adhering to established standards of care and standard operating procedures for safe medication administration (ACSQHC, 2013).

2.4 Medication Administration: Education and Training

There are multiple processes in place to reduce the number and types of medication errors caused by clinicians. Specifically for nurses, these sorts of processes include continuous education and training, policy and procedures, assessments, double and triple checking of medications including the "6 Rights" (previously "5 Rights") of medication safety. According to Medication Services Queensland, the 6 Rights are: 1. The Right Patient; 2. The Right Drug; 3. The Right Dose; 4. The Right Route; 5. The Right Time; and 6. The Right to Refuse (National Prescribing Service, 2008). More formally, strategies such as the implementation of standardised medication charts, improving medication distribution processes and technology, including the use of smart infusion pumps for IV medication administration, are facilitating some reduction in the number of in-hospital medication errors (ACSQHC, 2013). However, even with these quality control strategies in place, there is still evidence that inexperience and knowledge deficits contribute significantly to mistakes. Improving the continuous training of student nurses in the preparation and administration of medications has the potential to save many lives each year in hospitals worldwide.

In a recent study from New Zealand, newly graduated nurses applied educational principles to their management of medicines in order to prevent medication errors (Honey & Lim, 2014). The nurses who participated in the study had graduated within the past 24 months. It was identified in the study that applying educational principles, such as questioning why a drug is given, monitoring the effect of a drug, and researching and understanding the mechanisms and actions of drugs, had clear benefits in preventing errors (Honey & Lim, 2014). This strategy of increasing accountability in medication administration is one that should probably be adopted from the beginning of education into medication practices for student nurses, a principle supported by the findings of Page and McKinney (2007) in the UK. Unver and colleagues in Europe, who investigated medication errors by newly-graduated nurses, also recognised the importance of emphasising medication safety in the undergraduate education of nurses (Unver, Tastan, & Akbayrak, 2012).

Further suggestions for improvements derived from recent research include greater attention to medication administration techniques, administration instructions, and building more positive attitudes toward safety, to prevent medicating errors (Härkänen, Ahonen, Kervinen, Turunen, & Vehviläinen-Julkunen, 2014).

In the USA, the incidence of medication errors made by nurses in hospitals is just as alarming as in Australia. A report on medication errors issued by the Institute of Medicine on medication errors indicated that more than 1.5 million patients are injured every year in American hospitals, and the average hospitalised patient experiences at least one medication error each day (Anderson & Townsend, 2010). Many studies on medication administration errors by nurses in the USA have identified critical factors contributing to medication errors by nurses and suggest strategies to avoid their occurrence.

The Joint Commission (2014), a national USA health care accreditation body, in a review of patient safety and quality control, called on health organisations to develop and implement effective evidence-based policy and procedures for preventing the misuse of medications. Anderson and Townsend (2010) recommended careful consideration of not only the medication, name, labelling, stock, storage and dose, but also careful consideration of the patient receiving the medication, and the avoidance of negative environmental factors such as fatigue, excessive workload, and distractions.

Continuous education and competency testing for nurses are other key elements in error prevention and can be linked directly to correctly calculating medication doses (Brady et al., 2009; Sulosaari, Kajander, Hupli, Huupponen, & Leino-Kilpi, 2012; Wright, 2012). When it comes to medication preparation and administration, getting the medication calculation right is critical for the safety of patients. Teaching medication formulas and calculations is included as part of undergraduate nursing programs worldwide, but errors in calculations still account for 7.5–27% of medication errors in hospitals (Stolic, 2014).

A variety of teaching strategies for undergraduate nurses are highlighted throughout the literature, the most successful being those programs that adopted a variety of practices; including traditional numeracy education, computer-assisted programs, online activities, and practical simulations. As well as reporting the best outcomes related to performance, these programs also report high student satisfaction (Harris, Pittiglio, Newton, & Moore, 2014; McMullan, Jones, & Lea, 2011; Sears, Goldsworthy, & Goodman, 2010; Sherriff, Burston, & Wallis, 2012; Stolic, 2014; Weeks, Higginson, Clochesy, & Coben, 2013). This combination of practices describes a blended form of education delivery. There is certainly evidence that a blended delivery of nursing education has positive outcomes (discussed in more detail later in the chapter), but little has been reported on the use of computer-assisted technologies or devices to enhance skill development that improve practice in medication administration. The education of safe medication administration is an area, given the error statistics worldwide, where increased education and training is required or where teaching strategies need improvement to make them more effective.

The Joint Commission (2014), looking ahead to 2015 in its review, not only targeted IV medications and infusions but also promoted the adoption of infusion devices that carry alarm systems. The Joint Commission warns that devices with alarm signals that may be ignored or misunderstood are recognised as precursors to medication errors, emphasising the need to ensure that nurses understand the meaning and significance of the alarms. The document outlining new national guidelines, recommendations and goals for patient safety, included increasing awareness and staff education programs to address complacency in these areas of medication administration (Joint Commission, 2014). Infusion devices for administration of medications all have alarms and alerts that provide warnings about the progress of infusions. Highlighting the significance of alarms and warnings on clinical devices to undergraduate nursing students before they enter clinical environments for practicums is a matter of quality control to promote patient safety (Joint Commission, 2014).

The present program of research introduces the online IVPE as an innovative educational technology. This resource is accessed online and complements the face-to-face component, the combination of which is regarded as an effective form of educational delivery in contemporary higher education (Andersen & Avery, 2008; Bata-Jones & Avery, 2004; Campbell, Gibson, Hall, Richards, & Callery, 2008).

2.5 Delivering Education to Undergraduate Nursing Students

Education in universities is delivered to students in a number of ways. Courses, subjects or units of study, are often still delivered by the traditional face-to-face method in a classroom or lecture theatre. Recorded lectures, tutorials, or presentations are also delivered in a classroom setting, either face-to-face or synchronously via video conferencing equipment. Some course content material is delivered exclusively online via the internet or virtually where students view the information and interact asynchronously with the lecturers and fellow students from a computer device. Programs of study may be offered totally on-campus, exclusively by distance or online, or a combination of delivery modes, which is known in the tertiary sector as blended or flexible delivery (Redmond, 2011; Singh, 2003). The options seem endless in the world of education today and this combination of education delivery in particular, provides flexibility and accessibility to university students worldwide. A number of undergraduate nursing programs, at the tertiary level in Australia, use a blended form of education delivery, and this is the case for most practice disciplines that are competency based (George et al., 2014; Harder, 2010). These include our multidisciplinary counterparts in medicine, physiotherapy, occupational therapy, dentistry, pharmacy, podiatry and radiography (George et al., 2014).

Along with the delivery of theoretical information to nursing students, comes the delivery of practical knowledge and clinical skills, usually by way of simulation in hospital ward-like laboratories. Like other health professions, the clinical education or practical teaching of skills has moved away from facility- or hospital-based training to the university sector where opportunities to practice skills in real situations is limited. The old hospital training paradigm for educating RNs no longer exists in Australia (Russell, 2005), so educators are constantly searching for innovative ways to effectively expose and familiarise nursing students to the real-life clinical environment throughout their education at university.

Unfortunately, the reality also includes a heavy demand on health facilities to accommodate the large and growing number of nursing students seeking to gain real-life clinical experience on their clinical placements (Siggins Miller Consultants, 2012). Health Workforce Australia (HWA) recently reported the strain of numbers competing for clinical placements which, in turn, means that tertiary facilities need to integrate more educational technology or web-based teaching of clinical skills to enhance clinical experiences (Siggins Miller Consultants, 2012). The practice of teaching and learning skills through clinical simulation is traditionally a face-to-face activity and continues in this way throughout much of the tertiary sector (Rushford, 2007). However, this practice is now more than ever supported by electronic technology and simulation is typically used in conjunction with various digital formats.

2.6 Delivering Education: Comparing Online to Face-to-Face

The body of knowledge about student nurses' perceptions of solely face-to-face teaching compared to solely online teaching of material is relatively sparse. There are a number of studies nevertheless, which have compared traditional face-to-face education with web-based education for nurses. These studies show mixed results. In one study comparing the two types of teaching methods, a small proportion of students preferred material presented in the traditional face-to-face way in a classroom (Stiffler, 2008). More recently, a study of first year external nursing students and their evaluation of an online version of a biomedical course, normally taught on-campus, showed the opposing view, preferring the electronic version of material (O'Flaherty & Laws, 2014). Similarly, Bata-Jones and Avery (2004) reporting on nursing student's perceptions, found that online students commented more positively on their learning experience than face-to-face students, whereas a study of Korean undergraduate nurses comparing online and face-to-face methods of education, showed that the students preferred a combination of the two methods of teaching (Yom, 2004).

There is more on the topic from the Education discipline where university students voiced strongly their preference for face-to-face education compared to online education, for reasons such as personal interaction, reassurance and general communication (Poon, 2013). Even though some university students find studying online more challenging than face-to-face, given that online does not suit all learning styles and individual needs, the emphasis on face-to-face teaching alone appears to be dwindling (Billings & Halstead, 2013). Whatever the reasons, university educators are being pressured to steer away from solely face-to-face methods and instead adopt a blended approach to education which includes online components in the curriculum (Redmond, 2011).

The evidence supporting whether online education for undergraduate student nurses is better, worse, or equivalent to face-to-face is still being gathered, but it appears that a combination of both has become accepted as the most effective approach. As early as 2000, it was evident that the introduction of web-based education for student nurses was becoming widely accepted (Halstead & Coudret, 2000). It was established then, however, that student nurses struggled with the computer-based education and the self-directed style of web-based learning and technology, and so course design and resource development needed to be carefully considered (Finan et al., 2011; Kenny, 2002; Schulz, 2002). Even today, it is recommended that the internet resources for online course development and content must be well researched and appropriate for the learning needs of nursing students (Schnetter et al., 2014). In 2004, the growing success of the internet based-teaching of student nurses was reported by Chaffin and Maddux (2004). Teaching of clinical skills, normally confined to a classroom, was being enhanced using computer-based resources, programs and multi-media such as CD-ROMs, videos and other interactive material, all of which remain features of nursing programs today (Billings & Halstead, 2013).

More research and positive results about online education for nurses is evolving. Veredas and colleagues reported the limitations of face-to-face lecturing and seminars on wound management when they showed that students who engaged in web-based information technology on wound management achieved better results than those who were educated on the topic face-to-face (Veredas, Ruiz-Bandera, Villa-Estrada, Rufino-González, & Morente, 2014). Better assessment results were also achieved by student nurses enrolled in a postgraduate course of study who engaged in online activities than those who did not (Campbell et al., 2008). Similarly, Thiele (2003) not only reported significantly better assessment results from nursing students engaging in an online course of study but also demonstrated that the students were more independent, responsible, and motivated. In another example where better assessment results were achieved by students enrolled in a practical-based course with an online component, online communication forums were reported to have fostered more discussion, more insightful thought processes and challenges, compared to traditional face-to-face activities in the classroom (MacNamara, 2014).

Comparing online and face-to-face education for student nurses has shown that a combination of the two is a popular and successful method for delivering nursing education in universities. Computer-assisted educational technologies along with traditional methods of teaching defines blended learning (Garrison & Kanuka, 2004; Jefferies, 2013; Singh, 2003). This blended style has benefits with positive results reported in student satisfaction and assessments (Hudson, 2014), including self-directed learning and motivation among students (Brydges, Carnahan, Rose, & Dubrowski, 2010; Brydges, Nair, Ma, Shanks, & Hatala, 2012; Gagnon, Gagnon, Desmartis, & Njoya, 2013). Not only does blended delivery of education offer more choices, but there is enough anecdotal and empirical evidence to suggest that it is more effective for students than either online or face-to-face methods alone (Singh, 2003). In addition, evidence has emerged that blended learning enhances the metacognitive ability in comprehension, critical reasoning, and various other positive educational experiences for nursing students (Hsu & Hsieh, 2014).

Medication and pharmacology courses that include traditional styles of teaching numeracy and formulas in combination with computer-assisted programs and activities online, have reported better outcomes in student assessment results and survey evaluations (Simonsen, Daehlin, Johansson, & Farup, 2014; Stolic, 2014). In another study, investigating RNs who undertook an electronic blood transfusion module, it was reported that the online program more successfully and actively engaged the normally "hands-on" and visual learners (Cottrell & Donaldson, 2013).

Whether or not clinical skills for nursing students can be successfully transferred and taught through a blended delivery process needs to be explored further. The literature provides a number of examples where current innovations in teaching practical aspects of nursing to undergraduates is flourishing. They include online or e-learning platforms including digital, virtual, and/or via mobile devices and social media forums. There appears to be very little to suggest that the online technologies used to support teaching and learning clinical skills are detrimental to the achievement of positive learning outcomes.

Early evidence showed that a computer-assisted program for nursing students instructed on the care of surgical patients produced positive results in assessments that were performed after a clinical placement (Madorin & Iwasiw, 1999). In a more recent study involving nursing students taught face-to-face to dispense an oral medication, where half the participants had unlimited access to an online instructional video, this latter group performed significantly better in assessment (Holland et al., 2013). In another study of nursing students, who were instructed interactively via videoconferencing to perform an electrocardiogram (ECG) showed a significant improvement in competence when they were asked to perform an ECG themselves (Celikkan, Senuzun, Sari, & Sahin, 2013). This concept was supported by Rush and colleagues, whereby nursing students interacted in the demonstration of insulin injections for diabetic patients via videoconferencing and agreed that it would improve their practical skills when it came time to give an injection to a real patient (Rush, Walsh, Guy, & Wharrad, 2011).

Other examples include Vorderstrasse and colleagues, who reported a positive outcome with a blended delivery approach to teach diabetic care to nursing students. Their approach similarly included a combination of web-based programmes and face-to-face simulation activities (Vorderstrasse, Shaw, Blascovich, Johnson, 2014). Further, where nursing students were taught to take a patient’s vital signs, a number of computer-assisted technologies were used along with traditional methods and the students exposed to the blended option demonstrated superior performance in all the skills being developed (Kaveevivitchai et al., 2009). Bowden, Rowlands, Buckwell, and Abbott (2012) used a combination of simulation sessions along with online videos and online feedback to successfully teach cardiopulmonary (CPR) to nurses, and Jenson and Forsyth (2012) similarly reported that a virtual reality simulation exercise in their nursing curriculum was successful for teaching clinical skills.

Resuscitation techniques taught via simulation has been widely researched over the years. In a recent study, where nursing students were instructed using a variety of methods in CPR techniques, it was found that the students who learnt through computer-assisted simulation outperformed other groups who were instructed more traditionally with a hands-on approach (Roh & Kim, 2014). Furthermore, based on current online examples among health disciplines, using wiki, blog or podcast technology from mobile devices, research has demonstrated benefits for the acquisition of clinical skills for practice (Boulos, Maramba, & Wheeler, 2006; Clay, 2011; Dearnley, McClelland, & Irving, 2013; Vogt, Schaffner, Ribar, & Chavez, 2010).

There is evidence, on the other hand, showing that computer-based online simulation does not provide equivalent results to human-patient simulation. In one study with nursing students on diagnostic reasoning of cases studies, the group who performed the human-patient simulation outperformed those instructed with computer simulation (Wilson, Klein, & Hagler, 2014). Despite some equivocal findings, solid evidence exists to support the place of computer-assisted technology in contemporary nurse education.

A recent systematic review of the impact of online, face-to-face, and blended learning of clinical skills for nursing students, showed that online teaching of clinical skills is no less effective than the classroom education of teaching clinical skills (McCutcheon, Lohan, Traynor, & Martin, 2014). The focus of the review was to establish the most appropriate and effective teaching methods and educational technologies for the instruction of psychomotor and clinical skills for nurses. Particular attention was placed on performance of a clinical skill, knowledge, self-efficacy, confidence, and the student experience, in particular satisfaction with the different teaching and learning methods (McCutcheon et al., 2014). It was reported, based on findings of 10 studies, that learning skills online, including performing an ECG, intrapartum care, pre and post-operative surgical skills, hand washing, medication calculations, infection control practices, taking blood pressure, and demonstrating IV therapy, was as effective or more effective in developing nursing students' knowledge and performance of clinical skills than just learning via traditional means (Bloomfield, While, & Roberts, 2008; McCutcheon et al., 2014).

Among related health disciplines, recent studies have also shown that students learning practical skills online produces better outcomes. A review of multidisciplinary students enrolled in medical, dentistry, nursing, physical therapy, or pharmacology degrees, reported significantly higher levels of skill acquisition following learning in the online and computer-assisted environment than those learning by traditional means, suggesting that learning skills online is superior to face-to-face (George et al., 2014). In support of this, HWA reported that the development of technological innovations relevant to clinical placements enhances the quality of the placement experience for nursing students (Siggins Miller Consultants, 2012). The integration of electronic virtual patient case studies for clinical preparation has been positively evaluated by nursing students. Berman and colleagues found that it allowed them to develop their knowledge and skills more effectively than traditional learning methods, as there were no associated pressures from patients, preceptors and other onlookers (Berman et al., 2009).

The effectiveness of hands-on clinical and human simulation is supported by a plethora of positive research findings. These techniques are used widely in universities among practice health disciplines, as a mode of teaching clinical skills. Given that research articles related to clinical simulation in nursing are too numerous to review individually, a summary of the systemic reviews was undertaken. In several of these review papers, it has been reported that nurses grow in competence and confidence, extend their knowledge via clinical reasoning, and enhance critical thinking ability by treating low, medium and high fidelity manikins as patients (Cant & Cooper, 2010; Cook et al., 2011; Hayden et al., 2013; Issenberg, Mcgaghie, Petrusa, Gordon, & Scalese, 2005; Kable, Arthur, Levett-Jones, & Reid-Searl, 2013; Lapkin, Levett-Jones, Bellchambers, & Fernandez, 2010; Laschinger et al., 2008; Moule, 2011; Neill & Wotton, 2011; Ricketts, 2011; Solnick & Weiss, 2007; Yuan, Williams, & Fang, 2012).

There are doubters who dispute the benefits of such training for nursing students and research findings have identified limitations to clinical simulation. The limitations included accessibility and excessive cost (Nehring & Lashley, 2009; Smith & Roehrs, 2009), and the sometimes unfulfilled need for suitable education of the trainers in the functioning of highly sophisticated computer-assisted equipment that ensures effective instruction to students (Jeffries, 2005; Nehring & Lashley, 2009). However, given the positive findings about simulation, if these limitations pose a problem, they should be addressed by individual faculties. With this said, the implementation of university programs for nurses offered by distance and/or online, use of on-campus simulation as a training method is not always a viable option (Watson, Stimpson, Topping, & Porock, 2002). Simulation via the internet represents another chapter in nursing education delivery. It was reported in a recent study that simulation via the internet was highly acceptable to nursing students and provided learning outcomes that aligned with other simulation techniques from the face-to-face teaching model (Cant & Cooper 2014). Digital simulation is likely to have a major place in nursing curricula during the next decade (Cant & Cooper 2014) especially as distance programs grow in popularity where the desire for flexibility and accessibility are aligned.

2.7 Delivering Education: The Virtual World

Other computer-assisted technologies used to support classroom simulation, such as in virtual settings, are present in current undergraduate nursing programs.

Virtual worlds or Second Life (SL) technology emerged in 2003 but is a fairly recent online innovation in nurse education. However, it has really only captured the attention of technological-savvy nurse educators and students despite suggestions in the literature that it complements the blended learning paradigm (Ahern & Wink, 2010; Bauman, 2012; Day, Levett-Jones & Taylor, 2014; Skiba, 2009). There are innovative examples of virtual environments used in undergraduate nursing programs, such as interactive programs describing social health issues, which have been evaluated favourably by students (Day et al., 2014). Despite the positive findings regarding students' attitudes towards this technology, more research needs to be conducted to determine whether these resources are effective in transferring skilled clinicians to the bedside.

An investigation into SL technology, where child health nursing students in preparation for a clinical placement received case study scenarios in the form of virtual ward simulation, was given mixed feedback. Some students commented positively in relation to clinical preparedness in a stress-free environment, whereas the negative comments related to the complexity of the technology and that the time spent on the program would be time better spent in a real ward (Broom, Lynch, & Preece, 2009). Similarly, at the University of Michigan, an eight-bed virtual hospital ward was created and case study scenarios developed for the nursing students. Those who evaluated the program gave mixed feedback, likening it to a game rather than a beneficial educational resource (Aebersold, Tschannen, Stephens, Anderson, & Lei, 2012). Such issues have impeded the growth of virtual reality technology in the education of student nurses. Others factors include the advanced information technology skills required for designing programs, the cost, and computer infrastructure required, including hardware and software, and technological support

(Skiba, 2009). Another limitation is the high-specification computers with fast broadband internet connection required for most SL programs to run uninterrupted (Boulos, Hetherington, & Wheeler, 2007). Whether or not virtual wards and SL programs are effective educational technologies that enhance the knowledge and clinical skills for nurses remains to be demonstrated conclusively.

Web-based, digital or online education technology not only support students in knowledge and skill development, but patients can also benefit from this technology. Vorderstrasse and colleagues developed a theoretical framework and SL program whereby adult patients with diabetes could access an education program in a virtual environment. It was demonstrated in a preliminary evaluation that people in the community with diabetes who used this computer-assisted education technology to support the monitoring and controlling of their condition, gained improved knowledge of their disease (Vorderstrasse et al., 2014).

There is also evidence that using digital gaming in nurse education can maximise student interaction and engagement, and enhance problem-solving skills (Bauman, 2012; Johnston, Boyle, Macarthur, & Fernandez, 2013; Peddle, 2011). However, to date, there is little evidence to show how these technologies should be embedded into nursing curricula and even whether they provide positive learning outcomes for nursing students in terms of skill acquisition. One school of thought is that these sorts of fun, interactive, aesthetically pleasing and clinically safe computer-assisted technologies should not be implemented into a nursing program as a substitute for clinical practice, but rather be implemented as part of a holistic educational experience (Bauman, 2012). In summary, an enormous amount of supportive literature exists related to the productivity of various technologically-supported teaching methods and resources for the clinical education of nursing students. It is up to the educators to implement best practice based on the evidence, and what is appropriate for the institution, location, environment, and cohort of student nurses enrolled.

2.8 Remote Access Laboratories (RAL)

RAL is an example of a computer-assisted technology that is well-established among practitioners in engineering and sciences and, more recently, in health disciplines. Fundamentally, it is a system whereby actual experiments performed in a laboratory can be viewed and manipulated remotely from a computer, making it suitable for the external student learning by distance. The use of RAL in engineering has been well researched and there is much supportive literature labelling it a helpful feature for achieving undergraduate learning objectives (Helander & Emami, 2008). This is despite earlier literature suggesting that RAL technology was too complex, expensive and required considerable administrative support to maintain (Trevelyan, 2003). As technology has advanced and the software has become easier to navigate, it is generally accepted that RAL allows students to easily and conveniently conduct experiments repeatedly, practicing without risks, allowing for mistakes until the concepts are understood, with the capacity to generate immediate feedback and results for the student user (Bowtell et al., 2012; Gomes & Bogosyan, 2009; Gordon, Wilkerson, Shaffer, & Armstrong, 2001; Hanson et al., 2008; Ma & Nickerson, 2006). Furthermore, RAL programs promote the adult learning qualities of autonomy and self-directed learning whilst enhancing problem-based, critical, creative, active, and reflective thinking (Barak, 2006; Gomes & Bogosyan, 2009); all necessary for students to be effective in a university environment.

In a comparative review of disciplines using hands-on, simulation, and remote laboratories to learn concepts, procedures, and skills, and conduct experiments, all three methods showed advantages and disadvantages for performance, most of which have already been mentioned. It was concluded that, having a combination of technologies would meet the needs of the different learning styles of students, providing that the technology promoted a sense of reality, interaction with other students, and objectives adhering to skills acquisition education (Gomes & Bogosyan, 2009; Helander & Emami, 2008; Ma & Nickerson, 2006). The capacity of RAL to host and support learning activities, such as through engineering laboratories, medical procedures and clinical skills equipment, provides the potential for it to become an inter-university platform for distance education from a global perspective (Gomes & Bogosyan, 2009; Helander & Emami, 2008).

The application of RAL technology has been trialled in non-technical disciplines such as business, arts and nursing, not with physical experiments from a laboratory, but for more conceptual learning situations and computer-assisted activities (Kist, Maxwell, & Gibbings, 2012). In one particular study it was described how, by changing the scope of RAL, external university students studying from distance were given access to hardware and software programs that provided learning resources appropriate to each discipline (Kist et al., 2012). From student feedback, it was evident that RAL accessed via the internet, could be successfully used in different contexts and disciplines as an on-demand vehicle for external students to learn specific concepts.

There is, however, a downside to RAL for the practical education of nursing students. Traditional nurse education in the classroom pays much attention to psychomotor skills incorporating hand dexterity. An example of this is using a fine needle and syringe to extract liquid medications from tiny glass ampoules and administering intramuscular (IM) injections. Often this skill is associated with repeated practice until nursing students are confident with the technique. This "hands-on" practice still exists today in the education and training of student nurses in simulated laboratories. Drawing up and administering an IM injection cannot be performed via RAL to improve motor skills but there are other skills that can be practiced repeatedly via RAL, and there is much scope for developing new innovations related to nursing education with the technology.

Remote access in health developed from the concepts of telemedicine in the early 1990s, followed by telehealth using information technology, computers, videos, and telemetry, to communicate or deliver health and education services to staff and patients in remote locations (Darkins & Cary, 2000). Since then, telehealth has evolved into an important and fast-growing vehicle for the provision of health care in today's society (Ali, Calton, & Ali, 2015). One example of the diversity and capacity of telehealth is the performance of robotic surgical procedures remotely; specifically robot-assisted laparoscopic procedures. This was the first of the medically-invasive surgical concepts that were performed using remote technology (Rothenberg, Yoder, Kay, & Ponsky, 2009) and the education and training of skills and procedures for students and surgeons using remote computer-assisted technologies has advanced as a consequence (Schreuder, et al., 2012). The robotic technology, in this instance for education, allows a student to perform or practice a skill endlessly with realistic equipment and in an environment free of risk to a patient (Bowtell et al., 2012; Camarillo, Krummel, & Salisbury Jr, 2004).

Robotic surgical procedures are performed routinely but few studies have reported on the development of competency among students learning about, and training with, the technology. Having said that, two recent and similar studies have investigated the performances of medical students using computer-assisted and virtual robotic technology compared to experienced surgeons who performed laparoscopic techniques with traditional instruments. Kim and colleagues reported, in their comparative study, that the students who were instructed and who used robotic laparoscopic equipment compared to experienced surgeons showed significantly better performances including superior technique in skills and often completed the procedure faster (Kim, Choi, Park, & Park, 2014). Similarly, in another study, the performances of the unskilled students were just as proficient as the experienced surgeons, with the researchers concluding that the acquisition of skills was the result of repetitive and goal-directed training with robotic virtual simulator technologies (Bric, Connolly, Kastenmeier, Goldblatt, & Gould, 2014). A review by Schreuder et al. (2012), looking specifically at the learning outcomes for medical practitioners using similar technologies, concluded that to facilitate and improve the practice of surgical techniques, competency or proficiency-based training (Cleary & Nguyen, 2001) and more computer-assisted technology should be readily available for use.

The use of remotely-programmed robotics in engineering and medicine is commonplace and widespread, but in nursing robot technology is scarce. In one study, however, academics from a university nursing faculty instructed students in the skills of insulin administration and wound care via remote robotic technology in a one-hour clinical laboratory class (Sampsel, Bharwani, Mehling, & Smith, 2011). The aim of the study was to assess the relevance and effectiveness of remote robotics as an educational technology to teach clinical skills. The feedback was resoundingly positive, highlighting the potential for further development and research in the area (Sampsel et al., 2011).

The ability to access an online clinical or skills training activity remotely, such as via RAL, would be an attractive option for distance or external nursing students, but there is a paucity of evidence in the literature about the use of RALs in nurse education. Recently there have been some inroads made, with one study looking specifically at establishing a real-time link to simulated nursing laboratories or a clinical activity that distance students could access for repeated practice, skill acquisition, and competence (Kist et al., 2012).

As a pre-cursor to the present research, demonstrations were conducted with an IV pump enabling users to view IV fluid dripping through an IV line as fluid passed through the peristaltic pump device (Bowtell et al., 2012), although subsequent testing showed no obvious benefit in learning outcomes for nursing students. The project was taken a step further, whereby an IV pump program and all of its functionality and activities were developed as a computer program enabling nursing students to access the pump via the RAL platform (Bowtell, Kist, Osbourne, & Parker, 2013). This type of interactive computer technology, known as emulation, is defined by Laplante (1999) as "a model that accepts the same inputs and produces the same outputs as a given system or to imitate one system with another," or more simply "having a computer act exactly like a piece of equipment." Similarly, the American Heritage Dictionary of the English Language (2012) defines emulation as "to imitate the function of (another system), by modifications to hardware or software that allow the imitating system to accept the same data, execute the same programs, and achieve the same results as the imitated system."

The literature on emulation in nurse education is sparse. However, in 2002, a computer-assisted initiative labelled emulation, was implemented into a nursing course in response to advances in technology and education in nursing at the time

(Huffstutler, Wyatt, & Wright, 2002). It took the form of a hand-held device housing a pharmacology software program with full internet access enabling users to source information with the touch of a button, anywhere, anytime (Huffstutler et al., 2002). It was a successful innovation prompting very positive feedback from students and academics, and is probably considered a pioneer development in computer-assisted, hand-held devices that nurses now use at the bedside.

There is more evidence alluding to the concepts of emulation in other disciplines. An emerging principle is that using and learning with emulation technology is an individual experience, as the programs and activities accessed by a computer device make learning an autonomous and self-directed experience (Gomes & Bogosyan, 2009). There are suggestions that there may be great value in self-directed learning for nursing students, providing them with increased autonomy, accountability, and confidence (Gagnon et al., 2013) as they prepare for the challenges of the workforce. Some on the other hand, recognise there will always be students who benefit from close interaction and a more guided and teacher-centred traditional style of instructional learning (Levett-Jones, 2005). However, on balance, there is more evidence for than against that self-directed learning of clinical skills, using computer-assisted simulation rather than instructor-led hands-on simulation, is more beneficial in terms of skill retention (Brydges et al., 2012).

A psychomotor skills learning study demonstrated that nursing students who self-directed their practice tended to learn more than those who practiced skills led by an instructor (Brydges et al., 2010). This potential educational benefit of the self-directed learning of clinical skills is further supported by Jowett and colleagues who found that self-directed practice by medical students led to improved skill retention and better transfer of skill than instructor-controlled learning (Jowett, LeBlanc, Xeroulis, MacRae, & Dubrowski, 2007). Offering distance education to students assumes students must exercise a certain amount of self-direction (Fisher & King, 2010). In general, the research evidence is encouraging and supports the notion that computer-assisted technologies to teach nursing students online is a viable option.

2.9 Undergraduate Nursing Students Learning by Distance Education

There is, on the other hand, some interesting literature about nursing student's perceptions and experiences related to studying by distance. External programs for undergraduate nursing students in Australian universities is a relatively new phenomenon, but such programs have been offered by universities overseas since the turn of the century (American Association of Colleges of Nursing, 2000). The shift to distance education for nurses has occurred in response to projected nurse shortages in the workforce, increasing accessibility to communities in remote locations, and keeping up with trends of technology and web-based education delivery online (Mancuso-Murphy, 2007; Mayville, 2007; Patterson, Krouse, & Roy, 2012), including incorporating the principles of andragogy (Lewis & Price, 2007). Models of practice and associated guidelines have been evaluated and implemented to ensure that distance nursing programs are designed and tailored for successful learning outcomes. Suggestions for distance programs include ensuring a social, cognitive and teaching presence (Pecka, Kotcherlakota, & Berger, 2014), interactive activities that promote critical thinking, forming connections between theory and the real-life situations and scenarios (Banks, Gilmartin, & Fink, 2010; Legg, Adelman, Mueller, & Levitt, 2009), offering a variety of resources building on practical skills using effective technology, and creating motivation to learn by providing meaningful and authentic tasks relevant to the learners profession (Bennett & Lockyer, 2004).

Early studies of nursing students and their perceptions of distance programs highlighted feelings of inadequacy and isolation (Mayville, 2007). For the most part, however, research reports positive aspects of nursing students' experience, which include increased critical thinking skills and empowerment (Hyde & Murray, 2005; Patterson, Krouse & Roy, 2012), improved clinical reasoning skills (Kenny, 2002), and convenience and accessibility of material (Mancuso-Murphy, 2007). Furthermore, Patterson and colleagues reported distance education in nursing is certainly viable and should remain as an alternative to on-campus education (Patterson et al., 2012). Being a self-directed learner is fundamental to the distance learning journey although, it has been identified that some nursing students would still prefer a more student-centred approach (Levett-Jones, 2005; O'Shea, 2003). Self-direction is generally considered to be a characteristic essential to interact and succeed as an adult learner (Knowles, 1975; Mayville, 2007; O'Shea, 2003).

The research literature reports independent learning styles, self-directedness or self-guided learning, as having positive impacts on student nurses' learning. For example, in one study of nursing students learning the skill of IV catherisation, it was reported that participants assigned to learning with online resources benefitted from the autonomy of the program, where they were in control of their practice and scheduled according to their specific learning needs (Brydges et al., 2010). In a later study, Brydges and colleagues reported on students learning in a self-directed and self-regulated pattern how to perform a lumbar puncture. Not only did the students demonstrate improvement in performance at the time of assessment, but they maintained their knowledge and skill at 12 weeks (Brydges et al., 2012). Computer-assisted teaching tools can be accessed at the students' own pace and time.

Therefore, to support their educational experience, it is incumbent upon academic and other teaching staff to support and promote these adult learning behaviours.

Technology forms a large part of the debate about distance education and without a doubt must be reliable and user-friendly (Billings & Halstead, 2013; Hader, 2013) to keep students interested and motivated (Halstead & Coudret, 2000) preferably with technical support available 24 hours a day, seven days a week. It could be surmised that students today (for the most part) have computer skills commensurate for learning online in a distance education program, but that doesn't negate the necessity for technology to be easily navigated and well designed. Universities have in place policies regarding use of IT and technical skills along with an expectation that students be sufficiently computer literate and have internet access to enhance their learning journey. Using technology for learning has become almost second nature, but there will be computer-assisted educational technologies that are new or foreign to university students (Hader, 2013). Approaches have been recommended in the implementation of new technologies to influence and develop positive attitudes and motivation for their use (Kenny, 2002; Levett-Jones et al., 2009; Maag, 2006; Strand, Fox-Young, Long, & Bogossian, 2013). Such considerations relate to the design of new technology, clarity of usefulness and purpose to the user, ease of use and compatibility with common computing systems, and the support and training provided by the employer or institution from where the education service is delivered (Hader, 2013; Strand et al., 2013; Venkatesh, Morris, Davis, & Davis, 2003).

There are a number of qualitative studies reporting nurses' attitudes towards computer technology. Early studies reflected negative attitudes by RNs at a time when the nursing profession had little exposure to digital technology nor used computers in the day-to-day working environment (Fieschi, 2004; Huffstutler et al., 2002; Kenny, 2002). In particular, more mature nurses were anxious about using computer technology and, even in the past few years, barriers to nurses' engagement with digital technology have been highlighted (Eley et al., 2009; Maag, 2007). However, trends are now changing and use of informatics in health care, and health education via internet-based educational technology, is rapidly becoming ubiquitous and more readily available and accepted in the workforce (Hader, 2013; Hegney et al., 2007; Huryk, 2010). Nursing students now generally report more positive attitudes about working and studying with technology (Maag, 2006; Smedley, 2005). These more positive attitudes are encouraging for the success of the present research.

External nursing students studying by distance have limited or no access to clinical equipment in the simulated laboratories used by on-campus students. Teaching clinical skills with technology and computer-assisted resources, although advancing, presents the challenge of providing evidence of equivalence with traditional and more hands-on methods. It also raises the question of the academic staff time, resources, and education required to create something that is beneficial and well integrated into the online space, which aligns with learning objectives (Billings & Halstead, 2013; Bonnel, Wambach, & Connors, 2005; Pecka et al., 2014). Anderson and Avery (2008) found no significant difference in the time to produce and deliver a web-based course compared to a face-to-face course, whereas Mayville (2007) and Reed (2014) reported that web-based courses took longer to prepare. With the magnitude of online resources, variety of education platforms, abundance of learning and teaching methods available, and models and guidelines for the implementation, if time is a challenge for some educators, it should be more effectively managed (Bonnel et al., 2005; Mayville, 2007). Establishing the evidence base (Pearson et al., 2005) for the use of computer-assisted technologies in teaching and learning by assessing the competency and skills of nursing students, is of paramount importance for the future of professional nursing, and is the very foundation for the present research.

2.10 Competence and Assessment of Competency

The salient research suggests that clinical simulation produces positive results in teaching skills to nursing students, thereby adding to and strengthening competence among students. There are variations in the definition of competence in nursing practice, in terms of assessing skills and measuring outcomes, but whatever the definition, education of skills must be accompanied by clear practice guidelines on procedures and skills (Bradshaw, 1998). From the earlier literature, the term competence referred to a quality possessed by someone or being able to master certain things (Short, 1984). At some stage, confusion mounted around the term being synonymous with performance, although Eraut (1998) clarified that competence represented ability and/or capability whereas performance was simply demonstrating doing something whether there was any ability involved or not.

Most nurses accept Benner's (1986) definition of competence as having the ability to perform tasks with the desired outcomes depending on the changing situations in the real world of practice. Gonczi (1994) extended the term competency to include being task-based, where evidence of performance must be observed, having certain attributes crucial to effective performance and possessing a combination of knowledge, skills, attitudes, and behaviours that address the needs of the profession. It has been argued that these conceptualisations pose issues of whether direct observation methods can accurately measure performance and, unless generic competencies exist among professions, whether they can they be truly measured (Watson et al., 2002). Others suggest that competencies provide a clear framework for bringing together occupational polices and skills and regulating equity in performance (Cowan, Norman, & Coopamah, 2005). Nevertheless, a school of thought has existed whereby, if no clear definition of competency or level of competency surfaced in the practical aspect of nurse education, it could lead to gaps in training, constituting a threat to patient safety (Watson et al., 2002).

Within this arena of ambiguity, it was suggested that perhaps level of competency and learning outcomes should remain undefined and open to the interpretation of the educators and educational principles of the curriculum (Dimond, 1994). To a point, without clear standards or assessable guidelines, it seemed that nurses were expected to determine their own level of competency. Dimond (1994) pointed out that without testable guidelines to determine competency, nurses were left legally unprotected. Furthermore, for a court of law to determine misconduct, competence and standards of care go hand-in-hand with the laws of negligent practice (Dimond, 1994). So, without a doubt, nurses and nursing students must be clear about the level of competence to be attained in order to practice within legally-defined boundaries.

In a specific legal case in Scotland in 1993, a staff nurse incorrectly loaded a syringe of narcotic medication into an IV syringe driver that consequently led to a patient's death, dramatically highlighting the competency issue (Dimond, 1994). The inexperienced nurse was not convicted of a crime, but rather nurse management systems were held responsible for the inadequate provision of training to nurses and for including no competency testing of staff in managing IV syringe pumps (Bradshaw, 1998; Dimond, 1994). This case helps to define the impetus for the present research; educating and instructing student nurses efficiently on the effective use of an IV pump is critical to patient safety.

The issue of how best to assess the level of nurse competence has also been debated for years (Yanhua & Watson, 2011). Tollefson (2012) and Evans (2008) believe competence is difficult to assess because it is a balance of skill, knowledge, attitude, values and the ability of an individual nurse. Academics and educators have been formally assessing or examining the knowledge and skills of nursing students since the inception of university-based programs. The practice of nursing in the world today involves exposure to complex health issues and demands complex skills, procedures, equipment, and technology. The education and training of nursing students incorporates these complex issues so, where possible, the assessment of knowledge and skills represents assurance that nurses are suitably qualified and competent to care for patients.

The assessment of competency can be achieved through a variety of assessment techniques (Billings & Halstead, 2013; Bradshaw, 1997; Dolan, 2003; Tollefson, 2012; Yanhua & Watson, 2011), but clearly the subject of the competency needs to be defined first. Nursing education providers and program curricula must include explicit statements containing the learning objectives that provide the basis for learning outcomes evaluated through assessment methods (Allan, 1996; Dimond, 1994; Lenburg, 1999; Watkins, 2000). A learning outcome represents evidence of the skill and knowledge demonstrated or attained by an individual as a result of the education, training, or instruction received (Allan, 1996; McGrath et al., 2006; Neary, 2000a; Tollefson, 2004). How well and whether a learning outcome has been achieved can be measured at the point of evaluation, assessment, or examination, which determines level of competence (Billings & Halstead, 2013; Cowan et al., 2005; Evans, 2008). Statements about how a learning outcome will be assessed, directly or indirectly (Breslow, 2007) and graded (Allan, 1996), should be available so students are informed and reminded of their own learning needs throughout the education and assessment process (McGaughey, 2004; Tollefson, 2012; Watkins, 2000). Breslow (2007) described a direct measurement of a learning outcome achieved through observations methods and an indirect measure achieved through written means, assignments, or evaluation (Breslow, 2007).

Nursing and Midwifery Boards and Councils worldwide prescribe core competency or practice standards for nurses and nursing students from which clinical performance is assessed to provide a fit-for-practice assurance. In 2013, the Nursing and Midwifery Board of Australia (NMBA) released a newly-revised competency assessment framework for education providers comprising the principles, critical issues, and key elements in the assessment of nursing competencies. It stipulates above all else that assessment of clinical competence must use a model that focuses on the clinical performance that relates directly to the scope of practice of the nurse and must be carried out in the context of the practice setting and clinical situations encountered (NMBA, 2013). Key elements that must form part of the assessment model include self-assessment to determine the need for more training, observer assessment strategies by experienced clinicians, the assessment must be deemed valid and reliable based on the professional judgement of a knowledgeable and experienced nurse, and accurate recording of the assessors observations as evidence for analysis and interpretation (NMBA, 2013).

Based on this framework, there are models, instruments, tools, and guidelines for measuring learning outcomes, or a nursing student’s ability to perform a clinical skill or procedure, that can be appropriately applied in the context of determining the level of competency. However, evidence questions the quality and reliability of such tools (Evans, 2008; Yanhua & Watson, 2011). Despite many studies, there is little evidence demonstrating which assessment tools are the most reliable and should be formally implemented into nursing curricula (Evans, 2008). Neary (2000b) asserted that, although it is necessary to assess the skills nurses acquire, there must be a scientific basis for the assessment tools that are used in the process. Examples of these assessment tools include the Six-Dimension (6-D) Scale of Nurse Performance, Nurse Competency Scale (NCS), Self-Evaluated Core Competencies Scale (SECC), Competency Outcomes and Performance Assessment (COPA), Australian Nursing Council National Competency Standards (ANCI), Structured Observation and Assessment of Practice (SOAP), Objective Structured Clinical Assessment (OSCE), and various continuous assessment method instruments, peer review, self-assessment methods, and portfolios.

2.11 Objective Structured Clinical Assessment (OSCE)

In 2008, a review of numerous studies in nursing was undertaken to specifically identify which assessment of competence can best measure the clinical practice of nurses and nursing students. It concluded there was the need for more evidence from the models and tools to accurately inform the profession and educator providers (Evans, 2008). Most of the studies reported were qualitative and descriptive in nature, where the reliability and validity of the assessment tools (for the most part) were poorly reported, confounding the issue of which is best to use. The Objective Structured Clinical Assessment (OSCE) is commonly used in universities, where learning outcomes of a student's skill and knowledge can be a measure of their level of competency (Mitchell & Jeffrey, 2013). The OSCE was first developed in 1975 to assess the skills and level of competence of medical students by observing their performance during a clinical examination of actual patients (Harden, Stevenson, Downie, & Wilson, 1975). Since its inception, medical and nursing schools worldwide have adopted OSCE-style examinations, adapting it for their own assessment purposes (Rushforth, 2007).

OSCEs can be reliable, helpful and meaningful (Rushforth, 2007) indicators of practical and clinical competence and there are many studies that support their use as an assessment method in practical health disciplines (Mitchell, Henderson, Groves, Dalton, & Nulty, 2009; Mitchell & Jeffrey, 2013; Yanhua & Watson, 2011). One study reported such positive feedback and results from nursing students undertaking OSCE assessment activities, that the need for the use of any other assessment method came under question (Alinier, 2003). During that particular study, several clinical skills stations were designed through which nursing students rotated and practiced different scenarios and skills. Using an assessment tool adopted by the medical profession in the 1990s plus direct observation by a number of assessors, students were formatively examined at each station on their level of competence and then given a questionnaire about the overall experience (Alinier, 2003).

The results obtained from 86 nursing students showed that 93% felt the OSCE was beneficial and should be repeated regularly throughout the program, 89% found it confidence-building, and 92% believed it was relevant to and realistic for improving their practical skills (Alinier, 2003). In similar research on OSCE use in nursing, McGaughey (2004) reported feedback from nursing students who were observed while undertaking clinical activities and procedures, once again while rotating through a variety of skill stations. Although all students reported feeling stressed prior to the OSCE, 80% agreed it was a beneficial learning experience and the assessors involved agreed unanimously that the OSCE was useful in evaluating the clinical competence of students (McGaughey, 2004). The executive summary of a report prepared by a group of professors in nursing from a number of Australian universities concluded that nursing students strongly supported the use of OSCEs as a meaningful and authentic assessment activity in their preparation for practice (Mitchell & Jeffrey, 2013). In addition, academics embraced OSCEs as a form of assessment underpinning their delivery and practice as educators (Mitchell & Jeffrey, 2013).

The OSCE remains a favoured method for testing clinical competency in nursing (Cowan et al., 2005; Mitchell et al., 2009; Mitchell & Jeffrey, 2013; Nulty, Mitchell, Jeffrey, Henderson, & Groves, 2011; Yanhua & Watson, 2011), despite Evans (2008) reporting that there was still insufficient evidence about whether it is an accurate method for measuring level of competency. Some negative features have been reported (Evans, 2008), including that OSCEs are costly and time-consuming to ensure adequate preparation of students, assessors and equipment, but Alinier (2003) proposed that these factors are outweighed by the educational advantages delivered to students. Another potential negative feature of an OSCE is the anxiety experienced by the student or individual being assessed. This anxiety can create a performance that may be out of character for that person (Mitchell & Jeffrey, 2013). Furthermore, Evans (2008) among others, have noted the challenge of ensuring objectivity of an assessment based on direct observation, emphasising the importance of establishing inter-rater reliability (Evans, 2008; McGrath et al., 2006; Meretoja & Leino-Kilpi, 2003; Rushforth, 2007; Watson et al., 2002).

As the reliability and validity of direct observation assessment was questioned in early studies (Harden et al., 1975), recommendations have been implemented to ensure the robust assessment of skills (Neary, 2001; Norman, Watson, Murrells, Calman, & Redfern, 2002; Nulty et al., 2011). The assessment criteria should state, simply and in non-technical language, the expected learning outcomes or performance criteria in the form of statements (Neary, 2000b). It is also recommended that learning outcome statements are read and reviewed by experts to limit ambiguity, ensure quality, and allow for improvements, and to train and familiarise all assessors with the environment to ensure consistency, and finally to have the same trainers available for all assessments (McGaughey, 2004; Neary, 2000b; Norman et al., 2002; Rushforth, 2007). McGrath (2006) proposed that technical skills were easier to measure using a standardised assessment tool for assessment and that the tools that gave the most consistent ratings among assessors were the ones that were the easiest to complete. It has been suggested that focusing on a single skill in an OSCE examination strengthens the credibility of the assessment, enabling a more holistic aspect of competence (Harden et al., 1975; Rushforth, 2007; Tollefson, 2012).

A standardised assessment tool should include a scoring rubric aligning descriptions of performance specific to the skill or task (National Quality Council; NQC, 2009). In its guide for educators developing standardised assessment tools using observation methods, the NQC suggested the following inclusions: the assessment must be conducted in a real or simulated work environment, the tasks must be clearly outlined to the students, other assessors should be available, and each item or task should be represented by a number with corresponding statements or behaviours representing a typical pattern of skills as displayed by individuals progressing from novice to expert (NQC, 2009). Similarly, it was recommended that the marking tool should allow judgement of a student's performance related to certain behaviours expected in a clinical situation and be structured in a way that aligns directly with the mastery of the desired skill to enhance authenticity and accuracy of performance (Nulty et al., 2011; Mitchell et al., 2009).

Whether and how well a student can perform or execute a clinical skill is one component of the teaching and learning cycle. Other aspects of overall competency of clinical skills are highlighted in the following section and warrant discussion. For undergraduate nursing students these include: knowledge acquired and the possession of cognitive and technical ability (Tollefson, 2012), clinical reasoning and decision-making skills (Lapkin et al., 2010; Levett-Jones et al., 2009), self-confidence (Blum, Borglund, & Parcells, 2010) and whether or not, over a period of time, retention of knowledge and skill has been maintained. The next section will highlight not only how confidence is pivotal to performing clinical skills but also how competence can be retained effectively over time.

2.12 Building Confidence and Retaining Knowledge and Skills

Building and promoting confidence in a student's clinical performance through the application of simulation training exercises is vital (Samawi, Miller & Haras 2014), Generally studies support this as a characteristic of simulation techniques (Blum et al., 2010; Jeffries, 2005; Kaddoura, 2010; Lundberg, 2008; March, 2014; Nehring & Lashley, 2009) particularly Bambini and colleagues who, using a pre-post quasi-experimental study survey, reported a significant increase in the confidence of nursing students following simulation exercises in assessing the postpartum period (Bambini, Washburn, & Perkins, 2009). In addition, McCallum (2007) and Alinier (2003) in their research of nursing students undertaking simulation exercises in psychomotor skills, reported significantly greater confidence after receiving the training. Adding to the body of knowledge regarding simulation and increased confidence, Smith and Roehrs (2009) reported a significant correlation between the two. They suggested that simulation activities must be well planned, include clear objectives, and meaningful problem-solving activities. Furthermore, they suggested that with the increased complexities in technology, to maintain confidence-building in simulation, educators must evaluate these technologies to ensure their compatibility and effectiveness for preparing nursing students for clinical practice (Smith & Roehrs, 2009). Levett-Jones and colleagues (2009) supported this principle in a study that specifically explored nursing students' attitudes, levels of confidence, and performance with information technology throughout the first year of their program. They concluded that, for students to effectively engage with information technology, including online activities, they must be confident and feel competent with the resources provided (Levett-Jones et al., 2009).

The qualities of confidence, competence, and retention of knowledge were assessed in an investigation of nursing student's clinical skills. Hansen (2011) compared nursing students receiving traditional simulated training on the insertion of a urinary catheter with students learning the skill online from a mobile device. Although there were no statistically significant findings, it was concluded that online resources in the education of clinical skills, in addition to traditional simulation, enhance the qualities of confidence, competence, and retention of knowledge among nursing students. Viewing a clinical skill from a mobile phone for educational purposes is very much a modern, student-centred approach to learning (Bonnell et al., 2005; Boulos et al., 2007; Hansen, 2011). The accessibility and convenience of viewing a skill or procedure just prior to performing the skill on a patient, has clear benefits (Hansen, 2011) but whether this approach improves clinical performance, decision-making attributes, and retention, is uncertain. Further empirical research is needed to accurately assess whether the mobile phone revolution, for the education of clinical skills, contributes to improved confidence, competence, and retention of what was learnt.

Throughout the literature, clinical reasoning is typically associated with components of information related to patient care. In nursing, clinical reasoning can be considered synonymous with the terms critical thinking, problem-solving, and clinical decision-making (Banning, 2008; Lapkin et al., 2010; Levett-Jones et al., 2009; Simmons, 2010). In the present research, clinical reasoning can be related to the context of gaining and determining competence in psychomotor skill development (Levett-Jones et al., 2009). Banning (2008) identifies some of its multidimensional aspects where clinical reasoning surfaces from ideas that are presented and concepts that are collated logically, to reach a decision or conclusion. A practical example of this might revolve around a written patient scenario presented to nursing students online, where the treatment includes medication infusions and dosage calculations. These are important feature of educational technologies, such as the online IV pump, presented to nursing students in the context of developing clinical reasoning online, rather than at the bedside. Levett-Jones and colleagues (2010), in their “five rights” of clinical reasoning, proposed that effective clinical reasoning is paramount in avoiding iatrogenic harm. If nursing students gain proficient use of equipment and associated knowledge (such as medication calculations) prior to exposure to patients, then safe, professional practice should prevail.

Whether related to online or face-to-face teaching, on-campus or distance students, there is a paucity of evidence regarding the retention of knowledge and skills of nursing students. A few studies in the late 1980s and early 1990s explored the skill retention of nursing students performing CPR, but as teaching and technology has advanced so significantly and CPR methods have changed, more recent studies than these were sought. More recently, research has been conducted with approximately 100 nursing students who were learning CPR skills using high-fidelity simulation (Aqel & Ahmad, 2014). An experimental pre-post design was used, where one group received traditional face-to-face instruction using low-fidelity manikins, and another group, in addition, practiced CPR on computer-assisted, high-fidelity simulators. After three months, both groups demonstrated a significant reduction in skill acquisition, but the group instructed on the high-fidelity equipment showed greater retention of knowledge and skill (Aqel & Ahmad, 2014). Similar findings have been reported by Ackermann, Kenny, and Walker (2007) and Bloomfield, Roberts, and While (2010).

Wik and colleagues reported on the retention of CPR skills at 6-months follow-up. Once again, a combination of teaching strategies were implemented, but those who used the computer-assisted device for training and feedback produced the best outcomes initially and over time (Wik, Myklebust, Auestad, Steen, 2002). Another study, investigating the retention of knowledge and skill of cardiac arrhythmias with groups of nursing students who undertook different methods of instruction, showed those who were instructed and trained with simulation performed significantly better (Tubaishat, 2014). In another study, endotracheal suctioning was taught to one group of nurses in a simulated teaching program and this group performed the skill significantly better after four weeks compared to a group that received no additional instruction (Day, Wainwright, & Wilson-Barnett, 2001). Similarly, Bloomfield and colleagues (2010) compared the knowledge and skills of nursing students who received online and face-to-face instruction of hand washing. Although there were no significant differences at the initial assessment, nor at the 2-week follow-up, there was a significant difference in favour of the group instructed using online technologies after eight weeks.

Studies by Brydges et al. (2010, 2012) also support use of computer-assisted technology for retaining competence and confidence. Their study of nursing students who learnt psychomotor skills through self-directed video instructions reported improved retention of skill and confidence after a period of 12 weeks (Brydges et al., 2010). Another study conducted with medical students learning how to perform a lumbar puncture with computer-assisted technology, not only demonstrated improvement in performance at the time of assessment, but a maintenance of knowledge and skill at the 12-week follow-up (Brydges et al., 2012). On the other hand, nursing students instructed on clinical skills required for working in a surgical unit via online teaching technologies were initially found to be superior in knowledge and skill compared to a group receiving face-to-face instruction but showed no significance difference in level of competency at the 10-week follow-up (Fernández Alemán, Carrillo de Gea, & Rodríguez Mondéjar, 2011).

Many studies have supported the notion that computer-assisted technology in addition to traditional instruction in clinical skills, increases level of competency and in most cases this level of competency is retained better after a period of time. Finally, the results of a project conducted without the use of computer-assisted technology, which attempted to identify the best strategies to retain competency in cardiovascular assessment skills, showed that repeating tasks over and over in simulation laboratories led to significantly better retention of knowledge and skills than other strategies (Abe, Kawahara, Yamashina, & Tsuboi, 2013).

In summary, the assessment of clinical competence is central to teaching and learning in nurse education, and the ability of nurses to retain the knowledge taught, is just as central to education providers. In light of the evidence in the literature, and as stipulated by the NMBA, assessment of clinical competence must use a model that focuses on clinical performance relating directly to the nurse's scope of practice, carried out in the context of the practice setting, and clinical situations encountered (NMBA, 2013).

The present research focused on the performance of a specific skill of nursing students in the beginning stages of the nursing program and at the outset of their professional lives. Strategies were implemented, based on the evidence, to ensure a rigorous and robust evaluation of the level of competency in the use of an IV pump. The direct observation method was applied, inter-rater reliability established, and a simple non-technical standardised assessment tool was used by a team of experienced nurse academics. The following section will identify educational theories and a conceptual models that helped inform the research ideas and concepts, design and ultimately the research outcomes, particularly in relation to the nursing students.

2.13 Theoretical Issues for the Research

The theoretical issues that underpinned this research were primarily related to the education providers and the recipients of education, i.e., the principles adopted by the teacher and the learning behaviours associated with the students. Theories have been explored according to their relevance for quality education delivery to undergraduate nursing students that promotes competency of knowledge and skill, and accountability in professional practice. The theories and theoretical models that informed the present program of research were the diffusion of innovations process

(Rogers, 2003), self-determination theory (SDT; Deci & Ryan, 2002) and the principles of andragogy: the theory of adult learning (Knowles, Holton, & Swanson, 2005).

Diffusion of innovations, created and first published by Everett Rogers in 1962, is a well-established theoretical model that explains how a new idea or innovation is communicated or spread through a population over a period of time (Rogers, 2003). An innovation, an idea, or a practice can be a technological innovation designed to achieve a desired outcome and diffusion is the process of communicating through social channels and having the innovation gradually taken up. For a population or individuals to adopt and become users of an innovation, Rogers (2003) defined a five-stage decision innovation process, as seen in Figure 2.1. Knowledge, the first step, is characterised by the individual being exposed to the innovation but not inspired by it. Persuasion occurs when the individual seeks some information or details about the innovation that then informs the Decision about whether or not to accept or reject the idea. If the individual determines that the innovation will be useful and valuable then Implementation occurs and Confirmation is the final stage of the process which defines the individual's decision to continue to use the innovation.

Robinson (2009) similarly summarised how innovations are successfully communicated and how they "catch on" in certain social networks. First, the idea or innovation should be perceived by the group as an advantage or a convenience; second, it should align with existing values and practices; third, it must be simple and easy to use and demonstrated in a trial; and finally, the results must be visible (Robinson, 2009). There have been other nursing studies where diffusion of innovation theory informed the research.

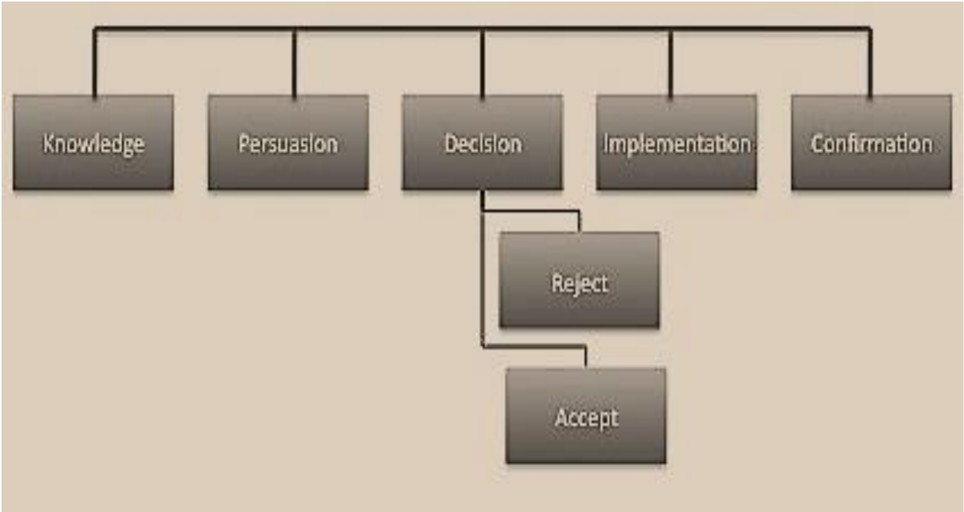


Figure 2.1. Five stages in the decision innovation process (adapted from Rogers, 2003).

Lee (2004) described a study where nursing students were invited to trial a new computerised care plan and reported the behaviours adopted by the students with the new technology, explaining the process in terms of Roger's model (Lee, 2004). In another study where new high-fidelity simulation was first introduced into a School of Nursing, diffusion of innovations was used to help guide the implementation of the innovation to success (Starkweather & Kardong-Edgren, 2008). The researchers were able to communicate the advantages of the technology, which were accepted by the student population as relevant and useful, and the trial demonstrated the ease of use and benefits for the students (Robinson, 2009; Rogers, 2003; Starkweather & Kardong-Edgren, 2008).

The diffusion of innovation framework was also applied to Sampsel's (2011) research on robotic technology in simulated nursing laboratories, where the characteristics of implementing an innovation provided a pathway for adoption of the technology. Similarly, Huffstutler (2002) reported on an innovative handheld emulation device for nursing students, where Roger's diffusion of innovations helped guide the decision-making process for its use throughout the program. The present research looked specifically at the design and implementation of a new technology for undergraduate nursing students (an online IV pump) in which Roger's (2003) diffusion of innovations help to guide the process for the researchers and educators involved.

Another theory that informed the present research was the self-determination theory (SDT) of human motivation. Distance education may seem like a lonely environment for some students. According to SDT, for individuals to initiate behaviours essential to thrive, there are three basic psychological needs that should be met. These are the need for competence, autonomy and relatedness (Deci & Ryan, 2002). This research particularly sought to promote a sense of competence and autonomy in nursing students engaging with the new technology. The work of Deci and Ryan (2002) described competence as having the need to control an outcome and experience mastery, and autonomy as having the urge to be in charge of, but live in harmony with oneself.

To successfully engage in online and distance education, students should use the inherent qualities of self-motivation to function and foster growth and success (Patterson et al., 2012). Unfortunately, there is little evidence that demonstrates the application of SDT in nursing research. Fonteyn and Cahill (1998) described nursing students use of completing reflective clinical logs designed to enhance their critical thinking skills and self-determination and autonomous practice. A similar study from Japan investigated the critical thinking abilities of nursing students, reporting that cultural influences inhibited self-determination and autonomy (Kawashima & Petrini, 2004). Finally, Fahrenwald and colleagues promoted autonomy and self-determination in their teaching of core values to nursing students and labelled those qualities as inherent characteristics that exemplified the professional nurse (Fahrenwald et al., 2005).

Academics and educators of adult students should consider SDT in their quest to encourage behaviours that influence interaction with different teaching and learning environments that promote positive outcomes (Mayville, 2007). The present research, with its implementation of computer-assisted online educational technology, was informed by SDT insofar as the methods used were designed to fulfil the basic psychological need to develop feelings of competence, autonomy and relatedness as a part of the learning process (Deci & Ryan, 2002).

Andragogy, theorised by Malcom Knowles in the late 1960's, is defined as an adult education-based conception of being self-directed and autonomous learners and including teachers as the facilitators of learning (Knowles, 1980). The term andragogy, specifically designed for academic disciplines throughout tertiary and higher education, focuses on the education of adults and emphasises concepts central to adult academic learning, especially reflection, critical and historical analyses (Knowles et al., 2005). Knowles' theory of adult learning is associated with the following six assumptions related to the motivation of adult learners:

1. Need to know: Adults need to know the reason for learning something.
2. Foundation: Experience (including error) provides the basis for learning activities.
3. Self-concept: Adults need to be responsible for their decisions on education, including involvement in the planning and evaluation of their instruction.
4. Readiness: Adults are most interested in learning subjects having immediate relevance to their work and/or personal lives.
5. Orientation: Adult learning is problem-centred rather than content-oriented.

6. Motivation: Adults respond better to internal rather than external motivators.

A well-established concept stemming from andragogy, which informs the present research, is a 5-step model for adult learners and educators, which emphasises diagnosing learning needs, formulating learning needs, identifying human material resources for learning, choosing and implementing appropriate strategies and evaluating learning outcomes (Knowles, 1975). The 5-step model has been recognised as an important concept in the education of nurses at all levels to enhance confidence, motivation, autonomy, assist in problem-based learning, and influence approaches to life-long learning (O'Shea, 2003) and promote successful study by distance (Lewis & Price, 2007).

2.14 Conceptual Model for the Research

The trend of online education using computer-assisted technology means educators must deliver a variety of resources online and students must access and engage with these resources. A research-to-practice conceptual model that fits with the present research reflected Salmon's (2012) five-stage model of teaching and learning online (Figure 2.2). The principles include having an understanding of the online environment, having computer and technical skills in using online programs, acquiring online communication skills to engage learners, content expertise to support learners' knowledge, and personal characteristics, such as adaptability, positivity and confidence (Salmon, 2012).

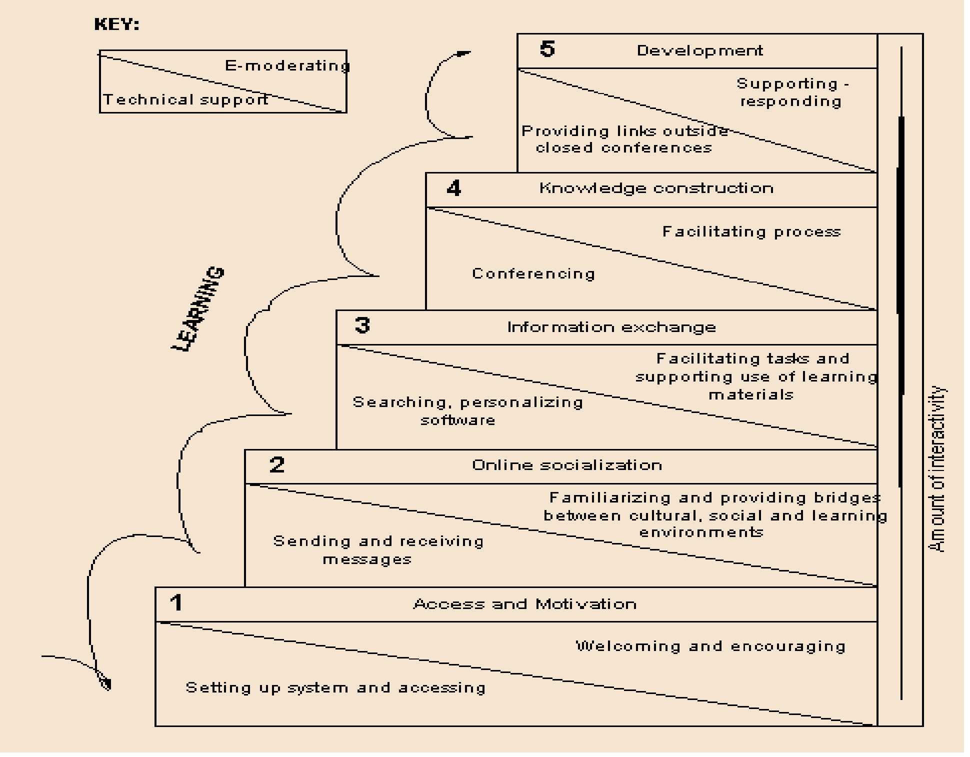


Figure 2.2. Five-stage model of teaching and learning online (adapted from Salmon, 2012).

The characteristics and features of the model are designed to demonstrate the student's participation in online learning and the educator's or e-moderator's role in facilitating the experience (Salmon, 2012). For the present research, each stage of the online model informed the process of providing an online resource that was easily accessed, instilled motivation in students, created online socialisation and engagement, and demonstrated acquired knowledge, thereby increasing confidence, autonomy, and self-regulated learning (Salmon, 2012). There are numerous studies from the nursing profession, many already mentioned, where innovative online teaching methods and computer-assisted technologies are strongly supported and endorsed by educators and students alike (Barak, 2006; Billings & Halstead, 2013; Bonnel et al., 2005; Dearnley et al., 2013; Halstead & Coudret, 2000; Hudson, 2014; Legg et al., 2009; Maag, 2006; Mayville, 2007; Schnetter et al., 2014). Issues related to internet-based learning for practical disciplines and barriers to technology have also been highlighted and discussed, setting the scene for the present research (Eley et al., 2009; Halstead & Coudret, 2000; Kenny, 2002; Reed, 2014; Thiele, 2003).

Although it has been criticised by some, Salmon's (2012) five-stage model has been adopted by many education providers as it demonstrates a simple and easily understood model for online education. Moule (2007) labelled the model as limiting, seeing it as purely designed for the online teacher and learner, and neglecting a variety of other educational concepts, such as face-to-face delivery, that when used in conjunction with online resources, are just as influential for student success. There is evidence in the literature which supports Moule's view, particularly in the nursing sphere, where much research comparing online to face-to-face has shown that a combination of both achieves the most favourable results (Brydges et al., 2010, 2012; Gagnon, Gagnon, Desmartis, & Njoya, 2013; Jefferies, 2013; Lewis & Price, 2007; Simonsen et al., 2014; Stolic, 2014; Yom, 2004).

2.15 Summary

The global shift to online university education has seen great innovation in education delivery via e-technology. Online teaching resources for use in the health professions, such as nursing, are plentiful but must be of high quality with evidence-based outcomes in order for clinicians to prosper in their professions. The idea of creating distance education resources for nurses was introduced in Australia more than a decade ago in an attempt to educate large numbers of qualified nurses to prevent a predicted shortage of professionals. At the time, the nursing profession had little exposure to digital technology or even used computers in the day-to-day working environment. Now, there is a great deal of informative research available for the nursing profession to move with these technological times. However, there are always gaps in knowledge when exploring any new development and implementing innovative technologies that demonstrate improvement in the clinical practice of nurses. The present program of research, in line with the shift to distance and online education, targeted this development, using remote-access technology, to assess the clinical competence of undergraduate nursing students in the use of an IV infusion pump.

Chapter 3

Stage 1 – Conceptualisation and Development of the Online IVPE

3.1 Introduction

Blended learning, a topic introduced in the previous chapter, is the delivery of education through technology that supports traditional teaching practices. Singh (2003) and Jefferies (2013) advocate for blended learning in education especially due to its capacity to include more delivery mode choices. This offers students social contact, engagement, interactivity and relevance, thereby creating a meaningful learning environment that ultimately improves the effectiveness of learning, as evidenced by the achievement of specific learning outcomes (Jefferies, 2013; Singh, 2003). The Remote Access Laboratory (RAL) can be categorised as a blended learning strategy. In the engineering discipline, for example, RAL has previously been discussed in terms of its ability to provide an accessible pathway to engage students, who perform physical and tangible experiments in on-campus laboratories from an off-campus computer, often at home.

A team of academics in a regional university decided to extend the concept of RAL from robotic laboratory experiments to other types of activities and skills in other practice disciplines. RAL had already been tested in education and arts disciplines using theoretical activities, so for a more practical approach, the nursing discipline was selected for investigation. The clinical equipment used by nursing students in the simulated laboratories was reviewed by the development team. This equipment included infusion devices, diagnostic equipment, procedures and skills from day-to-day teaching activities, some of which were considered as candidates to be channeled to students via RAL. Through a collaborative process, the IV infusion pump was chosen as a prime candidate for investigation. Nursing students practice regularly with an IV pump in the laboratories, testing knowledge and skills repeatedly, and exercising clinical reasoning and problem-solving using activities associated with IV fluids and medications.

To get a better understanding of the way nursing students, academics and tutors use actual IV infusion pumps in simulated laboratories for teaching and learning, a small project developed. It was entitled *Pedagogy of Remote Access Laboratories in Different Disciplines,* which received ethics approval from the University of Southern Queensland (USQ) Human Ethics Committee on 16/9/2011 - HREC Approval Number: H11REA102. Data were collected by two-hour observations of simulated nursing laboratory classes and feedback from a nursing student focus group. The aim of the project was to gain insights into the actions that students take to acquire the requisite skills to operate an IV pump and to determine whether it would be a suitable item of equipment for inclusion as an online educational tool.

Bowtell and colleagues reported enthusiasm from the student focus group for the idea of an electronic or computerised aid to learn about the functions of an IV pump (Bowtell et al., 2012). Some students in the forum described working with the actual IV pump in class as “frustrating,” “daunting,” and “overwhelming.” In the students’ view, a RAL system that facilitated additional practice time would alleviate problems inherent in a face-to-face class, wherein if a student struggles to gain competence they do not receive extra time to familiarise themselves with the equipment or the skill. The group reported that the time between practical classes was so long that they tended to forget important aspects of the equipment. The students also identified that the flexibility of accessing RAL online allowed practice at an individual’s own pace, and at a time that suited, keeping the IV pump operation fresh in their minds. In short, it appeared that the students were very interested in an IV pump via RAL for its flexibility of access and access to repeated practice. This project signalled the beginning of Stage 1 of the research which further explored the development of an online IV infusion pump.

3.2 Aims and Propositions

The purpose of Stage 1 of the research was to provide an authentic learning experience for undergraduate nursing students to access, utilise and practice with an online IV pump. The key aim of this first stage was to identify how well RAL could support an online IV pump with the inclusion of the skills acquisition required for learning, traditionally provided through hands-on activities performed in a nursing laboratory. It was expected that the outcomes of Stage 1 would provide a clearer picture of the value of RAL as a pedagogical learning tool in a practical health discipline such as nursing.

The propositions for Stage 1 were:

1. That an automated version of an actual IV pump could be successfully developed for the purpose of online nursing education;
2. That this automated version of the IV pump would realistically mimic features of an actual IV pump, including a fully functioning infusion;
3. That an automated version of the IV pump could be made accessible to undergraduate nursing students via a Remote Access Laboratory.

3.3 Method

The first stage of research involved transforming the intellectual processes involved in developing a computerised IV pump into a realistic and appropriate online education technology. This phase was dependent upon the clinical expertise of the research investigators, who, after time spent critiquing the literature on the topic of interest, refining and narrowing down all necessary aspects of the topic, developed a succinct research design and purpose. The sparse existing research on the topic was critically evaluated for its strengths and limitations and while very little was known about computerised or online IV pump programs, a collaborative stage of research was undertaken to discuss and test research ideas that assisted in guiding the design of an online IV pump prototype.

The decision to conceptualise and develop an online IV pump required an iterative process involving the nursing and engineering disciplines and moving towards successfully creating an educational technology that met specific learning objectives for the undergraduate nursing cohort. The required features and functions of this new online innovation were identified by the principal researcher and tested at each stage of development. The process of evaluating the clinical utility and relevance of various prototypes progressed towards the development of a workable resource that would meet the learning needs of undergraduate nursing students in using an IV pump. The final process involved producing the objectives and teaching plan including online instructions for the online IV pump. The instructional material for student users included images, videos and a case study scenario to enhance the learning experience. These aspects were embedded into the online program and all were vital key features commensurate with the teaching and learning of an actual IV pump in the classroom.

The steps in the development of the computer program and the fundamental aspects of the project are explained methodically, including the various stages of testing hardware, software, communication and feedback systems. The following sections chronicle this step-by-step process in the conceptualisation and development of the online IV pump for undergraduate nursing students.

3.3.1 Conceptualisation of the online IVPE. Conceptually, from nursing academic and clinical perspectives, a number of key concepts were identified as fundamental to the success of an online educational technology. These areas, assessed later in the project, were evidenced by student participation, improvements in learning outcomes, and skill acquisition related to using the actual IV pump. To aid conceptualisation and development, aspects of Salmon's (2012) five-stage model of teaching and learning online were adopted. Aspects considered in this stage included enhancing student interaction and engagement, a sense of realism, ease of accessibility and operability, and technological support and communication.

First, it was deemed necessary to include a level of interaction sufficient to maintain student interest and engagement necessary for knowledge and skill retention. Interaction in this context refers to activities performed by an individual student with the IV pump program and with the content displayed on a personal computer. The basic design of the online IV pump mimicked a one-on-one educational tool. Engagement in this context refers to the capability of the IV pump program to respond, restore, and move quickly and effectively from one screen to another, keeping the student engaged in the activities as they appear on the screen. Another concept important in the use of this educational technology was that of developing and improving the clinical reasoning skills of nursing students by incorporating medication calculation and other critical-thinking activities. The idea was to enable the online IV pump to deliver effective and interactive learning opportunities, keeping the nursing student engaged in skill development and problem-solving activities. The central aim was that the online IV pump should contribute to advancement in skill competency and achievement of desired learning outcomes in relation to using the actual IV pump.

Second, the concept of quick and easy access to any computer program or internet page is fundamental. Naturally, these concepts were foremost in the considering the steps required to access the online IV pump. Associated with ease of access comes effective communication about aspects of the program, logging on and off, instructions for use, network compatibility, password requirements and the availability of appropriate technical support. Promoting the benefits of the online IV pump to nursing students and linking the relevance of the online IV pump to the course content and its significance to improving clinical practice were all considered as aspects to enhance students' motivation for using the program (Salmon, 2012). A user-friendly computer program was deemed to be essential to motivate and maintain participation and repeated use.

An online IV pump possessing realistic features was considered the third essential concept in creating a successful and meaningful learning tool for nursing students. When replicating a device for teaching and learning purposes its functions and features must be as close as possible to the "real thing." The concept of the online IV pump being a realistic experience for nursing students was vital to determine the equivalence of an online IV pump to an actual IV pump. Not only was this important for student participation and engagement, it was vital for assessing the learning outcomes among the nursing students. Replacing classroom or traditional face-to-face equipment and activities with computer technology required both expert practitioners in the field and skilled technicians who were familiar with learning objectives required to advance skill competency.

Based on experience and feedback received in the preliminary project and having identified the conceptual aspects necessary for an online IV pump (see Figure 3.1), the need for collaboration between nurse practitioners and software engineers to develop and transform it into a viable computer program, followed next in this stage of research.

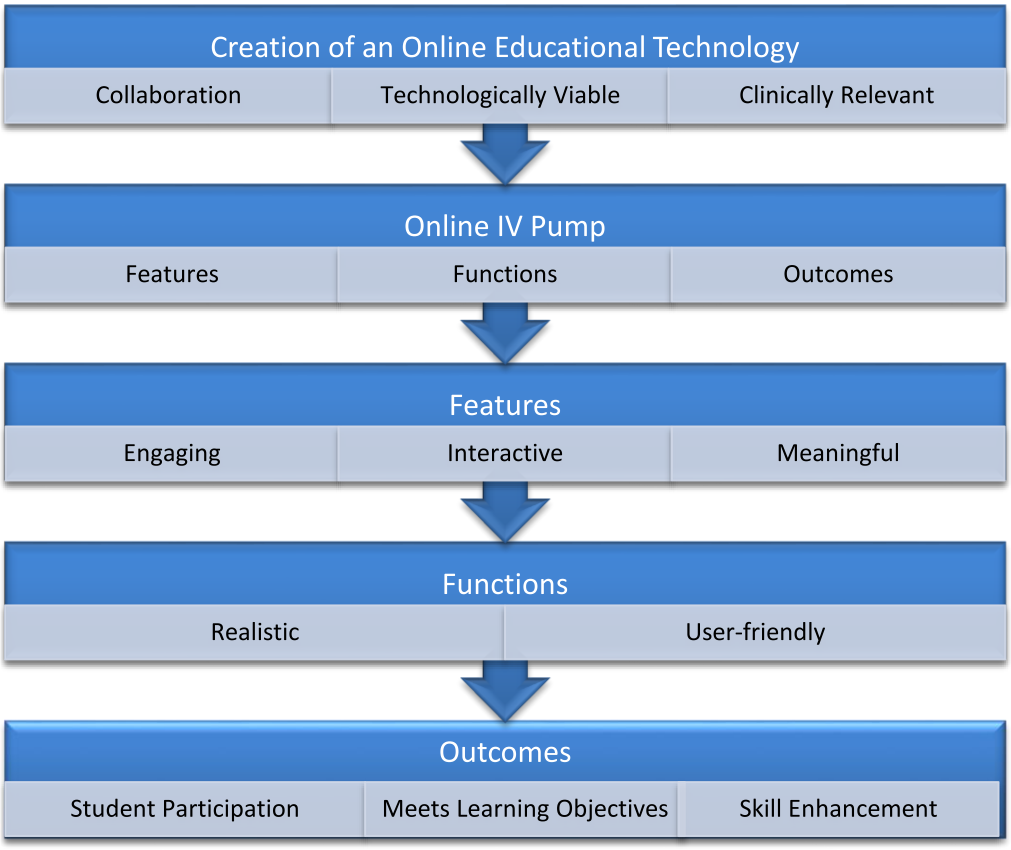


Figure 3.1. Conceptualisation of the online IV pump.

3.3.2 Development of the online IVPE. With a conceptual framework in place (see Figure 3.1), the next step was to design software to enable nursing students to view and interact with an IV pump on a computer, using a mouse or touch screen capability, following logical step-by-step functions as if using an actual IV pump. Also necessary were provisions to understand, navigate, practice and develop competency in clinical skills and critical reasoning related to the preparation and administration of intravenous infusions via an IV pump.

Supervisory control and data acquisition (SCADA) was the computer operating system used in the development of the online IV pump. This system is used in major industries designed for gathering, analysing and communicating real-time data. Some examples of where SCADA systems are used in industry include telecommunications, water and waste control, energy, oil and gas refining and many transportation sectors (Osborne, 2012). SCADA systems can also be relatively simple, and designed to be used in much smaller contexts and businesses. The computer operating feature of real-time automation is when a system has the capability to respond to input immediately such as in navigation systems, automatic bank teller machines, airport self-check-in desks, and supermarket self-checkouts. This operating feature in the system has the beneficial characteristics that aid in producing an interactive and user-friendly environment. These were appropriate features for the development of an online IV pump for the students (Bowtell et al., 2012).

Another key feature of the system is the ability to program a simulation operation such as for the training of machinery and/or aircraft personnel. Allowing the trainee (i.e., nursing student) repeated practice using a replay mode and other simulated modes of operation to help with practicing skills and procedures for real-life situations has obvious benefits. This type of program also allows the trainees' actions and responses to be logged and saved for later feedback and discussion (Bowtell et al., 2013). These features in an online IV pump program, whereby a nursing student can undergo various activities repeatedly and then follow-up with a self-assessment and evaluation of performance, has obvious benefits for learning.

One other component of the SCADA computer system is the human-machine interface (HMI), the apparatus that presents data to a human operator or user and, through this, the computer monitor interacts and responds with data inputs in a real-time automation context (Osborne, 2012). For the computerised IV pump, the HMI or IV pump interface on the computer screen was the main interactive element for data input by a student. The replication of the actual IV pump keypad, buttons and lights to produce realistic and interactive functions on the computer screen were considered essential features. In addition, where possible, the exact functionality of the visual and audible warnings and alarms were also included.

The various screens and graphics of the online IV pump were produced using programs such as Microsoft Paint™ and Microsoft Visio™ and the audio cues of the actual IV pump were recorded and programmed into the database to be enabled by a sequence of events (Osborne, 2012). Initially, the HMI interface could not use a touch-screen system and so, at that stage of development, a computer mouse was required for all data inputs. The online IV pump program was considered by the developer to be emulation, and hence the device was labelled an IV pump emulator (IVPE). Figure 3.2 is an image of the actual IV pump used for training purposes in the simulated nursing laboratories and Figure 3.3 is the IVPE.

Figure 3.2. Baxter IV pump.

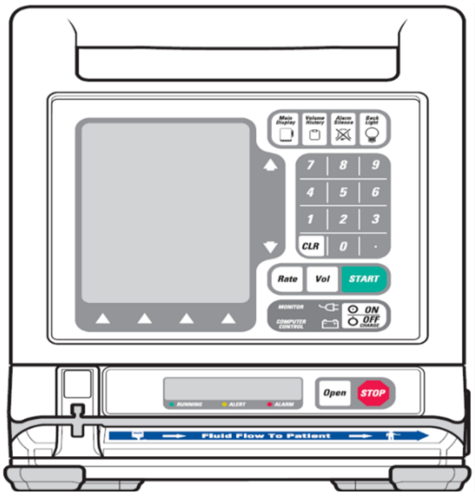


Figure 3.3. Emulated IV pump (IVPE).

Having the HMI platform was just part of the successful development of a functioning IVPE. In order for the interface to operate and respond as an actual IV pump, it needed to be controlled by a programmable logic controller (PLC) based on data inputs entered by the student. Flowchart-style programs were written to allow for what students might enter or input and all of the possible responses relayed to the PLC (Bowtell et al., 2012). Figure 3.4 represented the type of sequential flowchart designed to respond to possible student data inputs.

Conceptually, from an academic and clinical perspective, a vital property of the IVPE was replicating all of the responses with the press of a mouse for each button, icon or symbol on the IVPE interface, as they are seen and heard on the actual IV pump. This included activating and allowing all possible responses from the RATE, VOL, START, ON/OFF, OPEN, and STOP buttons, along with each numerical value and decimal, up and down arrows, and the alarm silence button. Therefore, the logical sequence and correct use of the IVPE program was developed to firstly activate the ON/OFF button which simultaneously enabled the audible alerts replicating how the actual IV pump sounded. Once turned on, the default steps and cues required a mouse press to progress through a start-up sequence corresponding with audio imitating the actual IV pump. These steps included, a sound check, clearing previous patient data, and confirming readiness to start the programming of the device. All of this information was considered important for students in the learning process for an infusion device.

The next step in the sequence was to input a rate and volume to be infused (VTBI). RATE and/or VTBI could be enabled using either the up/down arrows or by pressing on the corresponding button, allowing the user to input the required numerical values. Before starting the flow of IV fluid, loading the IV tubing into the IV pump had to be initiated. It was programmed into the IVPE that if START was activated before OPEN, an alarm sounded with a written alert on the interface stating "NO TUBE" to remind the user to load the IV tubing giving set.

The physical task of loading the IV tubing into the IVPE was impossible to emulate. Instead, the user could view a short resource video demonstrating how to load the IV tubing into the IV pump, by pressing an icon installed on the interface. Pressing OPEN activated the audio and visual objects that imitated the IV tubing loading into the actual IV pump. Once the tubing was loaded, the user was then able to program a rate and a VTBI.

Again, before START was activated, it was necessary to press the CONFIRM PRIMARY keypad button otherwise another alarm was activated displaying the warning “UNCONFIRMED PROGRAM.” Once the primary rate was confirmed and the infusion was enabled with START, the flow of fluid commenced. Flow commencement was indicated by the display of a visual indication and a recorded audio cue of the flow of fluid as heard from the actual IV pump.

This original prototype online IVPE was successfully programmed into and accessed via the RAL platform. The prototype showed a visual representation of a litre of IV fluid infusing through an actual IV pump. The IV infusion set-up was situated in an engineering laboratory with live video frame grabs via a webcam and adjustable frame rates to suit Internet bandwidth, allowing a remote user to visualise the IV fluid dripping into the IV giving set drip chamber.

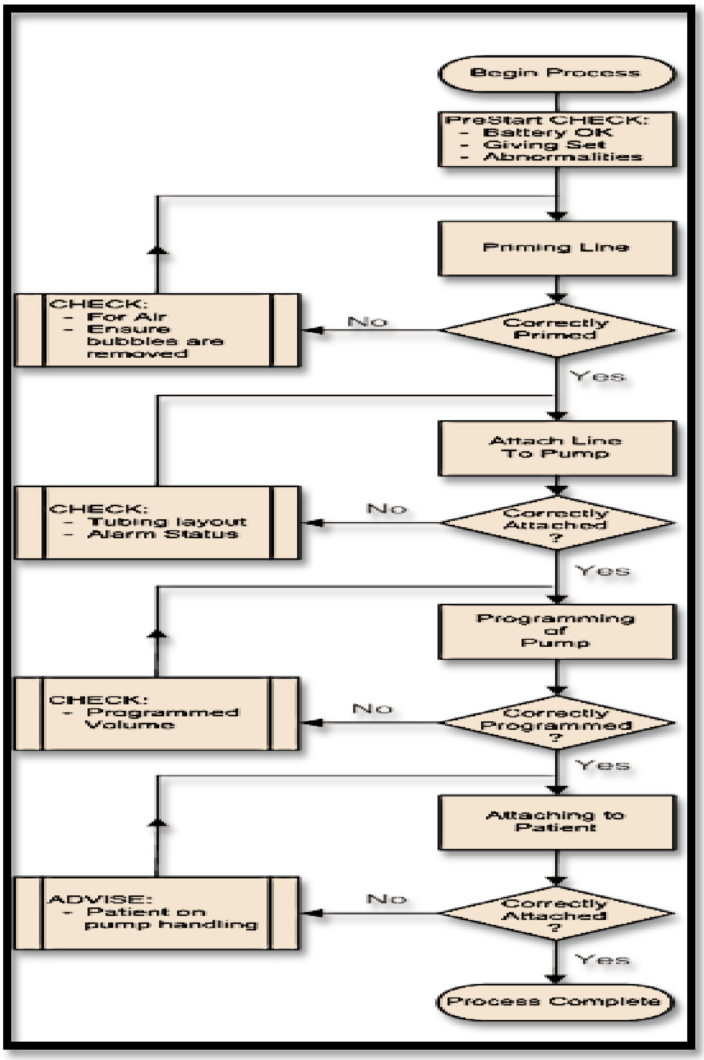


Figure 3.4. IVPE programmable logic controller (PLC) flowchart (Bowtell et al., 2012).

Through the iterative development process between the two disciplines, this prototype was judged to be inadequate as an educational technology, as demonstrating only the peristaltic function of IV fluid dripping from the bag into the drip chamber provided minimal educational benefit to a nursing student. Therefore, the activity in RAL was modified from a physical and tangible robotic laboratory experiment to a more conceptual activity accessed remotely, including a variety of tasks and activities with the online IVPE. The remote RAL platform enabled secure administrator rights, so that user traffic, including the time students spent using the program could be recorded if necessary throughout the subsequent stages of research.

Given that the pump interface emulation was readily accepted by students as very realistic, the visual feedback from the webcam was judged to be unnecessary and a hindrance to those accessing via low speed Internet. Access to the online IVPE via the RAL platform involved an online booking system linked with the student learning management system (LMS), known as Moodle™. With the aim of enhancing the students' experience and to better engage them, clear instructions and details about the booking process, steps to access, passwords and logins were added to the LMS. The original instructions for login and using the online IVPE are detailed in a step-by-step video sequence presented as Appendix E. Additional scaffolding resources were also incorporated into the emulation program. The splash screen of the online IVPE is presented as a screenshot image in Figure 3.5.

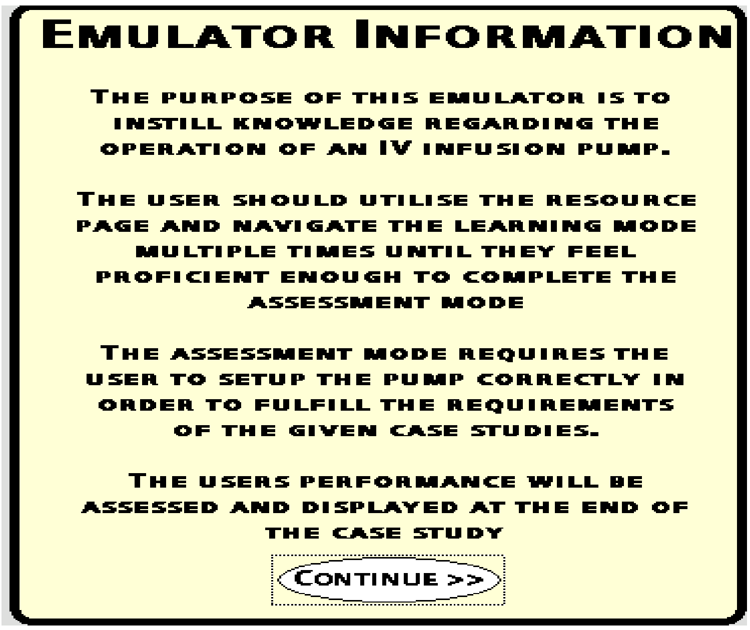


Figure 3.5. IVPE information screenshot.

Using a guided approach, the user continued through to the online IVPE welcome page, and was prompted through a series of optional activities including a LEARNING MODE, RESOURCE PAGE and ASSESSMENT MODE (see Figure 3.6).

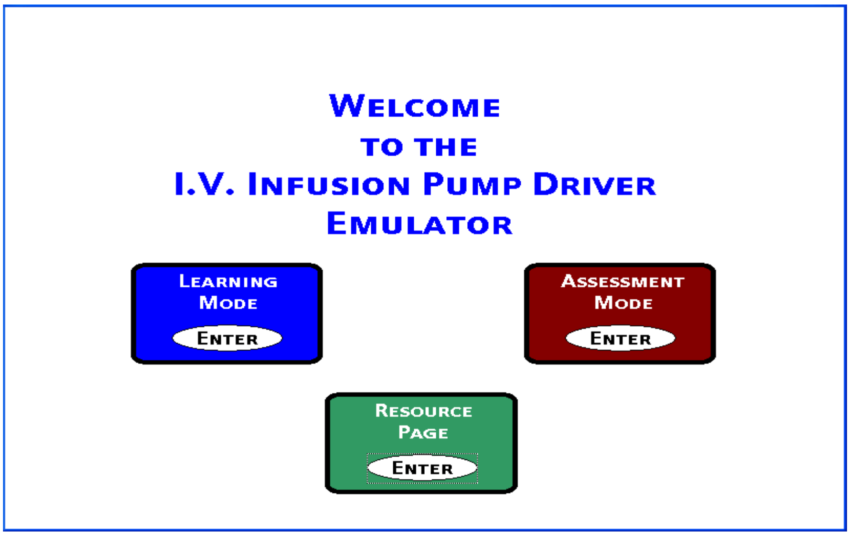


Figure 3.6. IVPE welcome screenshot.

The learning mode, before transporting users to the online IVPE interface, presented the user with selective hints providing guidance and instructions about some of its functionality (See Figure 3.7).

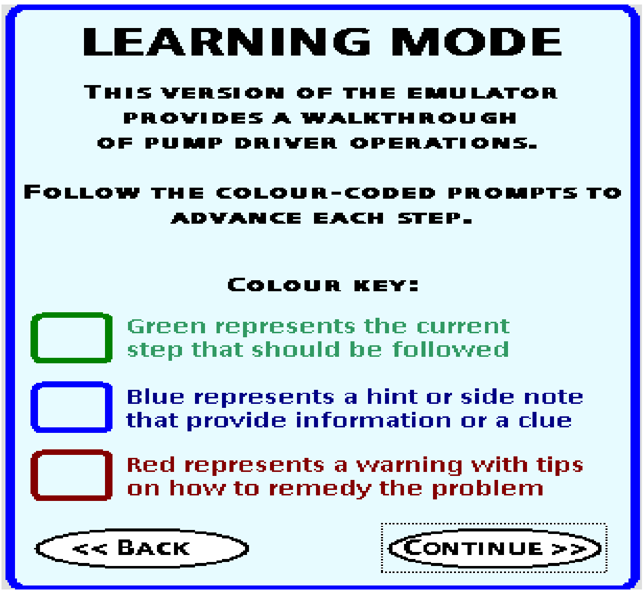


Figure 3.7. Learning mode instructions screenshot.

Bearing in mind that an external cohort of first year nursing students using the online IVPE typically would not have been in a real or simulated nursing laboratory, the resource page included a gallery of associated aspects of preparing IV fluids and medications to be infused by an IV pump. An example of this is presented as Figure 3.8.

Figure 3.8. Example of image gallery resource.

After becoming familiar with the practical aspects and associated details of IV pump usage, the students were able to assess their level of understanding with an online assessment. Students can do this by entering assessment mode in the online IVPE to work on a realistic case study scenario embedded in the online IVPE system. The case study scenario (see Figure 3.9), was designed to increase student interactivity and engagement with the program including clinical reasoning skills in delivering IV fluids.

Mr White aged 26, has been admitted to the surgical ward suffering severe acute right lower quadrant (RLQ) abdominal pain. After an initial examination his medical officer has ordered Nil by Mouth (NBM) and IV therapy 1000mLs of Sodium Chloride 0.9% to run over 6 hours.

1a.) How many mL/hr. to enter?

b.) What should be the volume to be infused?

Over the next couple of hours, Mr White vomits continuously large amounts of fluid and his pain increases. His temperature is recorded at 38.5 and he looks and feels listless.

His doctor orders the following:

Run 250mls of the Sodium Chloride 0.9% over one hour and prepare for Operating theatre (OT).

2 a.) How many mL/hr. to enter?

b.) What should be the volume to be infused?

Figure 3.9. Case study scenario for online IVPE.

After initial trials and developments, the capacity of the SCADA system to save, interpret and store data entered by a student was incorporated. In the assessment mode for example, the ability to progress to a self-assessment evaluation following the case study scenario was included and activated. Using the SCADA system functionality, all relevant information and outcomes regarding the case study scenario were stored. Then, based on numeric, contextual and response time data of the students, the case study scenario performance was evaluated and results calculated after each attempt. This was then presented to the student to show whether each aspect of the task had been performed correctly or not (see Figure 3.10).

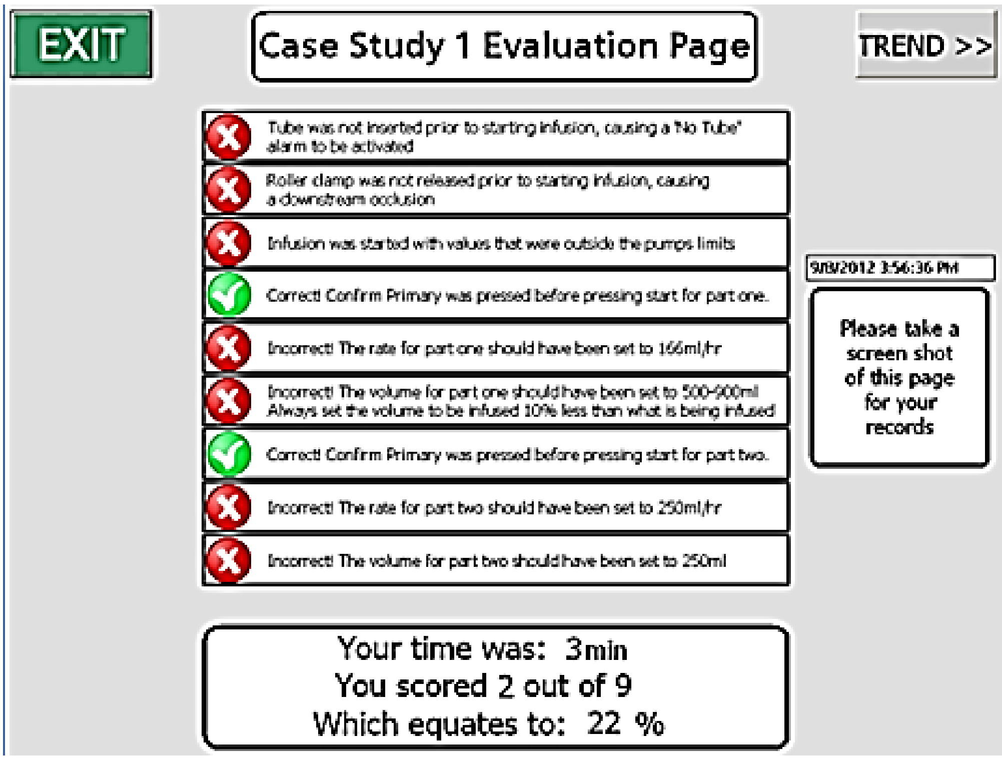


Figure 3.10. Case study evaluation screenshot.

After considerable consultation between disciplines in the conceptualisation and development phases, the finalised version of an online IVPE was ready for launching online for the next stage of research. Stage 2 was a preliminary evaluation of the online IVPE and will be discussed in detail in Chapter 4. During and following Stage 2, the iterative development process between disciplines continued, and refinements were considered and implemented for Stage 3, which included a more comprehensive evaluation of the online IVPE by groups of undergraduate nursing students as discussed in detail in Chapter 5.

3.4 Summary

The decision to develop an online IV pump training system stemmed from a consultative process between two practice disciplines; both seeking innovative ways to deliver effective teaching resources online. A small group of undergraduate nursing students indicated, in a focus group, that more online technology for learning was desirable, particularly for the introduction of a flexible or blended nursing program. An IV infusion pump was chosen for the project, based on learning needs perceived by nursing students and the regularity of its use, not only in the simulated nursing laboratories, but in day-to-day patient care in hospitals around Australia and overseas.

Through the methodical phases of conceptualisation and development of the online IVPE, key characteristics were monitored, trialled and revisited by the developers. At the conclusion of Stage 1, a computerised version of an actual IV pump was successfully developed for the purpose of teaching nursing students about IV pump use. The online IVPE program realistically mimicked features of an actual IV pump and was enabled for students to access through the RAL platform for remote use, such as from a home computer.

Chapter 4

Stage 2 – Preliminary Evaluation of the Online IVPE

4.1 Introduction

The purpose of Stage 2 was to conduct a preliminary evaluation of the online IVPE by undertaking an initial assessment of student learning outcomes. User perceptions between the traditional face-to-face method of instruction using an actual IV pump and the online IVPE, or a combination of both were examined. This stage also investigated the autonomous learning practices of participants and their willingness to access and engage with this new innovation.

The course *Medications: Theory and Practice* was selected for the research for the following reasons. First, the nursing students, whether external or on-campus, were just entering the program, with no prior experience or exposure to the features and functions of an actual IV pump (this assumption was later verified as correct). Second, IV pumps were first introduced at that stage of the program, pitched at a very basic instructional level, and introduced into the course about half way through the semester. This allowed time to prepare and inform the cohort of the new online innovation and its purpose in their competence development. Traditionally, IV pumps were made available to the nursing students for just one week, which included instruction on their use, demonstration and practice. This short and specific timeframe allowed a clear research delineation for the procedure and data collection.

4.2 Aims and Hypotheses

The aims for Stage 2 were to assess perceptions of useability and functionality of the online IVPE, including accessing the program via RAL. Stage 2, being the preliminary stage of the evaluation, was also aimed at gauging students' interest and motivation in accessing a unique online teaching tool. The main aim, however, was to compare student learning outcomes between nursing students who engaged with the actual IV pump and those receiving only online engagement with the online IVPE. Additionally, the final aim was to determine whether nursing students using a combination of both an actual IV pump in class and an online IV pump via distance achieved better learning outcomes. Learning outcomes were operationalised in terms of a score that reflected the competence of the participants using the actual IV pump.

The hypotheses tested for Stage 2 were:

H0: There will be no significant difference in assessment scores between participants who used the online IVPE and those who were instructed face-to-face using the actual IV pump;

H1: Participants in the combined group will achieve significantly higher assessment scores than participants in the other two groups.

4.3 Method

A mixed-methods research design was chosen to measure the undergraduate nursing students' learning outcomes and user perceptions for using online technology compared to a physical piece of medical equipment. Using a quasi-experimental design, competence in using the actual IV pump was assessed as described below. Additionally, a survey was used to assess user perceptions among those using the online IVPE, an actual IV pump, or a combination of the two. This combination of quasi-experimental and survey methodology is considered to be both pragmatic and appropriate to clinical practice in nursing. Moreover, the methodology used was judged to provide an effective strategy by which to conduct a between-group comparison to evaluate an online educational resource for a health discipline

(Roberts & Burke, 1989). With new ideas and innovations there is a need to identify strengths and weaknesses, and using experimental designs to answer clinical questions also builds evidence for best practice (Nagy et al., 2010).

In order to assess competence, a clinical assessment tool was developed. The tool comprised of a series of activities designed to guide participants through the general functions and features of an actual IV pump. Included in the activities were tasks related to calculating various rates of IV fluid infusions, commonly used in clinical settings. The rationale for including these IV rate activities was to enable the participants to perform programming and re-programming of the different rates and volumes of IV fluid that may be encountered in clinical practice. This activity was a direct reflection of the teaching objectives in the course of study.

Consideration was given to the content validity of the clinical assessment tool. The list of activities to be assessed were selected from reputable clinical sources. Expert opinion from nurses with a range of formal clinical education and experience judged the activities to be necessary in the education and training of an actual IV pump for a student nurse. The psychomotor skills clinical text, recommend to the student nurses in the course of study, also provided a guide in selecting what activities would be appropriate on an assessment tool measuring competence in using an IV Infusion device (see Tollefson, 2012).

Each activity were given a numerical score using a Likert-type scale to assess the required IV pump performance. Activities were designed to directly reflect the teaching and learning objectives provided to tutors and nursing students in the course material. Both face-to-face and online groups received instructions about either the actual IV pump, the online IVPE, or a combination of both. The activities were listed in a logical sequence for the participants, and for the purpose of the project was referred to as the Activity Assessment Tool (AAT; see Appendix F).

Using the AAT, all participants were assessed on their level of competence with an actual IV pump using the Objective Structured Clinical Assessment (OSCE) methodology. The assessor of the activities for Stage 2 was both an independent experienced nurse and a university nurse educator with many years of experience in the delivery of laboratory simulation equipment and techniques, assessment design, and format of practical examinations, particularly in the form of an OSCE.

Also included in the research design was a user perception survey (see Appendix G). The user perception survey was based on a previously-published survey that assessed the perceptions of users adopting a new form of information technology into their practice (Moore & Benbasat, 1991). The user perception survey was judged by the clinical assessors to have adequate content and face validity. Using a 5-point Likert-type scale and open-ended questions, the survey sought to identify thoughts, benefits and recommendations about the teaching instructions, class demonstration, and class activities performed on the actual IV pump. Response categories used a numerical rating scale: 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree. A survey using the same format and response categories was designed for the online only and combined groups, to assess perceptions of the online IVPE, including access instructions, user instructions, and features of the technology including its best and worst features. The level of user confidence in using the actual IV pump was assessed for all participants and open-ended questions were included related to the best features and areas of improvement of the online IVPE. Participants were also asked to indicate whether they would like more online teaching resources in the undergraduate nursing program.

4.3.1 Participants. Participants were 58 nursing students (male = 10, female = 48; age range = 18 – 42 years) enrolled in a first year, first semester practical medication course, from on-campus and external student cohorts. The external cohort was the first to be enrolled into a new structure delivering a flexible Bachelor of Nursing program to undergraduates. These external participants were allocated to the online group 1 reflecting the delivery on their education and training. On-campus participants were allocated to Groups 2 and 3 by random selection of student ID numbers. This random selection process reduced the possibility of initial group differences in competence.

Group 1: online only (ONL – treatment group 1; *n* = 18)

Group 2: on-campus only (ONC – control group; *n* = 20)

Group 3: online + on-campus (ONL + ONC – treatment group 2; *n* = 20)

The purpose of including the online + on-campus group was to address whether using the online IVPE in addition to face-to-face instruction on the actual IV pump was associated with superior outcomes than either form of instruction alone.

4.3.2 Assessment of Competence. Both direct and indirect methods were used to measure learning outcomes (Breslow, 2007) and other experiences of the participants. The direct measures included assessing the level of skill competence on an actual IV pump by observing participants performing a standardised set of activities outlined on the AAT (Appendix F). The indirect measure took the form of a survey to assess perception and performance including level of confidence using the actual IV pump and the online IVPE (Appendix G).

The AAT included a sequential step-by-step process as if preparing and administering an IV infusion to an actual patient. The first activity was to select the flask of IV fluid ordered on a simulated IV order document and prime the IV giving set or infusion line. The set of assessment activities continued until the final activity was to switch off the IV pump, as demonstrated in class and on the online IVPE. The participants were given a copy of the AAT to read.

The AAT was designed in collaboration with a team of experienced nursing academics with many years of experience in the education of laboratory simulation equipment and techniques. Their experience also extended to simulation assessment design for clinical examinations in nursing. The academics who were consulted were not part of the teaching team for the first year medication course chosen for the research, but were part of the teaching teams for other practical laboratory courses within the program. The rationale for selecting independent, non-teaching team members to assist in the AAT design was to avoid influencing the nature of assessment activities. Similarly, it was important that the members of the actual teaching team had no prior knowledge of the AAT to prevent any influence on their in-class delivery of instructions for the IV pump operation.

The expert academics agreed that they would expect a first year nursing student, after receiving instructions on using an IV infusion device, to be able to perform the following basic functions: turn the device on and off, load the correct fluid, syringe or IV tubing into the device, calculate a rate using a medication formula, program a rate and enter an appropriate volume to be infused.

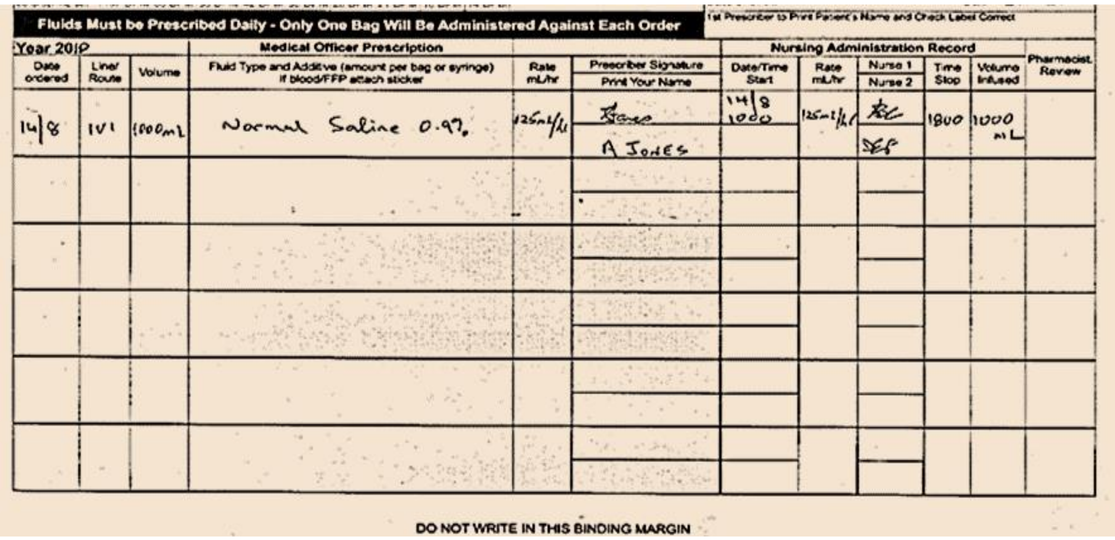
Tutors of the face-to-face simulated laboratory classes were given a teaching plan that comprised a set of instructions for the actual IV pump. This ensured that each class had the same information details presented to them by any given tutor (see

Appendix H). The course leader instructed each tutor to deliver the instructions as per the information provided by the researcher to ensure uniformity and continuity for the participants in Group 2 (ONC) and 3 (ONL + ONC). The instructions for accessing and use of the online IVPE were posted on the LMS for Group 1 (ONL) and 3 (ONL + ONC) (Appendix E). The teaching plan and case study provided in the face-to-face laboratory class were the same educational resources that were placed in the online environment. All participants had access to same teaching material aligned to the learning objectives for that module of study. The case study scenario and including the simulated medication order for IV fluid is shown in Figure 4.1.

Assessment of competence on the actual IV pump required participants from each group to perform the same six activities from the AAT, numbered Activity 1 – Activity 6. A documented medical order (see Figure 4.1), with 1000mL of IV sodium chloride to infuse at 125mL/hr., was provided to the participants. Participants were timed when they began reading through the AAT until the completion of all of the assessment items, which concluded with switching off the IV pump.

AAT activities followed a chronological sequence as if preparing an IV infusion for a patient: Activity (1a) select 1000 mL of sodium chloride and prime the infusion set, (1b) turn on the IV pump, (1c) load the infusion set into the IV pump, (1d) set the rate at 125mL/hr., (1e) set the volume to be infused (VTBI), and (1f) start the infusion. The initial IV rate, 125mL/hr. was selected as it is a common rate of infusion for IV fluids in any health care setting and is in line with course objectives.

Mr Uri Cad
D.O.B. 11.09.60
UR: 589245
Patient is a 51 year old male with a history of COPD, Atrial fibrillation and insulin dependent diabetes. He has been admitted to medical ward with an exacerbation of COPD and Bell's palsy which has affected his ability to speak clearly. He is being fasted for theatre in the morning at 0900 for an ORIF of his Right arm (fell in bathroom yesterday). He has been ordered by the surgical team to be NBM from 2400 hours (midnight) and will need ongoing IV fluid until then. He states he is in pain.
** Please administer the 1000mL of Sodium Chloride 0.9% at 125 mL/hr.*
Why has this rate been selected for the patient? How do I assess an IV site?
What formula do I use to calculate mL per hour? What is special about the fluid chosen?
Once that is done, consider this. The Surgical Team have phoned to inform you that Mr. Cad's theatre has been cancelled due to an emergency case and he can now have a normal diet and recommence his normal medications.
It is 0745 hrs. Breakfast is being delivered. Please administer his morning medications.
Sim-Lesson 5 (IV Fluid orders) NUR2000 S2, 2012 produced by Ben Mackie (2012)


Fluids Must be Prescribed Daily - Only One Bag Will Be Administered Against Each Order

1st Prescriber to Print Patient's Name and Check Label Correct

Year 2010

Medical Officer Prescription						Nursing Administration Record					Pharmacist Review
Date ordered	Line/ Route	Volume	Fluid Type and Additive (amount per bag or syringe) If blood/FFP attach sticker	Rate mL/hr	Prescriber Signature / Print Your Name	Date/Time Start	Rate mL/hr	Nurse 1 / Nurse 2	Time Stop	Volume Infused	
14/8	IVI	1000mL	Normal Saline 0.9%	125mL/hr	[signature] / A JONES	14/8 1000	125mL/hr	[initials] / [initials]	1800	1000 mL	

DO NOT WRITE IN THIS BINDING MARGIN

Figure 4.1. Case study for actual IV pump training.

Activity 2 required participants to identify two causes of a downstream occlusion. Activity 3 asked the participants to list the six rights. Activities 4 and 5 required participants to program into the actual IV pump a variety of rates and volumes from the problem-based medication calculations. The formula taught to the participants was Volume/Time (in hours). Six problem-solving tasks were included, requiring medication calculations, re-programming the rate, setting the VTBI, and re-starting the flow of fluid each time. All content was related to the safe delivery of IV infusions, as per the course objectives and teaching material.

An OSCE framework was adopted for the assessment of competency in using the actual IV pump. It has been reported that the OSCE can be a reliable, helpful, and meaningful source of practical and clinical competence (Rushforth, 2007) and there is supporting evidence to suggest that is a reliable assessment method in nursing (Mitchell, Henderson, Groves, Dalton, & Nulty, 2009; Mitchell & Jeffery, 2013; Yanhua & Watson, 2011). An independent and experienced nurse academic assessed the participants. Marking criteria were created whereby the level of competency for each activity was scored on a numerical Likert-type scale (see Appendix I). Assessment was based on marking criteria that were well established within the program to assess the competence of student nurses performing clinical procedures. In addition, expert opinion from nurse educators with extensive formal clinical education and experience judged the criteria to be appropriate for a student nurse using an IV pump. Furthermore, the marking criteria were developed with close reference to standard competency assessment tools already validated for clinical skills (see Tollefson, 2012).The marking criteria designed for the assessments included detailed descriptions of performance. These descriptions were included on the marking guide in several places to allow the assessor continuous reference to the criteria, strengthening the consistency of scoring the AAT across activities, and between participants (see Figure 4.2).

4: Perfect
3: Hesitation but achieved
2: Some mistakes but achieved
1: Many errors but achieved
0: Could not perform task

Figure 4.2. Statements on marking criteria to assess level of competence.

4.3.3 Assessment of User Perceptions. Following the assessment activities on the AAT, participants completed the user perception survey. The survey varied between groups with Group 2 (ONC) responding to items about the instruction and time spent with the actual IV pump in class. The Group 1 (ONL) survey on the other hand was designed specifically for the online IVPE. Group 3 (ONL + ONC) participants completed both surveys, giving their perceptions of training on both forms of technology.

User perception items for the online IVPE related to the access, the effectiveness of instructions, usefulness of the learning resources, and perceived level of confidence in using the online IVPE. Open-ended questions were included to determine the best features of the online IVPE and anything about the IVPE that could be improved. The user perception items for Group 2 (ONC) and Group 3 (ONL + ONC) participants related to effectiveness of instructions, practice time, and their perceived level of confidence in using an actual IV pump. All participants responded to a statement related to the perception of whether there should be greater use of online technologies for educating nursing students in the use of laboratory equipment.

4.3.4 Procedure. To create interest in the online IVPE and to aid in participant recruitment, a short recorded presentation about Stage 1 was produced, including the design, development and functionality of the online IVPE. This recording was uploaded onto the LMS for access by all students enrolled in the course. Recruitment of on-campus participants occurred face-to-face following a course lecture. Recruitment of external student participants was conducted via the LMS. Entry into a draw for four, $50 vouchers was included for all participants as an incentive to participate.

Electronic documents, including information for participants and the participant consent form (see Appendix D), were made available on the LMS. The documents required external nursing students to electronically tick a box if they agreed to participate and anonymously submit their consent form. Participants allocated to Group 1 (ONL) and Group 3 (ONL + ONC) were given exclusive access to the instructions and details for the online IVPE activities on the LMS. Group 1 (ONL) had no access to an actual IV pump during the assigned period.

Group 1 (ONL) participants were external nursing students allocated a maximum two-hour period of time to use the online IVPE. Group 2 (ONC), the on-campus participants, had the same allocation of time to use the actual IV pump in a weekly laboratory class but no access to the online IVPE. Group 3 (ONL + ONC) had the same allocation of time in class with the actual IV pump as Group 2 (ONC), plus the option to access the online IVPE.

Two weeks following recruitment, mid-way through the teaching semester, Group 2 (ONC) and Group 3 (ONL + ONC) received a demonstration and the instructions for the actual IV pump and commenced practice during a 120 minute simulated laboratory class. The training on the actual IV pump outlined in the course objectives included the basic functions of the IV pump and a case study incorporating the equipment. Medication formulas for IV fluids and drugs also formed part of the teaching objectives.

The instructions for how to access and use the functions of the online IVPE via RAL were posted simultaneously on the LMS for Group 1 (ONL) and Group 3 (ONL + ONC) participants. The case study (including IV fluid orders) which was incorporated into practice with the online IVPE, was available on the LMS. These participants received reminders and messages of encouragement to use the online IVPE at various times throughout the access period. Time of use was monitored to ensure that no participant exceeded two hours or 120 minutes of practice. Group 3 (ONL + ONC) received the on-campus engagement for two hours in class on the actual IV pump and, in addition, had unlimited optional access to the online IVPE and its resources.

The assessment of activities, or OSCE, to assess level of competence on the actual IV pump occurred one week following the completion of training on either the actual IV pump or the online IVPE. For Group 1 (ONL), assessment occurred during a residential school on-campus, in the following week. Assessment was conducted face-to-face during class time in a simulated laboratory class. Group 2 (ONC) participants had no access to the actual IV pump between the period of training and the assessment of competency. Similarly, access to the online IVPE was blocked to the participants in Group 1 (ONL) and Group 3 (ONL + ONC) between the period of training and the assessment of competency.

The OSCE assessor called participants out from their laboratory classes individually, to perform the activities on the AAT. The assessor, who was blind to group membership, assured participants that their performance, the time taken and/or the scores achieved, would not be reflected in any way in their course grades. Participants were informed that the assessment would take approximately 15 – 30 minutes.

The assessor did not communicate or assist the participants' performance in any way, other than allowing the participant to move onto the next activity if there was evidence of inability to perform an activity, at which point a score of was 0 allocated. Start and completion time were recorded. The maximum total score for all activities on the AAT was 130 points. Following the assessment of activities, Group 3 (ONL + ONC) participants reported whether or not they had used the online IVPE, and for what period of time. This was recorded by the assessor. Finally, all participants completed the user perception survey about the technology they used, either the actual IV pump, the online IVPE, or a combination of both.

4.3.5 Data Analysis. Comparison of assessment scores between Groups 1 (ONL) and Group 2 (ONC) determined whether using the online IVPE was equivalent to traditional in-class instruction for preparing students in the use of the actual IV pump. The purpose of including Group 3 (ONL + ONC) in the study was to address the question of whether using the online IVPE in addition to in-class instruction on the actual IV pump was associated with better outcomes and performance than just using one form of technology or the other.

Prior to using inferential statistics, the dataset was first checked for non-normality by calculating skewness and kurtosis indices, and checking for univariate outliers (z-scores > 3.29) and multivariate outliers (using Mahalanobis distance statistics). Having confirmed that data met the assumptions of the relevant statistical procedures, for the quantitative analyses, the dependent variables were the AAT total scores, participant practice time, and completion time. The independent variable was group membership; namely, Group 1 (ONC), Group 2 (ONL), and Group 3 (ONC + ONL). Descriptive statistics for the three groups were calculated and between-group comparisons were conducted using a single-factor ANOVA and Tukey post-hoc comparison tests. Pearson correlation analysis was used to test relationships between the dependent variables. Given the modest sample size in this stage, probability analyses were augmented with a calculation of effect sizes using Cohen's d, where 0.2 represents a small effect, 0.5 a moderate effect, and 0.8 a large effect.

User perceptions were analysed in two ways. First, comments were categorised qualitatively as positive, neutral or negative, and percentages of each category of comment were calculated to establish the general tone of user perceptions. Second, open-ended comments were reproduced verbatim.

4.4 Results

A total of 20 female participants completed all assessment activities and the user perception survey, representing a modest participant retention rate of 34.5%. Final group numbers were Group 1 (ONL; $n = 4$), Group 2 (ONC; $n = 10$) and Group 3 (ONL + ONC; $n = 6$). The poor retention of participants particularly from Group 1 (ONL) and Group 3 (ONL + ONC) was likely associated with the timing of the data collection, which coincided with the introduction of an online mode of delivery within the Bachelor of Nursing undergraduate program for the first time. *Medications, Theory and Practice* is a course within the program whereby external nursing students are required to access and engage with all material online, including the online IVPE. This was a new concept and a steep learning curve for many nursing students and educators alike.

Data were checked for distributional characteristics and no significant non-normality was detected, meaning that the dataset was retained intact for analysis.

Descriptive and inferential statistics for the three groups are shown in Table 4.1. Consistent with H0, the average overall assessment scores for Group 1 (ONL) and Group 2 (ONC) were almost identical, indicating that the level of competency on the use of the actual IV pump for the participants in these two groups was essentially the same. This demonstrates that gaining competence in using an actual IV pump by practicing on the online IVPE was just as effective as the traditional face-to-face instruction in a classroom setting.

In support of H1, Group 3 (ONL + ONC) participants scored, on average, more than 6 points higher on the AAT than the other two groups. Given the modest sample size, this comparison was underpowered and hence did not reach statistical significance. However, effect sizes showed the difference between Group 3 (ONL + ONC) and the other two groups to be large to very large, suggesting that the difference was meaningful even though not statistically significant. Further, significant between-group differences were found for practice time, whereby Group 3 (ONL + ONC) practiced for longer than the other two groups. Effect sizes showed the differences in practice time to be large to very large (see Table 4.1). Given the small sample size used in this stage of the research, the possibility that the large effects observed may be explained by measurement error should be noted. This possibility points to a clear need to replicate the study among a much larger sample of participants, as conducted in the next stage of research.

Results also showed that Group 1 (ONL) took longer to complete the assessment activities than the other two groups. This is probably due to the fact that Group 1 (ONL) participants were unfamiliar with the actual IV pump, had not previously seen or had experience using it, and hence took more time to become accustomed to using it manually even though they knew how it worked from their experience of practicing on the online IVPE. Differences in completion time between the three groups were not statistically significant, although effect sizes pointed to the differences in completion time being meaningful in practice (see Table 4.1).

Among participants overall, a significant positive correlation was found between practice time and AAT scores ($r = .57$, $p = .009$), indicating that those participants who practiced for longer tended to gain higher assessment scores. A significant inverse correlation was found between time to complete the activities and the AAT scores achieved ($r = -.49$, $p = .029$), indicating that those participants who completed the assessment faster tended to gain higher assessment scores.

When participants were grouped by practice time (< 30 minutes, 30–120 minutes, > 120 minutes), an interesting trend emerged (see Figure 4.3). Those participants who practiced for 30-120 minutes did not significantly outperform those who practiced for less than 30 minutes ($p = .68$, $d = 0.38$). However, those participants from Group 3 (ONL + ONC) who practiced for more than 120 minutes outperformed those who practiced for less than 30 minutes by 11 points on average ($p = .028$, $d = 1.48$) and outperformed those who practiced for 30-120 minutes by 8 points on average ($p = .084$, $d = 1.10$). This finding suggested that practicing on the online IVPE for more than two hours provided additional benefit in terms of level of competency using the actual IV pump. Practice time for participants in Group 2 (ONC) was standardised at 120 minutes, whereas Group 1 (ONL) participants were allocated up to 120 minutes practice on the online IVPE although some practised for much less than the maximum time. The variation evidenced in Figure 4.3 is largely attributable to Group 3 (ONL + ONC) participants who used the optional allocation of time to practice on the online IVPE in addition to their 120 minutes of practice in class. Therefore, this preliminary evidence of a practice effect, whereby more practice time leads to greater competence, should be considered as tentative.

Table 4.1

IV Pump Statistics for Three Groups of Nursing Students (N = 20)

Variable	Group	*M*	*SD*	$F_{2,17}$	*d*	Sig. Group Differences
Assessment Score	ONL	112.5	4.7	1.71	0.04	
	ONC	112.8	7.9		0.80	ONL + ONC > ONC
	ONL + ONC	119.0	6.3		1.02	ONL + ONC > ONL
Practice Time (min)	ONL	65.0	41.2	4.38*	0.59	
	ONC	43.5	35.0		1.21*	ONL + ONC > ONC
	ONL + ONC	124.2	79.7		0.83*	ONL + ONC > ONL
Completion Time (sec)	ONL	837.3	14.6	1.95	1.41	ONL > ONC
	ONC	721.9	94.2		0.55	ONL + ONC > ONC
	ONL + ONC	785.7	143.5		0.47	ONL + ONC < ONL

Note. Maximum Assessment Score = 130. ONL = Online only group (*n* = 4), ONC = On-Campus only group (*n* = 10), ONL + ONC = Online + On-Campus group (*n* = 6); **p* < .05.

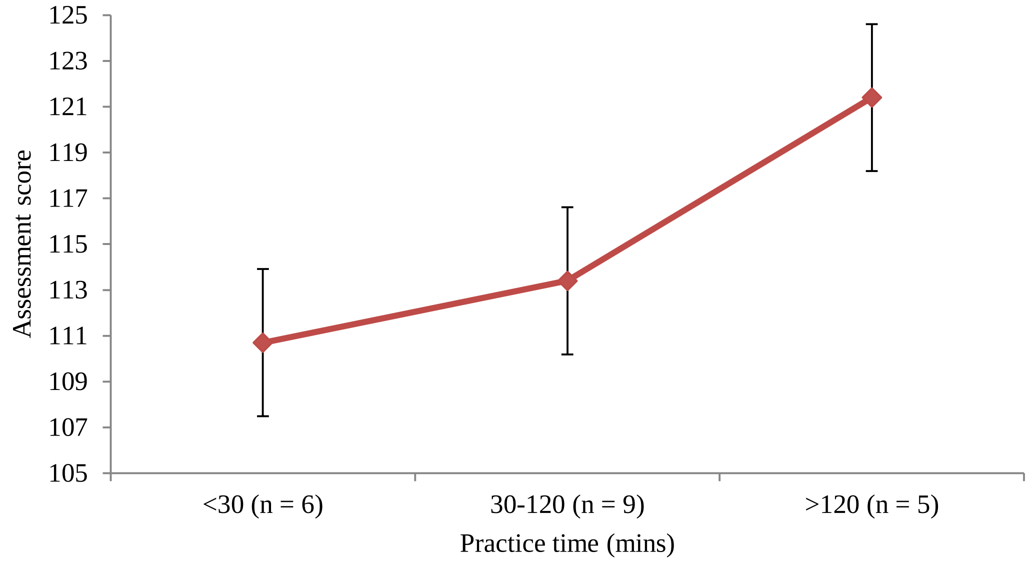


Figure 4.3. Effect of practice time on assessment scores.

Following the assessment activities on the AAT, participants completed the user perception survey. The survey varied slightly between groups. Group 2 (ONC) responded to items about the instruction and time spent with the actual IV pump in class. The survey for Group 1 (ONL), on the other hand, focused specifically on the online IVPE and Group 3 (ONL + ONC) participants completed both surveys to gauge their perceptions about the two forms of technology.

The user perception survey showed positive ratings about the online IVPE from participants in Group 1 (ONL) and Group 3 (ONL + ONC). Questions related to accessing, logging in and booking the online IVPE through RAL are shown in Figures 4.4 – 4.8. The large majority of participants either agreed or strongly agreed that the instructions for logging in were simple (ONL = 75%, ONL + ONC = 65%; see Figure 4.4). In relation to the number of steps required to log in and book the online IVPE, 50% of Group 1 (ONL) disagreed that there were too many steps whereas 67% of Group 3 (ONL + ONC) agreed there were too many steps required in the log in process via RAL (see Figure 4.5). This finding became a consideration in the next stage of research as ease of accessibility to the technology was a priority. It was clear that the instructions were easy to follow (ONL and ONL + ONC = 100%; see Figure 4.6), there were enough times available to book use of the online IVPE (ONL and ONL + ONC = 100%; see Figure 4.7), and the booking system was straightforward (ONL = 75%, ONL + ONC = 85%; see Figure 4.8). There were a small number of participants who indicated some negative responses. For instance, 25% of Group 1 (ONL) participants reported that logging in was not simple (see Figure 4.4), and 15% of Group 3 (ONL + ONC) reported the booking system was not straightforward (see Figure 4.8).

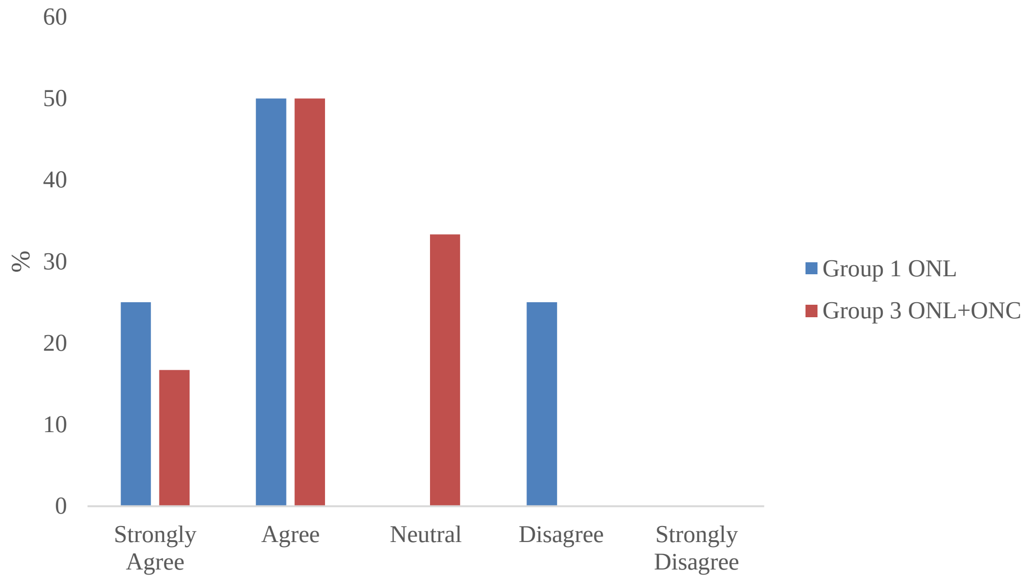


Figure 4.4. Participant responses in user perception survey to question 3a. *Logging in to the online IV pump was simple*; ONL = Online Group 1 (*n* = 4), ONL + ONC = Online + On-Campus Group 3 (*n* = 6).

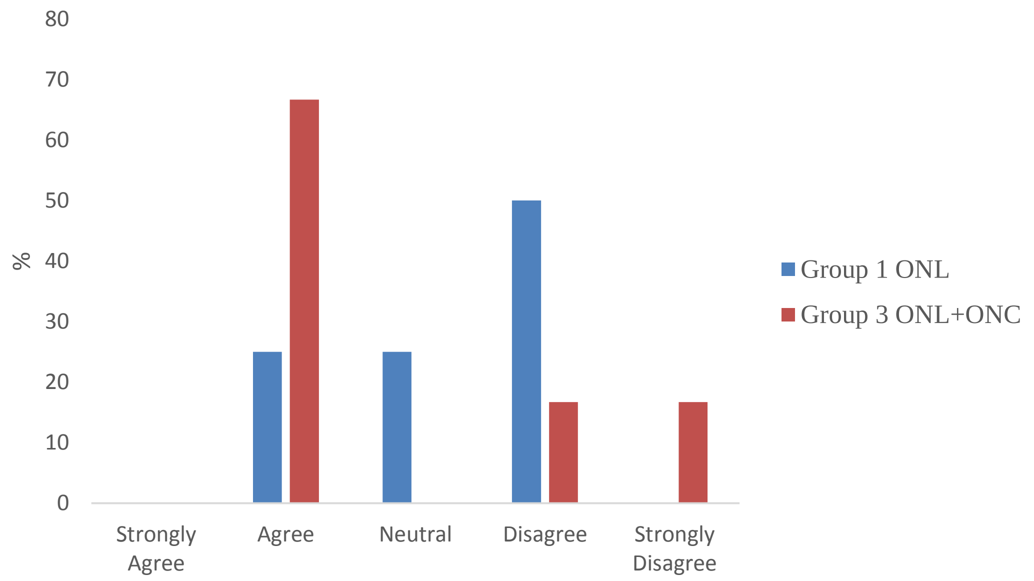


Figure 4.5. Participant responses in user perception survey to question 3b. *There were too many steps in the instructions for login and booking into the program*; ONL = Online Group 1 (*n* = 4), ONL + ONC = Online + On-Campus Group 3 (*n* = 6).

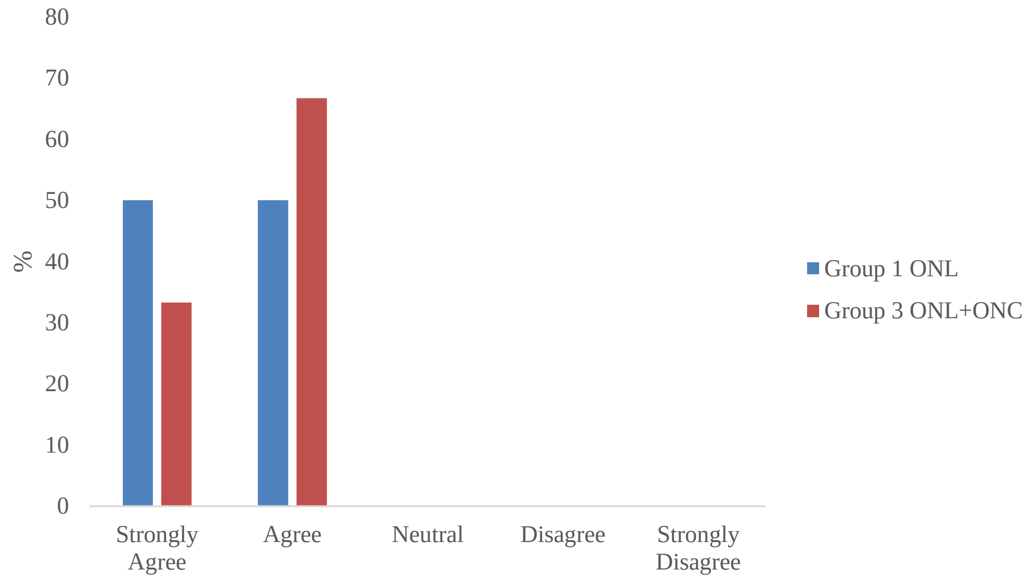


Figure 4.6. Participant responses in user perception survey to question 3c. *The emailed instructions about booking into the IV pump were easy to follow*; ONL = Online Group 1 (*n* = 4), ONL + ONC = Online + On-Campus Group 3 (*n* = 6).

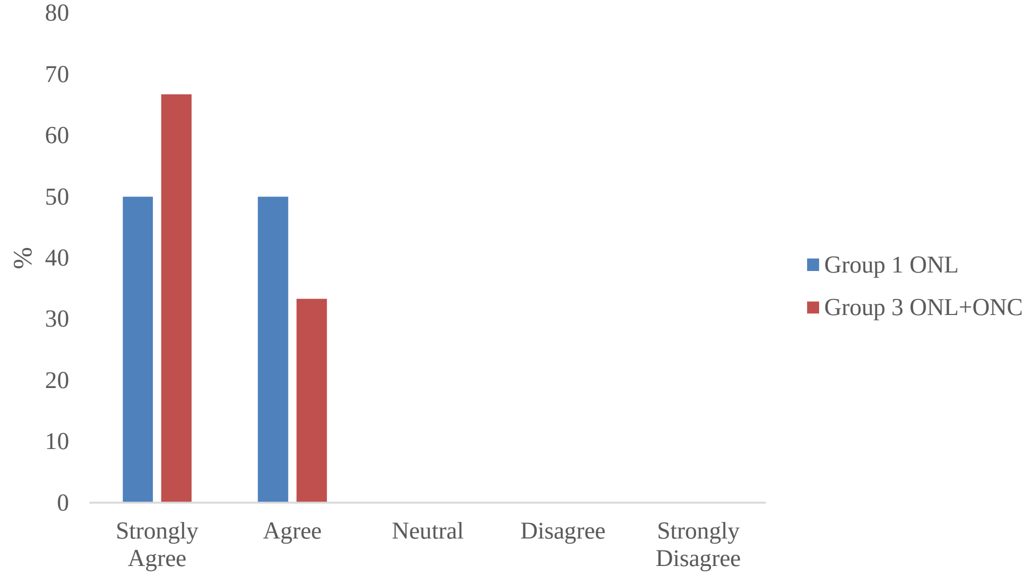


Figure 4.7. Participant responses in user perception survey to question 3d. *There were enough time slots available to book the online IV pump*; ONL = Online Group 1 (*n* = 4), ONL + ONC = Online + On-Campus Group 3 (*n* = 6).

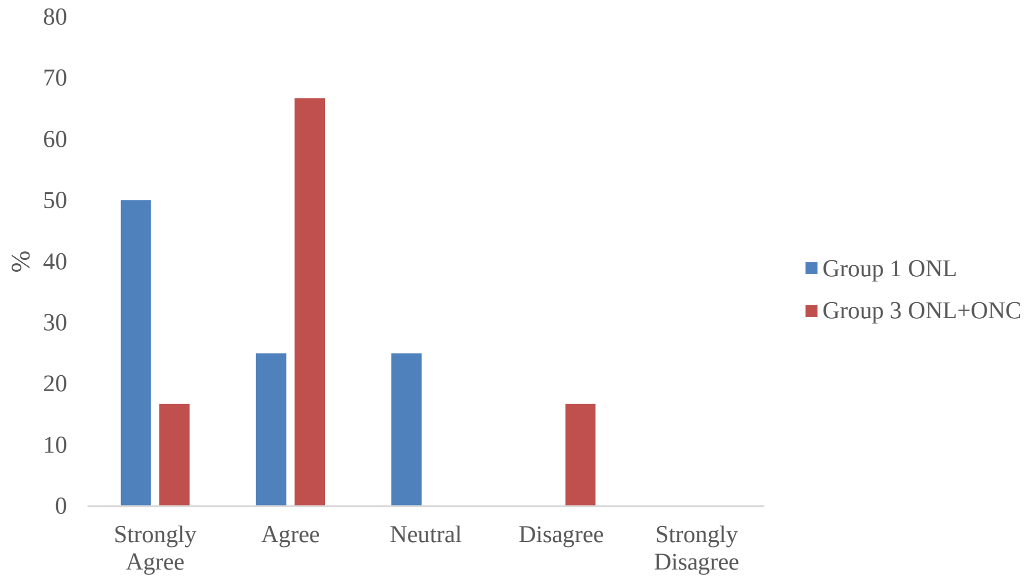


Figure 4.8. Participant responses in user perception survey to question 3e. *Booking to use the online IV pump was straight forward*; ONL = Online Group 1 (*n* = 4), ONL + ONC = Online + On-Campus Group 3 (*n* = 6).

Figures 4.9 – 4.15 show the results related to the participant's perceptions of the teaching instructions and features of the online IVPE as learning resource. Firstly, all participants either agreed or strongly agreed that the instructions in the learning mode were easy to follow (see Figure 4.9), that there was enough information provided in the learning mode (see Figure 4.12) (ONL and ONL + ONC = 100%) and that the resource page was helpful (ONL = 100%, ONL + ONC = 50%), with the exception of 50% of Group 3 who indicated a neutral response (see Figure 4.10). Similarly, almost all participants either agreed or strongly agreed that the image gallery was of benefit (ONL = 100%, ONL + ONC=67%), leaving a small percentage of Group 3 (ONL + ONC = 33%) feeling neutral about it (see Figure 4.11).

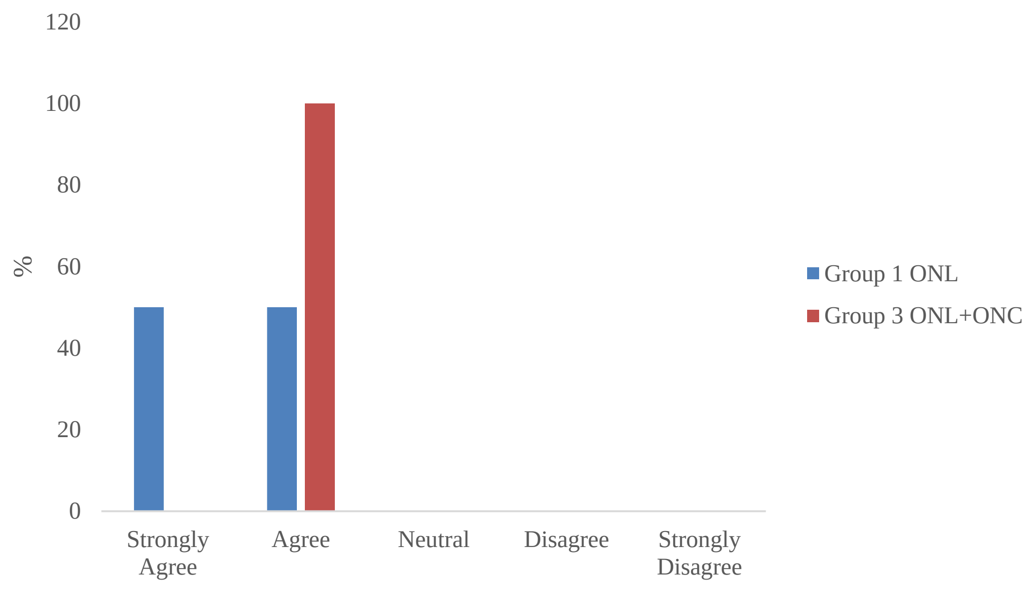


Figure 4.9. Participant responses in user perception survey to question 4a. *Learning mode about the use of the online IV pump was easy to follow*; ONL = Online Group 1 (*n* = 4), ONL + ONC = Online + On-Campus Group 3 (*n* = 6).

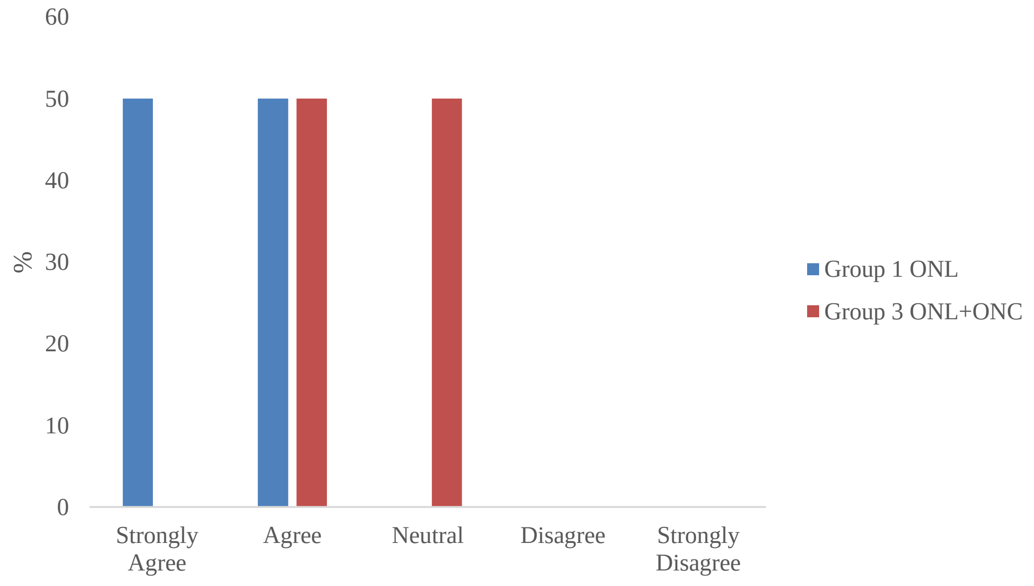


Figure 4.10. Participant responses in user perception survey to question 4b. *Resource page for the online IV pump was helpful*; ONL = Online Group 1 (*n* = 4), ONL + ONC = Online + On-Campus Group 3 (*n* = 6).

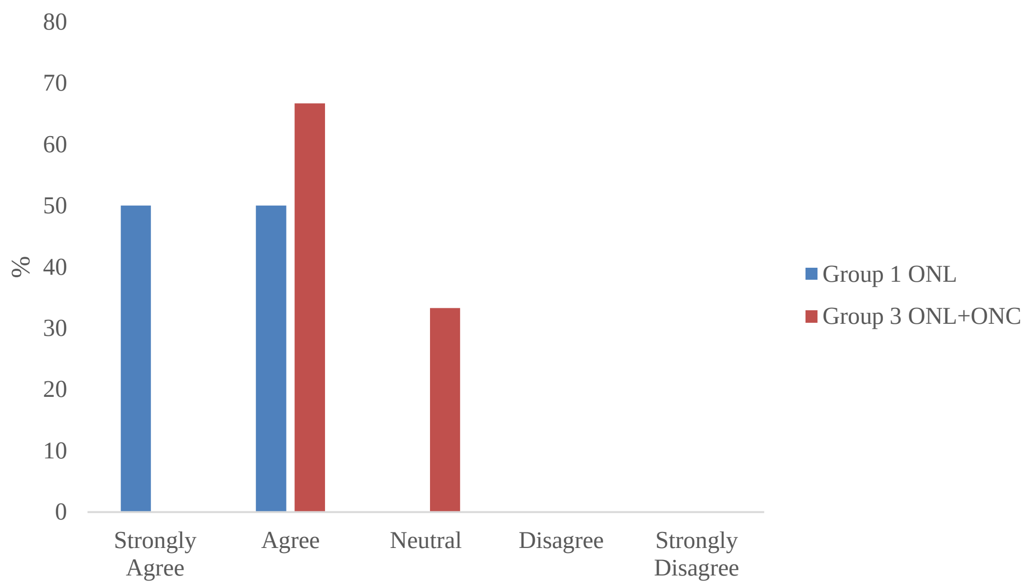


Figure 4.11. Participant responses in user perception survey to question 4c. *Image gallery for the online IV pump was helpful*; ONL = Online Group 1 (*n* = 4), ONL + ONC = Online + On-Campus Group 3 (*n* = 6).

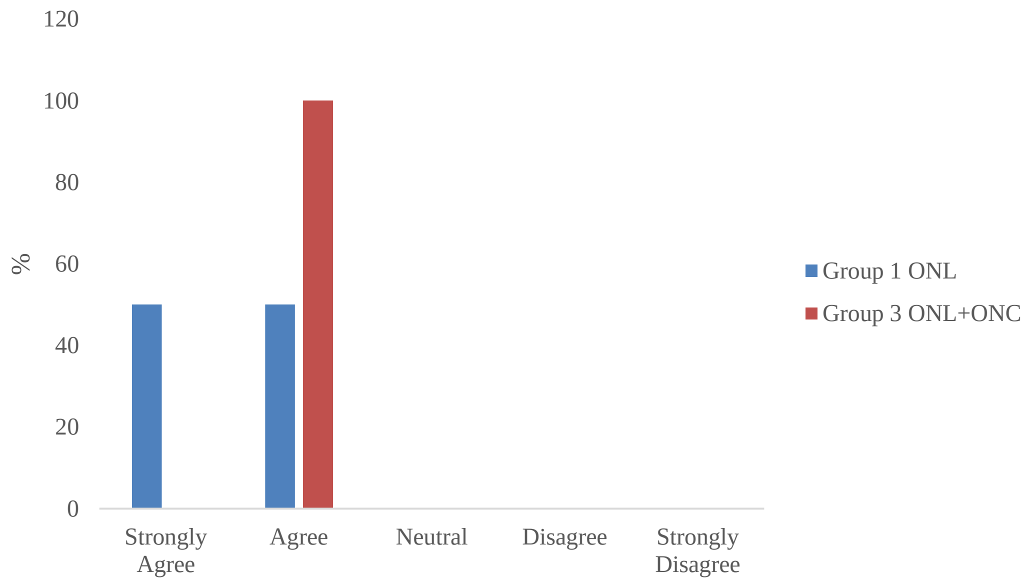


Figure 4.12. Participant responses in user perception survey to question 4d. *Enough information was supplied for learning mode*; ONL = Online Group 1 (*n* = 4), ONL + ONC = Online + On-Campus Group 3 (*n* = 6).

When it came to the assessment mode, participants were asked to rate whether they agreed that it was not easy to work through; 75% of Group 1 (ONL) responded that they either agreed or strongly agreed, whereas 50% of Group 3 (ONL

+ ONC) disagreed with the statement. Over 50% of participants from the groups combined were unsure (see Figure 4.13). Having the statement constructed as reverse scored may have contributed to the negative perceptions. Either way, instructions about working through the assessment mode were simplified in the online IVPE for Stage 3.

When asked if the case study in the assessment mode was an excellent example, there were no negative responses from either group with almost all of the participants indicting that they agreed or strongly agreed with that statement (ONL = 85%, ONL + ONC = 75%; see Figure 4.14). Hence, additional case studies were introduced to the online IVPE assessment mode for Stage 3.

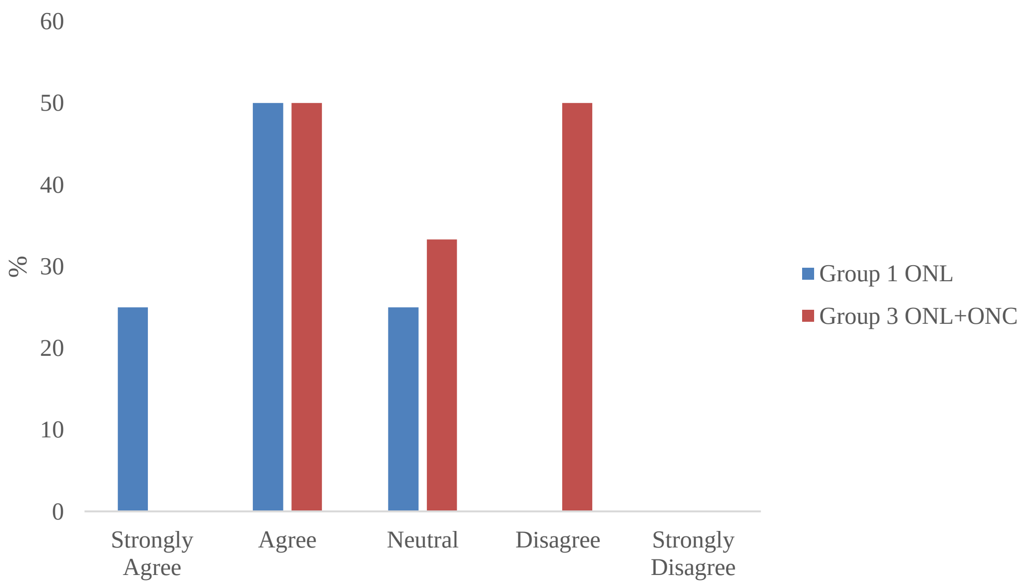


Figure 4.13. Participant responses in user perception survey to question 4e. *The assessment mode was not easy to work through*; ONL = Online Group 1 (*n* = 4), ONL + ONC = Online + On-Campus Group 3 (*n* = 6).

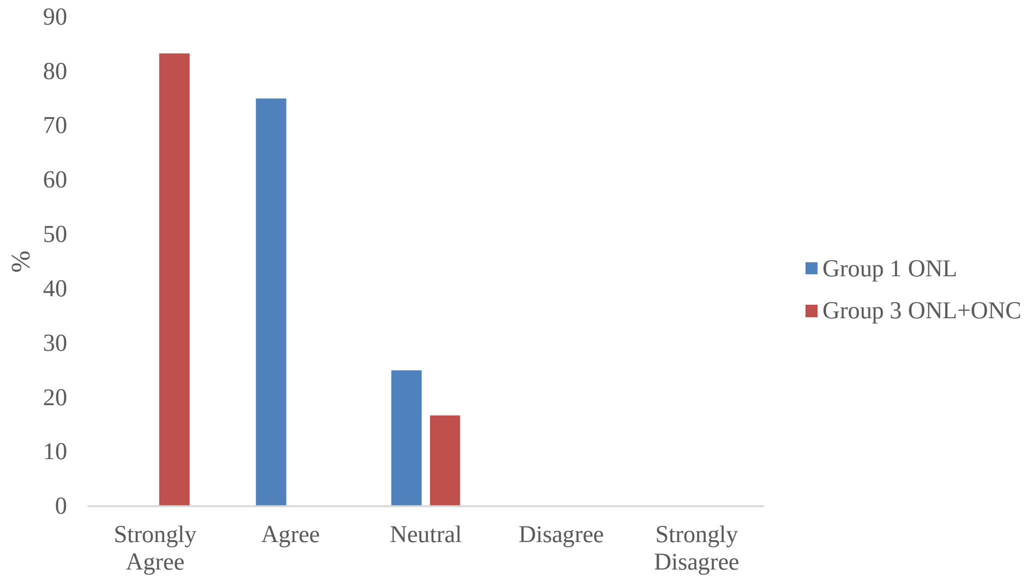


Figure 4.14. Participant responses in user perception survey to question 4f. *The case study was an excellent learning example*; ONL = Online Group 1 (*n* = 4), ONL + ONC = Online + On-Campus Group 3 (*n* = 6).

To determine whether the online IVPE instructions and education provided were sufficient for the participants' needs, they were asked to respond to a statement about whether they were allocated enough time to practice. Once again it was presented as a reverse scored statement where the large majority of participants either disagreed or strongly disagreed (ONL = 75% & ONL + ONC = 83.5%) they were not given sufficient time (see Figure 4.15). All participants agreed or strongly agreed that they felt confident using the online IVPE (see Figure 4.16) and 100% of participants from these two groups indicated that they would like to see greater use of online teaching technologies for the education of nursing students in laboratory equipment (see Figure 4.22).

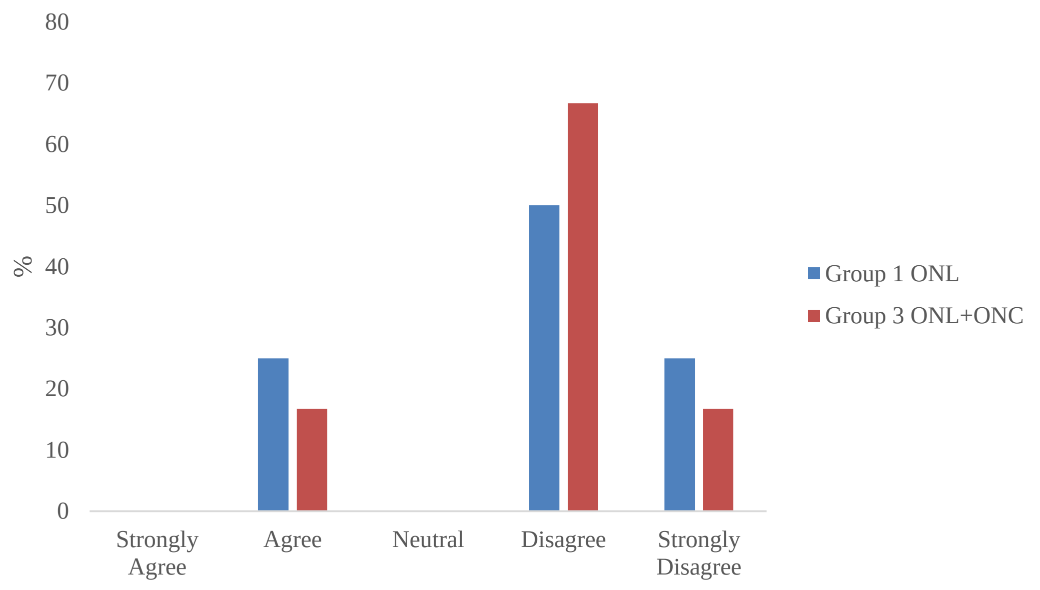


Figure 4.15. Participant responses in user perception survey to question 4g. *Insufficient time was allocated for practice*; ONL = Online Group 1 (*n* = 4), ONL + ONC = Online + On-Campus Group 3 (*n* = 6).

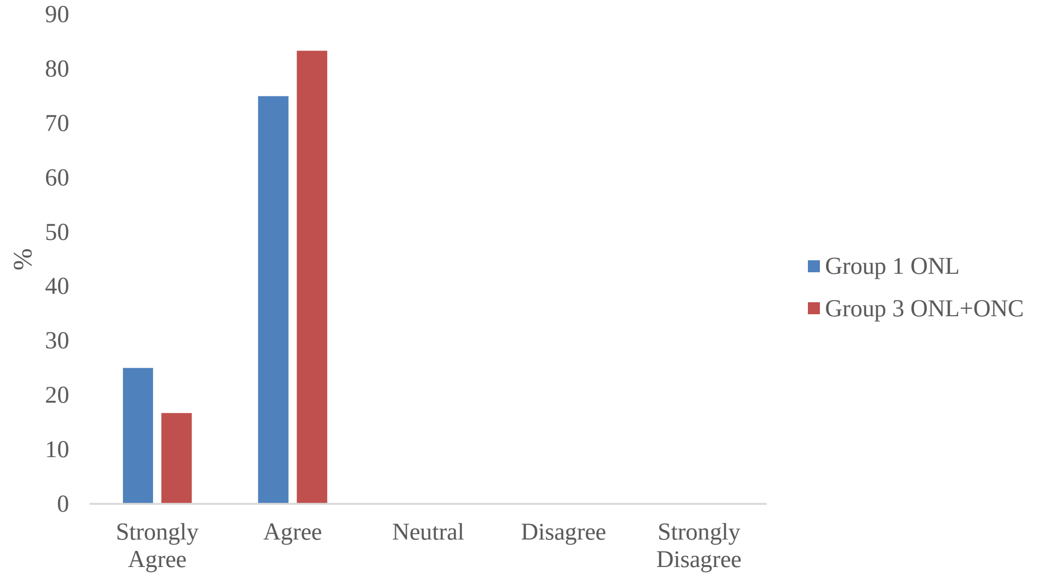


Figure 4.16. Participant responses in user perception survey to question 4h. *I feel confident using the online IV pump*; ONL = Online Group 1 (*n* = 4), ONL + ONC = Online + On-Campus Group 3 (*n* = 6).

Group 2 (ONC) participants, who completed a survey pertaining to the actual IV pump, also responded positively to the items related to the effectiveness of instructions, practice time and their perceived level of confidence (see Figures 4.17 – 4.20). Up to 85% of participants in Group 2 (ONC) and 80% in Group 3 (ONL + ONC) either agreed or strongly agreed that the face-to-face instructions and education on the use of the actual IV pump was easy to understand (see Figure 4.17). Although 50% of Group 2 (ONC) and 33% of Group 3 (ONL + ONC) felt neutral about the video demonstrations using the IV pump, generally most participants (ONC = 50%, ONL + ONC = 67%) either agreed or strongly agreed that the videos were helpful in the education about the actual IV pump (see Figure 4.18).

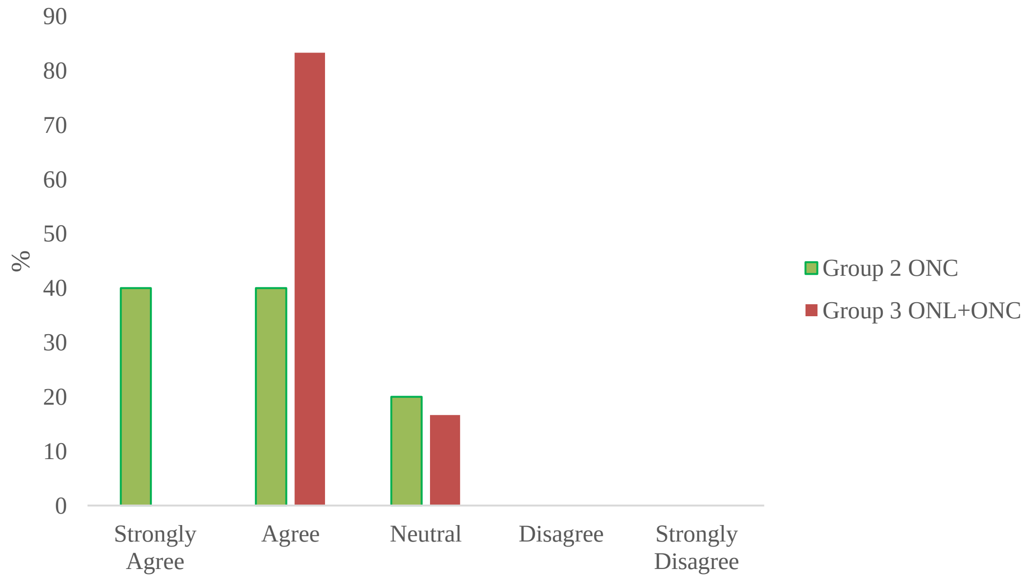


Figure 4.17. Participant responses in user perception survey to question 7a. *Teaching instructions about use of the actual IV pump were easy to understand;* ONC = On-Campus Group 2 (n = 10), ONL + ONC = Online + On-Campus Group 3 (n = 6).

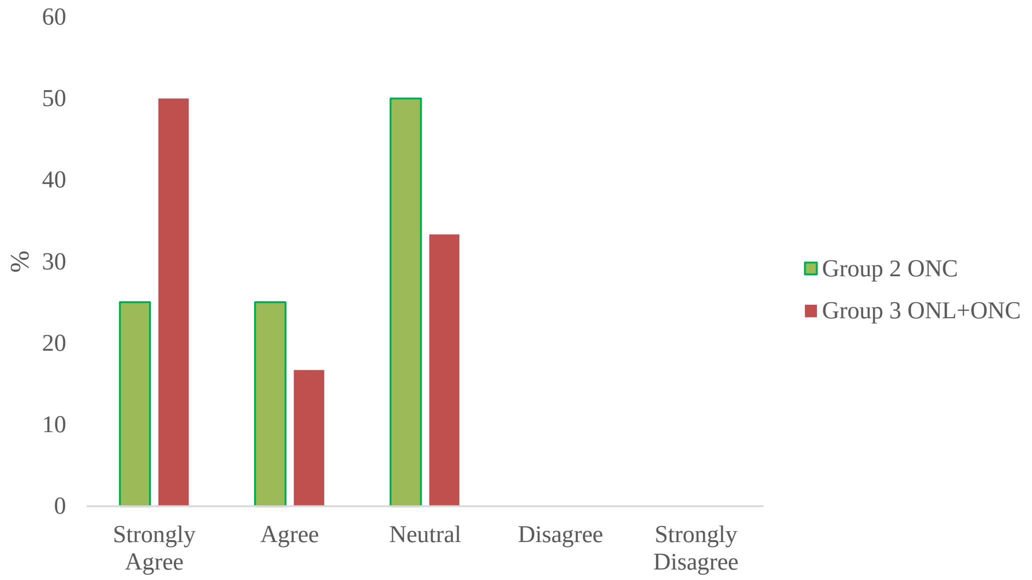


Figure 4.18. Participant responses in user perception survey to question 7b. *Video demonstration about using the actual IV pump was helpful;* ONC = On-Campus Group 2 (*n* = 10), ONL + ONC = Online + On-Campus Group 3 (*n* = 6).

Regarding face-to-face instruction and hands-on practice with the actual IV pump, the perceptions among the two groups varied. Only 30% of Group 2 (ONC) felt that not enough time was allocated for face-to-face instruction with the remaining 70% feeling that enough time was allocated. Most of Group 3 (ONL + ONC = 67%) perceived there was not enough time allocated to the classroom instruction and the remaining 33% either disagreed or felt neutral about this (see Figure 4.19).

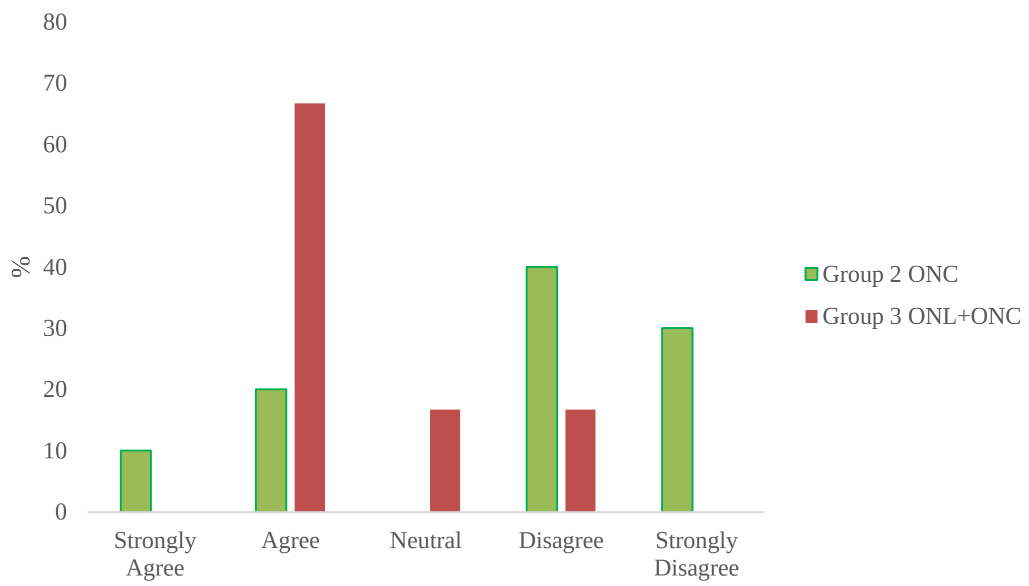


Figure 4.19. Participant responses in user perception survey to question 7c. *Insufficient time was allocated for instruction on the actual IV pump;* ONC = On-Campus Group 2 (*n* = 10), ONL + ONC = Online + On-Campus Group 3 (*n* = 6).

When asked about the time allocated for in-class practice, 67% of Group 3 (ONL + ONC) disagreed that there was not enough time, with the other 33% either agreeing or strongly agreeing with the statement. Generally from Group 2 (ONC), 70% either agreed or strongly agreed, with the remaining participants either feeling neutral (ONC = 20%) or disagreeing with the statement (ONC = 10%; see Figure 4.20).

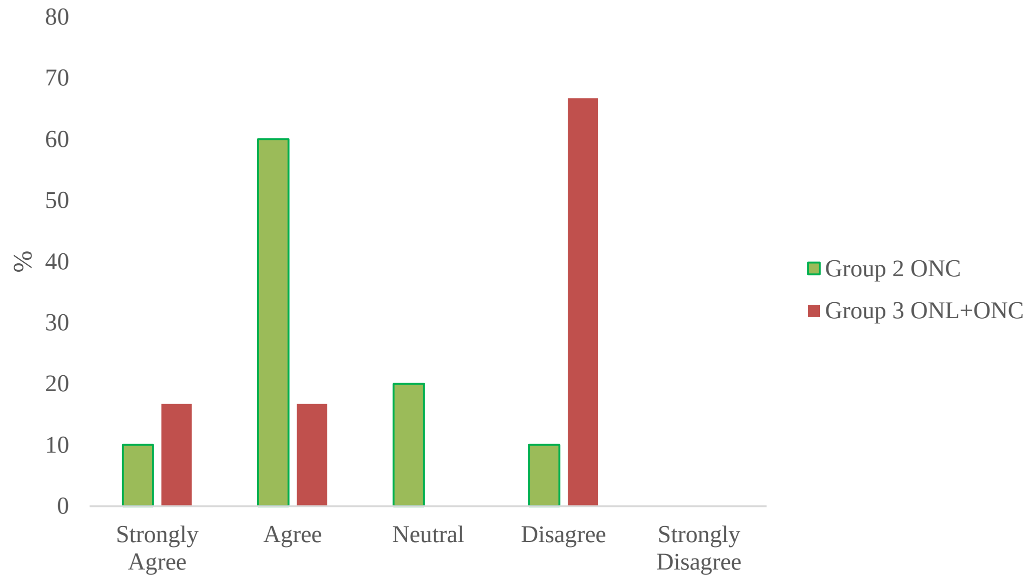


Figure 4.20. Participant responses in user perception survey to question 7d. *Enough time was allocated for practice;* ONC = On-Campus Group 2 (*n* = 10), ONL + ONC = Online + On-Campus Group 3 (*n* = 6).

Finally, although the majority of Group 3 (ONL + ONC) felt there was not enough time allocated to instruction or practice during class time (see Figure 4.20), 100% agreed they felt confident using the actual IV pump. This result may be due to the group also having access to the online IVPE and that the combination of both increased user confidence in performing the tasks on the actual IV pump. Group 2 (ONC) also generally felt confident using the actual IV pump, with 80% either agreeing or strongly agreeing, although 10% disagreed that they felt confident and another 10% were not sure how they felt (see Figure 4.21).

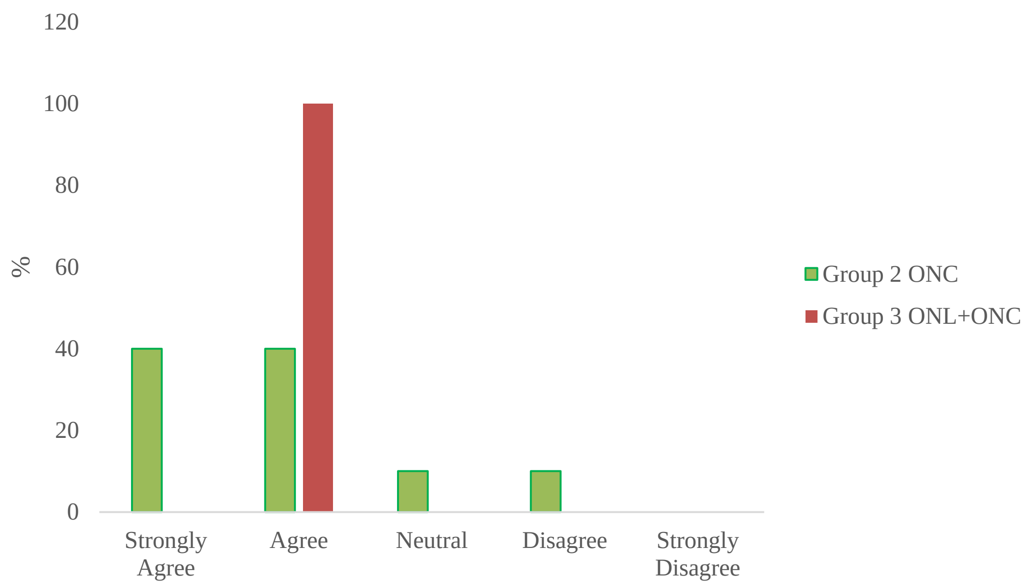


Figure 4.21. Participant responses in user perception survey to question 7e. *I feel confident using the actual IV pump;* ONC = On-Campus Group 2 (*n* = 10), ONL + ONC = Online + On-Campus Group 3 (*n* = 6).

The final question asked the participants if they would like to see greater use of online technologies for educating nursing students in the use of laboratory equipment. The two groups with exposure to the online IVPE all said "yes" (ONL and ONL + ONC = 100%), whereas among Group 2 (ONC) participants, who had no exposure to the online IVPE, 80% responded "yes" and the remaining 20% indicated "no" to greater use of online technologies for laboratory equipment (see Figure 4.22). There is evidence that nursing students tend to prefer teacher-led instruction and direction (Levett-Jones, 2005) and it was possible the 20% who stated "no," reflected that in their response.

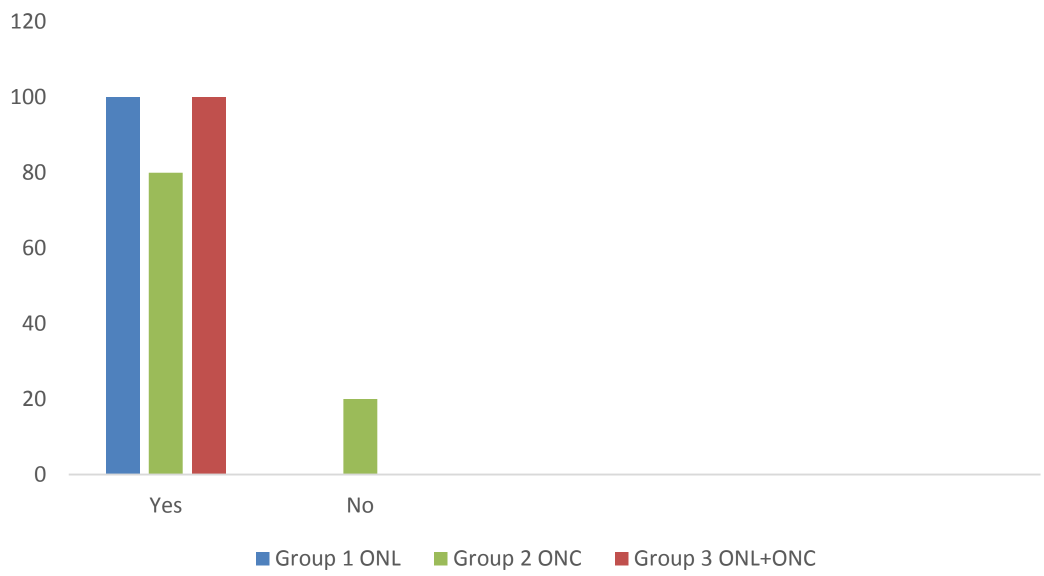


Figure 4.22. Participant responses in user perception survey to question 8. *Would you like to see greater use of online technologies for educating nursing students in the use of laboratory equipment*? Online Group 1 ONL = (*n* = 4), On-Campus Group 2 (*n* = 10), ONL + ONC = Online + On-Campus Group 3 (*n* = 6).

There were two open-ended questions in the survey to which participants from Group 1 (ONL) & Group 3 (ONL + ONC) responded. When asked about the best features of the online IVPE, two participants commented about the benefits of "being able to practice anytime." Other comments included "great explanation, easy instructions" and reference to the "visual" and "real-life" features of the online IVPE. There were also positive comments about the video resources and case studies being helpful learning tools. When asked about the features of the pump that could be improved, one respondent commented about "improving the graphics." Another participant suggested that the program should "just be available and not have to book into a particular session." Finally, one participant commented that the video instruction on loading the line into the pump should be "more interactive" (see Appendix J).

4.5 Summary of Stage 2

A preliminary evaluation of the online IVPE showed, as hypothesised, equivalent competency in using an actual IV pump between those who trained using the online IVPE and those who were trained face-to-face, and superior competency among those who trained on both an actual IV pump and the online IVPE. Results also indicated that those participants who practiced for longer tended to gain higher assessment scores and that those participants who completed the assessment faster tended to gain higher assessment scores.

Perceptions of the participants indicated a desire for ongoing utilisation of online educational tools in the nursing program. Although retention of participants between the recruitment and data collection phases proved problematic, there were clear elements of enthusiasm (evidenced in the user perception surveys) among the participants for this innovative online educational tool to be formally introduced into the nursing program. It was apparent throughout Stage 2 that to establish more compelling evidence of the effectiveness of the online IVPE, some revisions needed to be applied to the next stage of research.

4.6 Refinements for Stage 3

Reflecting on the positive elements of Stage 2 in preparation for Stage 3, it was determined that refinements to some aspects of the procedures and methodology should be implemented to produce a more rigorous next phase of research. Based on the experience of conducting Stage 2 and considering the preliminary findings, a subsequent, more comprehensive and refined evaluation and comparison of the online IVPE and actual IV pump was conducted in Stage 3. The methodological and procedural improvements (see Table 4.2) are discussed in more detail in Chapter 5.

In relation to the specific measures, fewer medication calculations relating to delivering different rates of IV fluids for infusion were considered for the next stage of research. In Stage 2, participants were asked to perform six calculation activities and almost all participants scored perfectly (100%) by the last of these activities and it was obvious to the assessor that a practice effect had occurred. For the purpose of Stage 3, the calculation activities were reduced from six to three with slight variation to the examples of IV fluid, thus reducing the probability of a practice effect. Another revision for the next stage included removing the activity that required participants to prime the IV giving set. As this had no direct association with the physical functions of the actual IV pump nor the online IVPE, it was considered an unnecessary skill to assess. The activity requesting participants to verbalise (for the assessor) two causes of a downstream occlusion was dropped for the next stage of research. This had created a time delay in Stage 2 as participants thought about two possible causes. The AAT was renamed the revised activity assessment tool, or RAAT.

Similarly, given the tentative findings of a practice effect, whereby additional practice time led to increased competence, it was decided to standardise practice time at 120 minutes for Group 1 (ONL) and Group 2 (ONC) to isolate the effect of mode of delivery (i.e., online IVPE vs. actual IV pump). This was achieved by having Group 1 (ONL) participants complete their training on the online IVPE from computer terminals in the nursing laboratories, where practice time could be standardised, rather than from off-campus where practice time could be monitored by RAL but not controlled.

Some of these refinements were made to the online IVPE program itself. For the purpose of Stage 3 a more accessible, realistic and interactive version of the online IV pump was produced for the participants. Additional prompts were imbedded into the emulator program to help students learn all features of the actual IV pump. For example, in the case that 1000mL of volume was ordered, the user was required to set VTBI less than 1000 at approximately 900mL; if the user programmed > 900 mL an alert was activated indicting “Over limit! Program VTBI 10% less than what is being infused.” Furthermore, during normal activity on the actual IV pump, if the roller clamp on the IV giving set was not released, the IV pump, once started, would activate an “OCCLUSION” alarm and the problem would be rectified. This alarm feature was added to the online IVPE program whereby a mouse click on an image of the roller clamp reminded users that the step was required when using an actual IV pump. During the assessment activity on the actual IV pump, leaving participants to physically troubleshoot the “OCCLUSION” alarm was a more realistic assessment of competence.

Another feature added to the online IVPE program for Stage 3 was to include an alert to the 6 Rights of medication administration prior to commencing the infusion. The rationale for this addition was because it added an important element of safety when preparing IV fluids or IV medication infusions for administration. Also, it directly reflected the teaching objectives for the course and finally, given the capacity of the software to include interesting features like the 6 Rights prompt, the originality of the online IVPE was enhanced. In Stage 2, when participants selected the IV fluid for infusion, few were inclined to check the fluid against an order for safety purposes. So, in Stage 3 when the user of the online IVPE selected “START” an alert appeared “DID YOU CHECK THE 6 RIGHTS” which was a safety step reinforced in the on-campus, face-to-face lessons on the actual IV pump (see Figure 4.23).

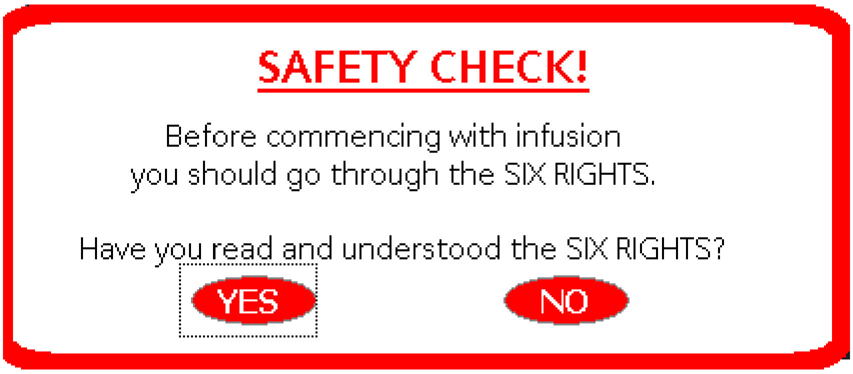


Figure 4.23. Did you check the 6 Rights?

Competency tasks were reduced in number on the assessment activity form following the preliminary stage and simple, unambiguous language relevant to the tasks and expected behaviours replaced some irrelevant statements on the marking criteria (Meretoja & Leino-Kilpi, 2003; Watson et al., 2002). Also, greater emphasis was placed on testing inter-rater reliability, to establish the reliability of the content of the assessment activity tool and marking criteria (Evans, 2008) as determined by the consistency of responses across different assessors. The academics, instructors or tutors for each of the face-to-face laboratory classes were given a revised teaching plan, which comprised a more direct set of instructions for the actual IV pump. For the next stage, these instructions were made more specific to the assigned tasks and included a timeframe in which the instructions were to be delivered to each of the laboratory classes. This ensured greater uniformity for the participants in Group 2 (ONC) and Group 3 (ONL + ONC), ensuring the same period of face-to-face practice.

To complement the existing assessment mode, additional case study scenarios were added to the online IVPE, creating activities that promoted clinical reasoning skills (see Appendix K). Participants could choose up to four different case study scenarios with a selection of different IV infusion orders depending on patient outcomes. The original research team confirmed that the SCADA system had the capacity to save, interpret, and store any data entered by a student, and hence a performance evaluation page was created that displayed a graphic trend page. In the assessment mode, for example, the student would progress to a self-assessment evaluation following the completion of a case study scenario. Based on data entered by the student, the case study scenario performance was scored and evaluated and the results displayed (see Figure 3.10). This is particularly pertinent for self-assessment where students can monitor their own performance and gauge their own learning needs (Fereday & Muir-Cochrane, 2006; Watson et al., 2002). These feedback features, (originally described in Chapter 3, Stage 1) albeit valuable in the learning and teaching sphere, were not included in the subsequent stage of research but instead were considered in relation to future directions of implementing an online IVPE within an undergraduate nursing program.

Improvements to the recruitment and retention of participants were planned and implemented for Stage 3. As a result, the recruitment procedure was managed more effectively, producing and maintaining a much larger group of participants. In relation to the methods, both the instructions for tutors and the activity assessment tool and marking guide for the assessors were refined to provide an improved measure of competence. New statements were added to the user perception surveys to better capture the participants' thoughts about the new and improved online IVPE.

Table 4.2

Refinements from Stage 2 to Stage 3

Refinement
Improved access to the online IVPE
Additional functions, alerts and prompts on the online IVPE
Additional case study scenarios to Assessment Mode to enhance user experience
Timing of recruitment of the participants
Location of recruitment of the participants
Improved strategies to retain participants
Standardised practice time for Group 1 (ONL) and Group 2 (ONC) participants
Teaching instructions for tutors refined to include an allocated timeframe
Revised Assessment Activity Tool (RAAT)
Reduced number of repetitive medication calculations on RAAT
Removed activities from RAAT indirectly related to the functions of an actual IV pump
Descriptions of actions on the marking guide more informative to assess accurately
Revised user perception survey to capture improvements made to online IVPE

Chapter 5

Stage 3 – Comprehensive Evaluation of the Online IVPE

5.1 Introduction

The results from Stage 2, despite the modest sample size, provided preliminary support for online resource complementary to the traditional utilisation of simulated clinical equipment. The combined use of online and traditional instruction produced better competency assessment scores by undergraduate student nurses in comparison to those instructed on just one or the other form of technology.

The value of producing graduate nurses who achieve excellent learning outcomes on the knowledge, function and skill using clinical equipment in common use throughout hospital wards cannot be underestimated. Hence, the purpose of Stage 3 was to provide a more comprehensive evaluation of the online IVPE in comparison to the actual IV pump or a combination of both, as a learning resource. Further to this, the intent of this more comprehensive and detailed evaluation was to establish a stronger evidence-base for the benefits of incorporating this type of complementary learning technology.

To enhance rigour, it was necessary to secure a much larger sample of participants and include the refinements made to the methods and procedures that resulted from Stage 2. Therefore, Ethical approval was granted for amendments to the original application (see Appendix C) and the information to participants (see Appendix L) which included the procedural changes for Stage 3. Simultaneously, a fourth stage of the research process was planned and added to the program of research, which was included in the same Ethics application for amendment.

The online IVPE was once again implemented into a course of study for the purpose of the Stage 3 evaluation. Increased participant willingness and motivation to access and engage online resources was apparent, given that by this time, online access had become standard practice throughout all courses within the program. The results and feedback from the user perception survey in Stage 2 showed that the online IVPE was well received and worth refining in order to undertake a more comprehensive evaluation in Stage 3.

5.2 Aims and Hypotheses

The primary aim for Stage 3 was to more comprehensively evaluate the equivalence of learning outcomes among nursing students who were taught and practiced with the actual IV pump compared to the nursing students who received only online instructions and used the online IVPE. A further aim was to assess whether nursing students using a combination of both an actual IV pump in class with the addition of an online IV pump achieved better learning outcomes. As in Stage 2, the learning outcomes of participants were operationalised in terms of activity assessment scores that reflected competence in using the actual IV pump. In this more comprehensive evaluation, there was greater scrutiny of the learning outcomes of specific activities and functions performed on the actual IV pump. User perceptions were again established to gauge participants' ideas and interest in an online IVPE. Hypotheses tested in Stage 3 were:

H0: There will be no significant difference in assessment scores between participants who used the online IVPE and those who were instructed face-to-face using the actual IV pump;

H1: Participants in the combined group will have significantly higher assessment scores than participants in the other two groups;

H2: A significant relationship between assessment completion time and assessment scores will be found.

5.3 Method

Reflection on the experience and outcomes of Stage 2 of the research prompted refinements to methodological and procedural aspects of Stage 3, as described previously in Table 4.2. A mixed methods research design was again implemented in Stage 3 to assess and compare the learning outcomes for the three groups of participants using either the online IVPE, the actual IV pump, or a combination of both (see Figure 5.1). Using a quasi-experimental design, the competence of nursing students performing activities on an actual IV pump was assessed using the methods described below. This research design helped to establish the evidence base for whether training on an emulated IV pump online is equivalent to the traditional training method, in terms of improving the skill of using an actual IV pump. With new ideas and innovations there is a need to identify strengths and weaknesses, and using experimental designs to answer clinical questions also builds evidence for best practice (Nagy et al., 2010).

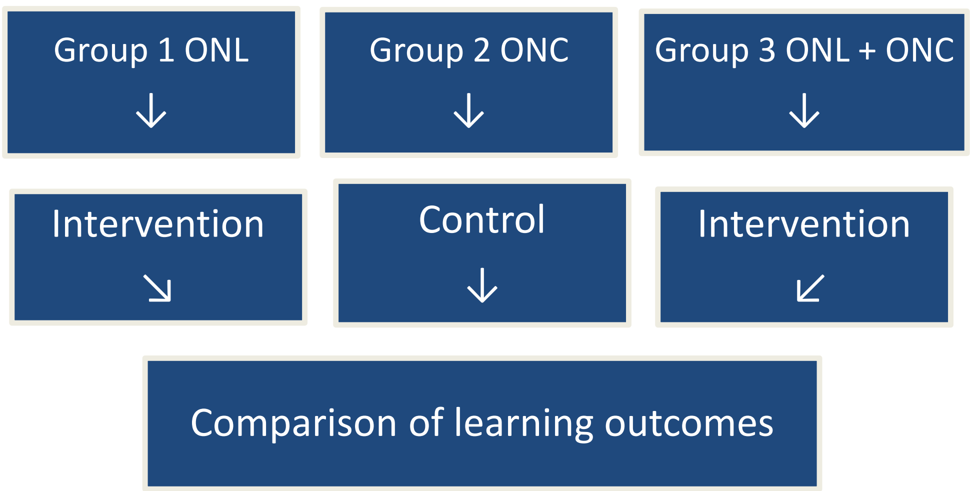


Figure 5.1. Research design in Stage 3.

A survey was used to assess user perceptions among those using the online IVPE, an actual IV pump, or a combination of both. This combination of quasi-experimental and survey methodology is considered to be both pragmatic and appropriate to clinical practice in nursing. Moreover, the methodology used was judged to provide an effective strategy by which to conduct a between-group comparison to evaluate an online educational resource for a health discipline (Roberts & Burke, 1989).

In order to assess competence, the activity assessment tool from Stage 2 was revised and renamed the RAAT. The tool comprised of a series of activities designed in using the general functions and features of an actual IV pump. Included in the activities were tasks related to calculating various rates of IV fluid infusions, commonly used in clinical settings, but fewer in number.

5.3.1 Participants. Participants for Stage 3 were 199 nursing students who consented to take part in the research and were allocated to one of three groups:

Group 1: online only (ONL – treatment group, n = 65)

Group 2: on-campus only (ONC – control group, n = 75)

Group 3: online and on-campus (ONL + ONC – treatment group, n = 59)

Participants studying the undergraduate nursing program online by distance were allocated to Group 1 because they were an intact group of online learners. Numbers in Group 1 were augmented by also assigning some on-campus students to the online-only group using random allocation. The remaining on-campus participants were assigned to Groups 2 and 3 by random selection of student ID numbers. This random selection process reduced the possibility of initial group differences in competence. Of the initial pool of 199 participants, a total of 179 participants completed all assessment activities and the user perception survey, resulting in a retention rate of 90%. The final group numbers for Stage 3 were:

Group 1: online only (ONL - treatment group, *n* = 57)

Group 2: on-campus only (ONC - control group, *n* = 73)

Group 3: online and on-campus (ONL + ONC - treatment group, *n* = 49)

The final sample included 29 males and 150 females. Participants were grouped by age: 18–24 yr. (*n* = 97), 25–34 yr. (*n* = 59), and 35–44 yr. (*n* = 23) with no participants aged 45 years or older. The sample included 60 international students and 119 domestic students.

5.3.2 Assessment of Competence. Both direct and indirect methods were used to assess learning outcomes and other experiences of participants in this stage. Direct measures included assessing the level of clinical competence by observing participants performing a standardised set of activities on an actual IV pump (i.e., the RAAT). The indirect measure took the form of a survey where participants provided user perceptions and level of confidence when using the technologies.

The RAAT (see Appendix M) reflected the teaching and learning objectives from the IV pump module in the course, *Medications Theory and Practice*. Assessment activities used to measure level of competence followed a chronological sequence as if preparing an IV infusion for a patient: Activity 1(a) Select 1000mL sodium chloride and check the order provided, 1(b) Turn on the IV pump, 1(c) Load the IV giving set into the IV pump, 1(d) Set the rate at 83mL, 1(e) Set the volume to be infused (VTBI), and 1(f) Start the infusion.

The initial IV rate, 83mL/hr. was selected as it is a common rate of infusion for IV fluids in any health care setting and is in line with course objectives. The VTBI amount was left up to the participants to decide. It was presented in the laboratory classes, students were instructed that, when infusing a litre of IV fluid, the VTBI should be 10% less than the amount in the flask to prevent drawing air into the line and to allow time to prepare for another infusion if ordered by a medical officer.

Activity 2 asked the participants to list the six rights. Activities 3 and 4 required participants to program into the actual IV pump a variety of rates and volumes from the problem-based medication calculations using the formula that had been taught in the IV pump module. The formula was Volume/Time (in hours). Three problem-solving tasks were included, requiring medication calculations, re-programming the rate, setting the VTBI, and re-starting the flow of fluid each time. Activity 5 was to switch off the pump.

Level of competency for each activity was scored on a Likert-type scale. A revised marking criteria (see Appendix O) re-designed for the Stage 3 assessments included descriptive statements commensurate with skill performance to strengthen consistency of scoring between assessors. The statements describing the level of competence varied in nature from positive to negative using numerical scores where the higher the number, the better the level of competence for a particular activity (see Figure 5.2). It was judged that this revised marking criteria enhanced the objectivity of the assessments in Stage 3 compared to Stage 2.

4: Perfect

3: Hesitant but achieved

2: Stumbled, some mistakes but achieved

1: Unsure, many errors/omissions but achieved eventually

0: Could not or did not perform task, instructed to move on

Figure 5.2. Revised statements describing level of competence.

An OSCE framework was again adopted to assess the competence of each participant when using the actual IV pump. Due to the large sample size and to ensure that all assessments were completed in the designated timeframe, four independent and experienced nurse academics were required to perform the OSCEs in Stage 3. In order to support the reliability of the RAAT and the consistency and equivalence of assessments, inter-rater reliability between assessors was tested. Two assessors independently assessed the same 20 individual participants, who were spread approximately evenly across the three groups, and the results were compared for equivalence. This is explained further in the Data Analysis section.

5.3.3 Assessment of User Perceptions. Following the assessment activities on the RAAT, participants completed the user perception survey (see Appendix N). The survey varied slightly between groups, with Group 1 (ONL) participants responding to items about the online IVPE, Group 2 (ONC) participants responding to items about the instruction and time spent using the actual IV pump in class, and Group 3 (ONL + ONC) participants providing their perceptions of both forms of technology. User perception items for the online IVPE related to its ease of access, the effectiveness of instructions, learning resources and assessment mode, and the individual's level of confidence in using the online IVPE. Open-ended questions were included to determine the best features of the online IVPE and anything that could be improved. User perception items for the actual IV pump related to the effectiveness of instruction, practice time, and perceived level of confidence in using the pump. All participants responded to a statement related to whether greater use of online technologies should be implemented for educating nursing students in the use of laboratory equipment. In addition, Group 3 (ONL + ONC) participants reported how much time they had spent using the online IVPE.

5.3.4 Procedure. To aid in participant recruitment and promote interest in the research, information was presented on the course LMS about the design, development and functionality of the online IVPE as an additional learning resource for learning to use an IV pump. This appeared just prior to the IV pump module content being delivered in class and online. Participation was encouraged by the course leader and teaching team. Recruitment of participants occurred in class time and via announcements on the course LMS site for the external students. Potential participants were informed that they would be involved in the development and evaluation of an innovative piece of online clinical equipment and possibly contribute to its implementation within the nursing program in the future. Participants were assured at different intervals that their performance, time taken, and scores achieved on the assessment would not be reflected in any way in their grades for the course. Entry into a draw for four, $50 vouchers was included for all participants as an incentive to participate.

An in-class, face-to-face invitation to participate was used to recruit the on-campus and combined group for Stage 3. This proved to be a more successful recruitment strategy than that used in Stage 2, as it offered a more direct and personal approach compared to an announcement in the lecture theatre. Recruiting participants from the laboratory classes just one week before the activities on the IV pump commenced created a sense of anticipation about the importance and benefits of an online IVPE, generating more interest in participating. Recruitment of external student participants was conducted via the LMS and then when the external students came on-campus into residential school.

The revised recruitment strategy and experimental procedure dramatically improved both the initial recruitment and the retention rate of participants. In assessment week, it was convenient to go directly to the same laboratory classes from where the participants were recruited to conduct the assessment activities. Participants had been difficult to locate for the assessment activities in Stage 2 as they were spread throughout a number of classes over various days and times.

Voluntary informed consent was obtained using the information for participants and the participant consent form, including electronic documents for the external cohort. There were three participant groups for Stage 3, the same as in the previous stage of research. Group 2, the control group, received the traditional educational in-class, face-to-face training on an actual IV pump. Group 1 and Group 3 received the intervention, training on the online IVPE, with Group 3 also receiving the traditional in-class, face-to-face training. Whether the students were studying externally or on-campus, it was established that they had no prior experience with IV pumps, either from a practical placement in a hospital or from another course.

Teaching material and instructions for both the actual IV pump and online IVPE were posted on the LMS. The following week, on-campus participants received the training on the use the actual IV pump or online IVPE during a 120 minute simulated laboratory class. This timeframe was shown in Stage 2 to be adequate to train nursing students in the use of the actual IV pump. Tutors for each of the laboratory classes were given the same set of instructions and the teaching plan was a revised version of the instructions used in Stage 2, whereby instructions included a specific timeframe in which the information was to be delivered (see Appendix P). Instructions for accessing and using the online IVPE for Group 1 (ONL) and Group 3 (ONL + ONC) were posted simultaneously on the LMS (see Appendix E).

Group 1 (ONL) participants had no access to an actual IV pump and Group 2 (ONC) participants had no access to the online IVPE. During their period of instruction on the actual IV pump, Group 3 (ONL + ONC) participants were offered unlimited optional access to the online IVPE. The assessment phase for the participants, regardless of mode of delivery of training, occurred one week after completing their training on the actual IV pump or online IVPE. External participants received training on the online IVPE during a residential school class for 120 minutes and were subsequently assessed on the use of the actual IV pump one week later. Assessment took approximately 15–20 minutes per participant.

The teaching plan from the course content, case study and medical orders that were provided in the face-to-face laboratory classes and/or online for Stage 3 were the same educational resources used in Stage 2. The specifics of training on the actual IV pump were outlined in the course objectives, and included the basic functions of the IV pump and a practical case study incorporating the equipment. Medication formulas for the rate of IV fluids also formed part of the learning objectives. The same practical case study was available online for Group 1 (ONL) and Group 3 (ONL + ONC) and formed part of the activities for the online IVPE training.

Because engaging and retaining the online users of the online IVPE through the RAL platform had proven ineffective and access to RAL could not be improved in the short term, the online IVPE was installed on computers in the nursing simulated laboratories to make online access easier for participants. Participants assigned to Group 1 (ONL) and Group 3 (ONL + ONC) trained on the online IVPE in the laboratory classes rather than exclusively from an external computer. This refinement to the procedures dramatically improved the retention of participants in the online-only and combined groups. For participants studying by distance, access to the online IVPE occurred during residential school classes.

Assessment week featured all participants from Group 1 (ONL), Group 2 (ONC) and Group 3 (ONL + ONC), who individually completed a series of assessment activities (listed on the RAAT) on an actual IV pump, during class time in their simulated laboratory class time. Once assessment was completed, the actual IV pumps were removed from the laboratory classrooms, including the online IVPE program from the laboratory computers. Similarly, access to the online IVPE via RAL was blocked to participants. Removal of participant access to actual IV pumps and the online IVPE was implemented to facilitate evaluation of competency retention in Stage 4 of the research.

The clinical assessors were not part of the teaching team for the first year medication course and were blind to group membership. They were instructed to assure the participants that the assessment was not an exam, and that their performance, time taken, and scores achieved would not be reflected in any way in their grades for the course. The assessors were also instructed not to communicate or assist the participant’s performance in any way, other than allowing the participant to move onto the next activity if there was evidence of inability to perform to activity, at which point the score allocated was 0.

Participants were given a copy of the RAAT to read for themselves. The participants were timed from when they began reading through the documented order until the completion of the activity, which was after the IV pump was switched off. Start and completion times were recorded. The maximum total number of points for all activities on the RAAT was 80 points. Fewer points were allocated in this stage (Stage 2 scores totalled 130) due to the reduction of the number of activities related to IV fluid rate medication calculations. Following the assessment of activities, participants were invited to complete a revised user perception survey about the technology they had used in their learning activities, either the actual IV pump, the online IVPE, or a combination of both.

5.3.5 Data Analysis. Comparison of assessment scores between Group 1 (ONL) and Group 2 (ONC) determined whether instruction using the online IVPE was equivalent to traditional in-class instruction for preparing students in the use of an actual IV pump. The purpose of including Group 3 (ONL + ONC) in the study was to address the question of whether using the online IVPE in addition to in-class instruction on the actual IV pump was associated with better outcomes than just using one form of technology or the other.

For the quantitative analysis, the dependent variables were the RAAT total scores, scores for each individual activity, participant practice time, and completion time. The independent variable was group membership; namely, Group 1 (ONC), Group 2 (ONL), and Group 3, (ONC + ONL). Chi-squared tests were used to check whether participants were equally distributed across groups, according to their gender, age group, and residency status. Descriptive statistics for the three groups were calculated and between-group comparisons were conducted using single-factor ANOVA and Tukey post-hoc comparison tests. The effects of gender (male, female), age group (18–24 yr., 25–34 yr., 35–44 yr.), and residency (domestic, international) were assessed using the same inferential tests. Pearson correlation analysis was used to test relationships among the dependent variables. Probability analyses were augmented with calculation of effect sizes using Cohen’s d, where 0.2 represents a small effect, 0.5 a moderate effect, and 0.8 a large effect. Inter-rater reliability was established by correlating assessment scores for a sub-sample of 20 participants who were assessed independently by pairs of expert clinicians. The mean correlation among the four assessors (*r* = .966) indicated a very high level of inter-rater reliability for the marking criteria of the RAAT.

User perceptions were analysed in two ways. First, comments were categorised qualitatively as positive, neutral, or negative, and percentages of each category of comment were calculated to establish the general tone of the user perceptions. Second, the open-ended comments were groups into themes and reproduced verbatim in the results where appropriate (all responses are provided in Appendix Q).

5.4 Results

Prior to analysis, the dataset was checked for missing and out-of-range values. Where required, corrections were made with reference to the original hardcopies of the RAAT assessments. Scores on the RAAT ranged from 11–79 (*M* = 65.0, *SD* = 11.1). Although the distribution of scores showed some skewness towards the upper end of the scale, this deviation from a normal distribution was not significant (see Figure 5.3). Normal distribution for time to completion of assessment activities among participants was also assessed. The distribution of scores showed a small degree of skewness towards the lower end of the scale, although this deviation from a normal distribution was not significant (see Figure 5.4).

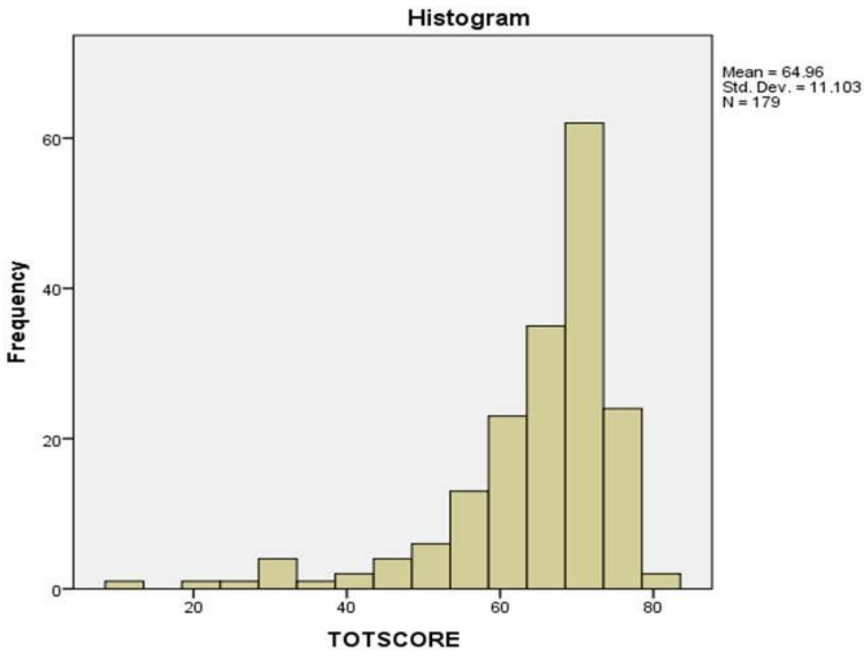


Figure 5.3. Histogram showing distribution of RAAT scores among 179 participants.

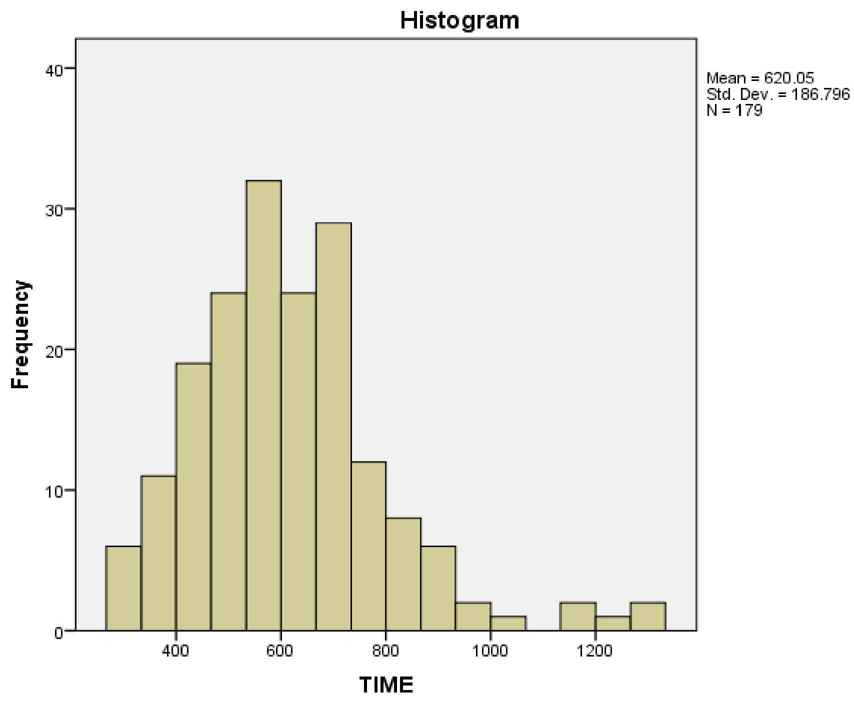


Figure 5.4. Histogram showing distribution of completion times among 179 participants.

Chi-squared tests showed that the distribution of participants across groups did not differ significantly by gender ($\chi^2 = 1.94$, $p > .05$) but did differ by age group ($\chi^2 = 11.37$, $p < .05$) and country of residency ($\chi^2 = 11.83$, $p < .01$). Group 1 (ONL) had an over-representation of participants in the 35-44 age group and an under-representation of international students. This was unsurprising given that many older students study by distance, and international students tend to study on-campus. These demographic differences had the potential to skew the results of between-group comparisons of competence. Therefore, subsequent tests for differences in competence according to the age group and residential status of participants became especially important. As reported below (see Tables 5.2 and 5.4), no between-group differences by age group or residency were found for any outcome variable, indicating that between-group variations in demographic characteristics did not influence between-group comparisons of competence.

It was hypothesised (H0) that there would be no significant difference in level of competency, as assessed by RAAT scores, between Group 1 (ONL) and Group 2 (ONC), who used the different forms of IV pump technology. The purpose of including Group 3 (ONL + ONC) was to address the question of whether using the online IVPE in addition to the actual IV pump was associated with better RAAT scores, than just using one or the other. It was hypothesised (H1) that Group 3 (ONL + ONC) participants would perform significantly better than Group 1 (ONL) and Group 2 (ONC) in assessment scores and time to complete the assessment. It was also hypothesised (H2) that a significant inverse relationship between assessment completion time and assessment scores would be found.

As hypothesised, no significant difference in the final assessment (RAAT) scores was found between Group 1 (ONL) and Group 2 (ONC), although Group 1

(ONL) participants scored on average 3.5 points more than Group 2 (ONC). A significant between-group difference was found, whereby Group 3 (ONL + ONC) out-performed Group 2 (ONC) in the final assessment scores (see Table 5.1). Other significant between-group differences were found. Group 3 (ONL + ONC) completed the RAAT significantly faster than the other two groups, and Group 1 (ONL) completed the RAAT significantly faster than Group 2 (ONC; Table 5.1).

Across all participants, a highly significant negative correlation was found between assessment scores and time to completion ($r = -.65$, $p < .001$). This indicated that those participants who completed the assessment faster tended to perform better, signifying a superior level of competency. On the other end of the scale, the participants who achieved lower assessment scores tended to take longer to complete the assessment activities, reflecting a lower level of competence working with the actual IV pump.

Table 5.1

IV Pump Statistics by Training Group (N = 179)

Variable	Group	*M*	*SD*	$F_{2,176}$	*d*	Sig. Group Differences
Assessment Score	ONL	65.5	9.2	7.03**	0.38 0.28	
	ONC	62.0	14.8		0.66	ONC< ONL + ONC
	ONL + ONC	68.7	4.9		0.66	ONL + ONC>ONC
Completion time (sec)	ONL	619.6	132.9	27.44***	0.49 0.71	ONL<ONC, ONL>ONL + ONC
	ONC	711.6	207.2		0.49 1.20	ONC>ONL, ONL + ONC
	ONL + ONC	486.1	120.0		0.71 1.20	ONL + ONC<ONL, ONC

Note. Maximum Assessment Score = 80; ONL = Online Group 1 (*n* = 57), ONC = On-Campus Group 2 (*n* = 73), ONL + ONC = Online + On-Campus Group 3 (*n* = 49); ** $p < .01$, *** $p < .001$.

Comparisons showed no significant differences in total assessment score or time to completion according to the age group (see Table 5.2), gender (see Table 5.3), or residency status of participants (see Table 5.4). These results confirmed that unequal between-group distributions of age and residential categories did not skew the results of between-group comparisons of competence.

Table 5.2

IV Pump Statistics by Age Group (N = 179)

Variable	Age Group (yr)	*n*	*M*	*SD*	$F_{2,176}$	*p*
Assessment Score	18–24	97	64.6	11.1	0.43	N.S.
	25–34	59	64.7	11.7		
	35–44	23	67.0	9.9		
Completion Time (sec)	18–24	97	605.3	196.4	0.67	N.S.
	25–34	59	639.4	182.0		
	35–44	23	632.5	156.5		

Note. Maximum Assessment Score = 80; N.S. = Non-Significant.

Table 5.3

IV Pump Statistics by Gender (N = 179)

Variable	Gender	*n*	*M*	*SD*	$F_{2,176}$	*p*
Assessment Score	Female	150	64.8	10.8	0.14	N.S.
	Male	29	65.7	12.6		
Completion Time (sec)	Female	150	618.1	182.1	0.10	N.S.
	Male	29	630.1	212.4		

Note. Maximum Assessment Score = 80; N.S. = Non-Significant.

Table 5.4

IV Pump Statistics by Residency Status (N = 179)

Variable	Residency	*n*	*M*	*SD*	$F_{2,176}$	*p*
Assessment Score	Domestic	119	65.7	9.5	1.66	N.S.
	International	60	63.5	13.8		
Completion Time (sec)	Domestic	119	605.0	153.1	2.35	N.S.
	International	60	650.1	238.8		

Note. Maximum Assessment Score = 80; N.S. = Non-Significant.

To gain a more detailed understanding of between-group differences, the three groups were compared by the specific activities that comprised the RAAT. Activity 1 included six tasks (labelled A–F in Table 5.5). The first activity was to check that the chosen IV fluid corresponded with the medication order, and the next four tasks were specifically to do with physically handling and programming the actual IV pump. Even though Group 2 (ONC) were significantly better at checking that the IV fluid matched the IV order, they were outperformed by the other two groups in some aspects related to physically handling and programming the actual IV pump (see Table 5.5).

Group 3 (ONL + ONC) were significantly better at turning on the IV pump than the other two groups. Group 2 (ONC) and Group 3 (ONL + ONC), who received training on the actual IV pump, performed significantly better than Group 1 (ONL) when asked to load the IV giving set into the actual IV pump. Group 3 (ONL + ONC) performed significantly better when asked to set the rate at 83mL/hr. compared to Group 2 (ONC). Both Group 3 (ONL + ONC) and Group 1 (ONL) performed significantly better than Group 2 (ONC) when setting the VTBI. When instructed to start the infusion, no significant group differences were found, therefore each group demonstrated the same level of competency for this particular task (see Table 5.5).

Activity 2 required participants to recall the 6 Rights, the results of which also showed significant between-group differences. Group 1 (ONL) and Group 3 (ONL + ONC) performed this task significantly better than Group 2 (ONC), meaning that participants who used the online IVPE scored higher in this activity than the group who were instructed and trained only on the actual IV pump in the laboratory classroom (see Table 5.6).

The results of Activity 3, which involved performing medication calculations with IV fluid rates and programming the actual IV pump, also showed significant between-group differences. In Activity 3A, Group 3 (ONL + ONC) performed better than the other two groups on every task, which included the IV fluid calculation, programming the rate and VTBI, and starting the pump, differences that were significant in the case of the IV fluid calculation and setting the VTBI (see Table 5.7). For Activity 3B, Group 3 (ONL + ONC) performed significantly better than the other two groups in the IV fluid calculation, and better than Group 2 (ONC) for setting the VTBI, whereas there were no significant group differences in programming the rate on the actual IV pump. When it came to re-starting the IV pump, there was a significant difference whereby the online IVPE users, Group 1 (ONL) and Group 3 (ONL + ONC), performed this task better than the on-campus users from Group 2 (see Table 5.8).

In Activity 4, which involved a more complex calculation involving clinical reasoning, similar results were found. Group 1 (ONL) and Group 3 (ONL+ ONC) performed significantly better than Group 2 (ONC) with the IV fluid calculation and restarting the actual IV pump (see Table 5.9). There were no significant between-group differences in Activity 5 (turning off the IV pump; see Table 5.10).

Table 5.5

RAAT Activity 1 Scores by Training Group (N = 179)

Variable	Group	*M*	*SD*	$F_{2,176}$	*d*	Sig. Group Differences
1A	ONL	2.6	1.3	28.76***	0.79	ONL>ONL + ONC
					0.58	ONL<ONC
	ONC	3.3	1.1		1.38	ONC>ONL + ONC
					0.58	ONC>ONL
	ONL + ONC	1.5	1.5		1.38	ONL + ONC<ONC
					0.79	ONL + ONC<ONL
1B	ONL	3.4	0.9	6.45**	0.56	ONL<ONL + ONC
	ONC	3.4	1.0		0.53	ONC<ONL + ONC
					0.56	ONL + ONC>ONL
	ONL + ONC	3.9	0.9		0.53	ONL + ONC>ONC
1C	ONL	1.0	1.2	17.83***	0.96	ONL<ONL + ONC
					0.93	ONL<ONC
	ONC	2.3	1.6		0.93	ONC>ONL
	ONL + ONC	2.3	1.5		0.96	ONL + ONC>ONL
1D	ONL	3.8	0.4	5.70**		
	ONC	3.6	0.8		0.57	ONC<ONL + ONC
	ONL + ONC	4.0	0.6		0.57	ONL + ONC>ONC
1E	ONL	3.7	0.7	9.85***	0.82	ONL>ONC
	ONC	2.8	1.5		0.56	ONC<ONL + ONC
					0.82	ONC<ONL
	ONL + ONC	3.5	1.0		0.56	ONL + ONC>ONC
1F	ONL	2.3	1.3	1.25		N.S.
	ONC	2.3	1.6			N.S.
	ONL + ONC	2.6	0.9			N.S.

Note. 1A = Select 1000mL Sodium Chloride & Check An Order; 1B = Turn On The IV Pump; 1C = Load The IV Giving Set Into The IV Pump; 1D = Set The Rate At 83mL/Hr; 1E = Set The Volume To Be Infused (VTBI); 1F = Start The Infusion. ONL = Online Group 1 (*n* = 57), ONC = On-Campus Group 2 (*n* = 73), ONL + ONC = Online + On-Campus Group 3 (*n* = 49); ** *p* < .01, *** *p* < .001, N.S. = Non-Significant. Only significant *d*-values are reported.

Table 5.6

RAAT Activity 2 Scores by Training Group (N = 179)

Variable	Group	*M*	*SD*	$F_{2,176}$	*d*	Sig. Group Differences
A2	ONL	5.9	0.4	4.90**	0.60	ONL>ONC
	ONC	5.6	0.6		0.60 0.60	ONC<ONL, ONL + ONC
	ONL + ONC	5.9	0.4		0.60	ONL + ONC>ONC

Note. A2 = Say the 6 Rights; ONL = Online Group 1 (n = 57), ONC = On-Campus Group 2 (n = 73), ONL + ONC = Online + On-Campus Group 3 (n = 49); ** p < .01, *** p < .001.

Table 5.7

RAAT Activity 3 Scores by Training Group (N = 179)

Variable	Group	*M*	*SD*	$F_{2,176}$	*d*	Sig. Group Differences
3A1	ONL	2.6	1.7	5.70**	0.59	ONL<ONL + ONC
	ONC	2.5	1.8		0.64	ONC<ONL + ONC
	ONL + ONC	3.4	1.0		0.64	ONL + ONC>ONC
					0.59	ONL + ONC>ONL
3A2	ONL	3.5	0.9	2.4		N.S.
	ONC	3.3	1.1			N.S.
	ONL + ONC	3.7	0.8			N.S.
3A3	ONL	3.6	0.9	5.23**		
	ONC	3.1	1.4		0.64	ONC<ONL + ONC
	ONL + ONC	3.8	0.8		0.64	ONL + ONC>ONC
3A4	ONL	3.3	0.7	0.71		N.S.
	ONC	3.2	1.2			N.S.
	ONL + ONC	3.4	0.9			N.S.

Note. 3A1 = Medication Calculation Infuse 1000mL Sodium Chloride over 24 Hours; 3A2 = Set The Rate; 3A3 = Set The VTBI; 3A4 = Start The Pump. ONL = Online Group 1 (*n* = 57), ONC = On-Campus Group 2 (*n* = 73), ONL + ONC = Online + On-Campus Group 3 (*n* = 49); ** *p* < .01, *** *p* < .001, N.S. = Non-Significant. Only significant *d*-values are reported.

Table 5.8

RAAT Activity 3B Scores by Training Group (N = 179)

Variable	Group	*M*	*SD*	$F_{2,176}$	*d*	Sig. Group Differences
3B1	ONL	3.2	1.5	8.69***	0.67	ONL<ONL + ONC
	ONC	2.8	1.7		0.96	ONC<ONL + ONC
	ONL + ONC	3.9	0.6		0.96	ONL + ONC>ONC
					0.67	ONL + ONC>ONL
3B2	ONL	3.7	0.8	1.74		N.S.
	ONC	3.3	1.2			N.S.
	ONL + ONC	3.5	0.9			N.S.
3B3	ONL	3.7	0.9	4.45*		
	ONC	3.2	1.4		0.55	ONC<ONL + ONC
	ONL + ONC	3.8	0.8		0.55	ONL + ONC>ONC
3B4	ONL	3.6	0.5	4.93**	0.53	ONL>ONC
	ONC	3.2	1.0		0.53	ONC<ONL + ONC
					0.53	ONC<ONL
	ONL + ONC	3.6	0.5		0.53	ONL + ONC>ONC

Note. 3B1 = Medication Calculation Infuse 1000mL Sodium Chloride over 6 Hours; 3B2 = Set the Rate; 3B3=Set The VTBI; 3B4 = Start The Pump. ONL = Online Group 1 (*n* = 57), ONC = On-Campus Group 2 (*n* = 73), ONL + ONC = Online + On-Campus Group 3 (*n* = 49); ** *p* < .01, *** *p* < .001, N.S. = Non-Significant. Only significant *d*-values are reported.

Table 5.9

RAAT Activity 4 Scores by Training Group (N = 179)

Variable	Group	*M*	*SD*	$F_{2,176}$	*d*	Sig. Group Differences
4A1	ONL	3.6	0.9	7.83***	0.62	ONL>ONC
	ONC	2.8	1.7		0.62	ONC<ONL
					0.59	ONC<ONL + ONC
	ONL + ONC	3.6	1.0		0.59	ONL + ONC>ONC
4A2	ONL	3.6	0.9	1.18		N.S.
	ONC	3.5	1.2			N.S.
	ONL + ONC	3.8	0.8			N.S.
4A3	ONL	3.2	1.3	2.19		N.S.
	ONC	3.7	1.7			N.S.
	ONL + ONC	3.1	1.6			N.S.
4A4	ONL	3.6	0.5	8.61***	0.50	ONL>ONC
	ONC	3.2	1.1		0.50	ONC<ONL
					0.80	ONC<ONL + ONC
	ONL + ONC	3.8	0.4		0.80	ONL + ONC>ONC

Note. 4A1 = Medication Calculation Infuse 500mL Sodium Chloride over 2 Hours; 4A2 = Set Rate; 4A3 = Set VTBI; 4A4 = Start IV Pump. ONL = Online Group 1 (*n* = 57), ONC = On-Campus Group 2 (*n* = 73), ONL + ONC = Online + On-Campus Group 3 (*n* = 49); *** $p < .001$, N.S. = Non-Significant. Only significant *d*-values are reported.

Table 5.10

RAAT Activity 5 Scores by Training Group (N = 179)

Variable	Group	*M*	*SD*	$F_{2,176}$	Sig. Group Differences
A5	ONL	1.9	0.3	2.30	N.S.
	ONC	1.7	0.5		N.S
	ONL + ONC	1.8	0.4		N.S

Note. A 5= Turn Off IV Pump; ONL = Online Group 1 (*n* = 57), ONC = On-Campus Group 2 (*n* = 73), ONL + ONC = Online + On-Campus Group 3 (*n* = 49); N.S. = Non-Significant.

Results of the user perception survey showed some variation between groups. Group 2 (ONC) responded to items about the instruction and time spent with the actual IV pump in class. The survey completed by Group 1 (ONL) was designed specifically for the online IVPE. Group 3 (ONL + ONC) participants were offered both surveys to assess perceptions about each form of technology. User perceptions showed very positive ratings about the online IVPE from participants in Group 1 (ONL) and Group 3 (ONL + ONC). The results showed some meaningful differences among the groups in relation to their perceptions of the IV pump technologies.

Participants from Group 1 (ONL) and Group 3 (ONL+ ONC) who received the same survey about the online IVPE, were asked to score its features on a Likert-type scale in relation to the instructions on the learning mode, resource page, image gallery, and assessment mode. Figures 5.5–5.12 display the results related to the participants' perceptions of the teaching instructions and features of the online IVPE as a learning resource. First, the majority of participants either agreed or strongly agreed that the information and instructions in the learning mode were easy to follow. In Group 1 (ONL), 46% strongly agreed and 39% agreed and in Group 3 (ONL + ONC), 46.7% responded in each category. From Group 1 (ONL), 15% of participants were neutral along with 6.7 % of neutral responses from Group 3 (ONL + ONC). No negative perceptions were recorded for either group (see Figure 5.5).

A similar response resulted in the next statement regarding how helpful the online IVPE resource page was to participants. From Group 1 (ONL), 35% strongly agreed and 45% agreed and from Group 3 (ONL + ONC), 42% strongly agreed and 39% agreed. Remaining undecided were 20% from Group 1 (ONL) and 19% from Group 3 (ONL + ONC). Again, no negative perceptions were recorded for either group (see Figure 5.6).

When asked if the image gallery was helpful, 27% strongly agreed and 55% agreed from Group 1 (ONL), and 44% strongly agreed and 40% agreed from Group 3 (ONL + ONC). This left 18% from Group 1 (ONL) and 16% from Group 3 (ONL + ONC) who responded neutrally (see Figure 5.7). Thus, almost all participants indicated positive perceptions (strongly agree or agree) of the online teaching resources provided with the online IVPE. Only 3.5% in Group 1 (ONL) did not agree that there was sufficient information in the learning mode (see Figure 5.8).

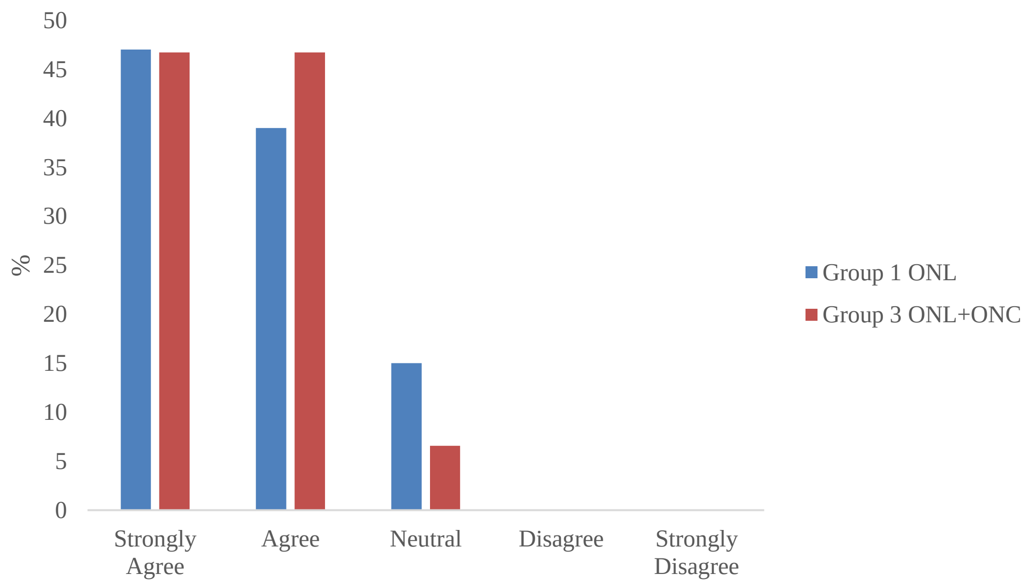


Figure 5.5. Participant responses in user perception survey to question 3a. *Learning mode about the use of the online IV pump was easy to follow*; ONL = Online Group 1 (*n* = 54), ONL + ONC = Online + On-Campus Group 3 (*n* = 45).

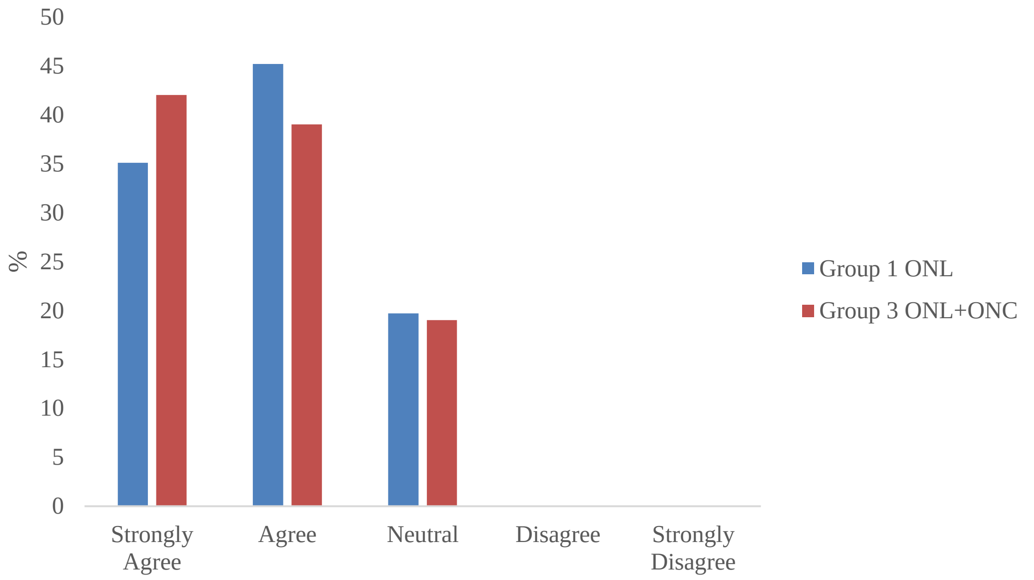


Figure 5.6. Participant responses in user perception survey to question 3b. *Resource page for the online IV pump was helpful*; ONL = Online Group 1 (*n* = 54), ONL + ONC = Online + On-Campus Group 3 (*n* = 45).

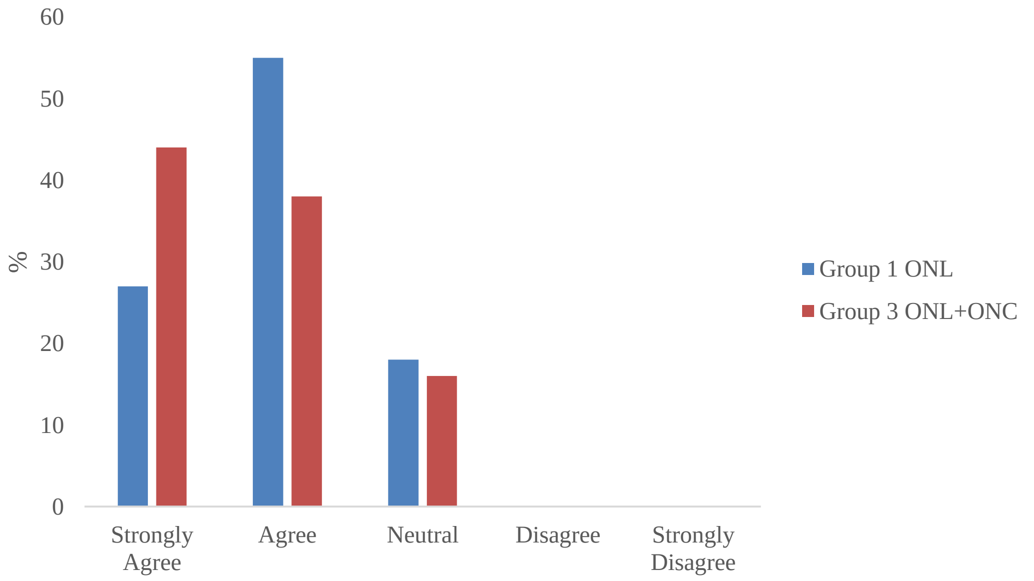


Figure 5.7. Participant responses in user perception survey to question 3c. *Image gallery for the online IV pump was helpful*; ONL = Online Group 1 (*n* = 54), ONL + ONC = Online + On-Campus Group 3 (*n* = 45).

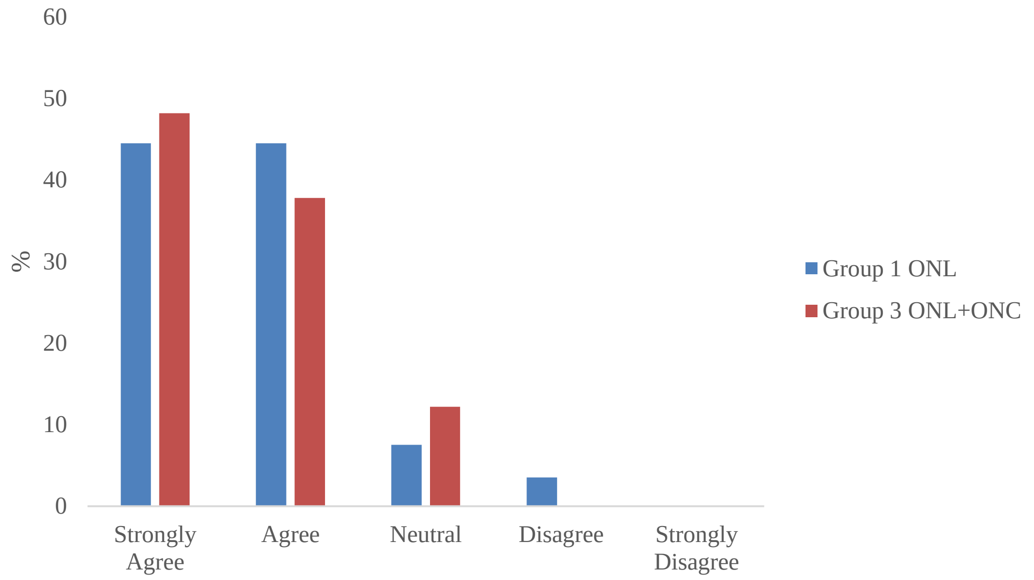


Figure 5.8. Participant responses in user perception survey to question 3d. *Enough information was supplied for learning mode*; ONL = Online Group 1 (*n* = 54), ONL + ONC = Online + On-Campus Group 3 (*n* = 45).

The results in Figures 5.9 and 5.10 show perceptions of the assessment mode and case study scenarios featured in the online IVPE. When asked whether the assessment mode was *not* easy to work through, encouragingly most participants either strongly disagreed or disagreed. From Group 1 (ONL), 22% strongly disagreed and 35% agreed, and from Group 3 (ONL + ONC) respondents, 18% strongly disagreed and 32% disagreed. A number of participants were undecided, 25% from Group 1 (ONL) and 32% from Group 3 (ONL + ONC). On the other hand, 4% strongly agreed and 14% agreed from Group 1 (ONL) that the assessment mode was not easy. Similarly, 5% strongly agreed and 13% agreed from Group 3 (ONL + ONC) had similar thoughts (see Figure 5.9). The case study scenarios were perceived as excellent examples by most of the participants from Group 1 (ONL) and Group 3 (ONL + ONC) with just a small percentage from both groups undecided. No participant (0%) disagreed or strongly disagreed with the statement that the case study scenarios were excellent examples to support their learning journey with the online IVPE (see Figure 5.10).

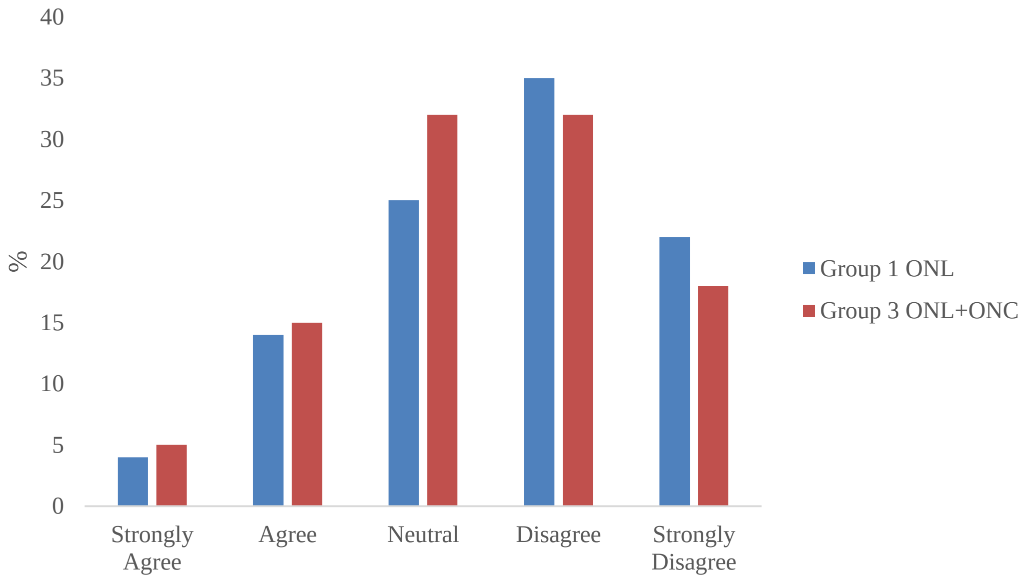


Figure 5.9. Participant responses in user perception survey to question 3e. *The assessment mode was not easy to work though*; ONL = Online Group 1 (*n* = 54), ONL + ONC = Online + On-Campus Group 3 (*n* = 45).

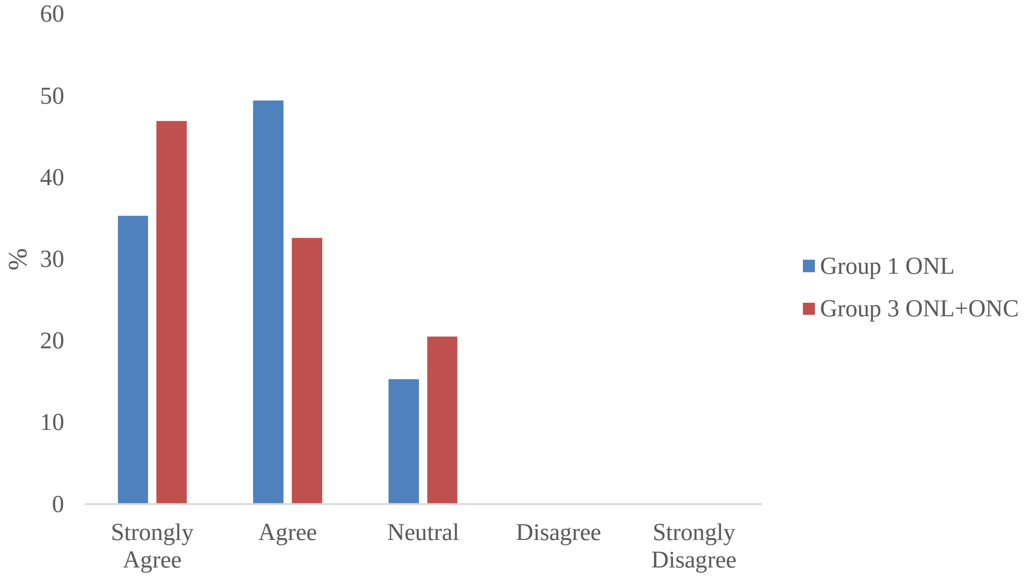


Figure 5.10. Participant responses in user perception survey to question 3f. *The case studies were excellent learning examples*; ONL = Online Group 1 (*n* = 54), ONL + ONC = Online + On-Campus Group 3 (*n* = 45).

Mixed perceptions were indicated in response to the reversed scored statement about time allocated for practice on the online IVPE. Two hours was allocated for instruction and practice with the IVPE though online means and the actual IV pump during face-to-face class time. Figure 5.11 shows that Group 1 (ONL) participants mostly either strongly disagreed (27%) or disagreed (25%) that *insufficient* time was allocated for practice, although some were not of the same opinion. Twenty four percent from Group 1 (ONL) agreed not enough time was allocated to practice on the online IVPE with a further 4.5% strongly agreeing and 18.5% undecided. Among Group 3 (ONL + ONC) participants, the feeling was similar, except that 8% strongly agreed that insufficient time was allocated for practice and 20% strongly disagreed.

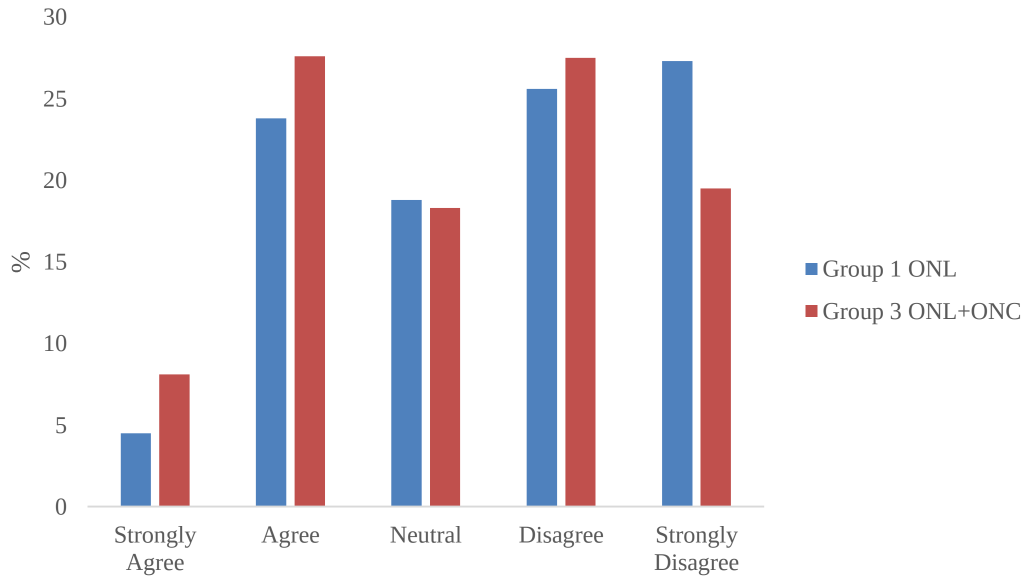


Figure 5.11. Participant responses in user perception survey to question 3g. *Insufficient time was allocated for practice*; ONL = Online Group 1 (*n* = 54), ONL + ONC = Online + On-Campus Group 3 (*n* = 45).

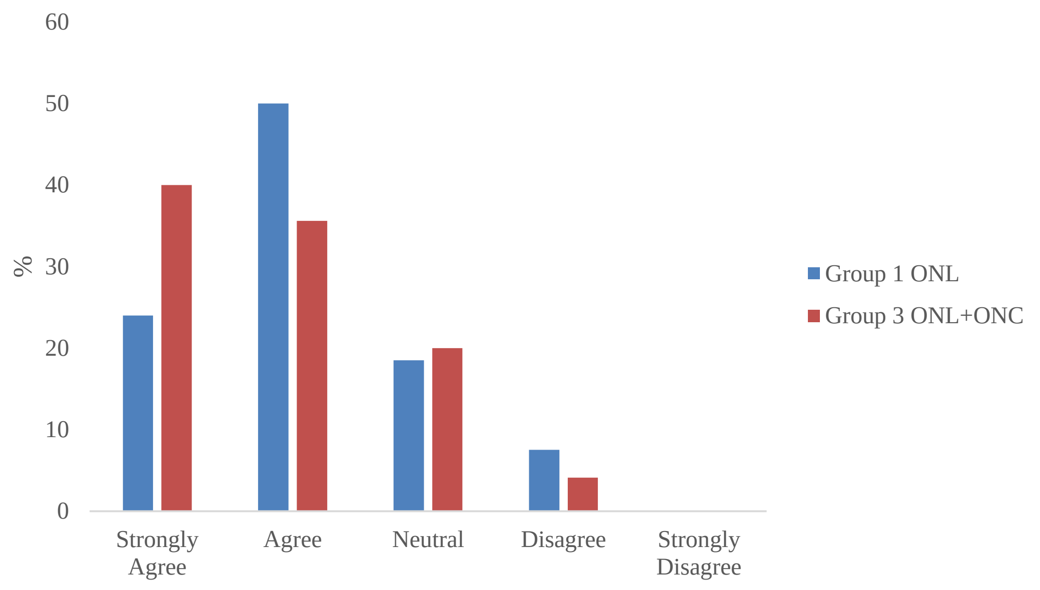


Figure 5.12. Participant responses in user perception survey to question 3h. *I feel confident using the online IV pump*; ONL = Online Group 1 (*n* = 54), ONL + ONC = Online + On-Campus Group 3 (*n* = 45).

In Figure 5.12 above, despite the concerns about not having enough time to practice with the online IVPE, a 1arge percentage of participants from both groups felt confident using the online IVPE as a learning tool. From Group 1 (ONL), 24% strongly agreed and 50% agreed to feeling confident using the online IVPE, 18.5% were unsure, and 7.5% disagreed. Group 3 (ONL + ONC) on the other hand felt a little more confident, probably due to the fact that the participants were instructed and practiced on both forms of the IV technology, with 40% strongly agree, 35.6% agree, 20% undecided and only 4.4% disagreeing about feeling confident.

Group 3 (ONL + ONC) went on to a respond to a question about the actual IV pump, which was also provided to Group 2 (ONC) participants and included statements about instruction, demonstration, practice time, and confidence using the actual IV pump (see Figures 5.13–5.17). First, similar responses were elicited from both groups in relation to the usefulness of the face-to-face teaching instructions outlining the features and functions of the actual IV pump. This traditional-style teaching of the actual IV pump was performed in the simulated laboratories for the two groups in question. Figure 5.13 shows that, from Group 2 (ONC), 28.8% strongly agreed and 52.1% agreed the instructions were helpful whereas 12.3% felt neutral, 5.5% disagreed, and just one participant (1.4%) strongly disagreed with the statement. From Group 3 (ONL + ONC), 32.4% strongly agreed, 61.2% agreed and 6.4% felt neutral. The video demonstration, used as an additional resource about how to use the actual IV pump, received positive responses. Twenty two percent of participants from Group 2 (ONC) strongly agreed, 61.6% agreed, but 16.4% felt neutral. From Group 3 (ONL + ONC) participants, 26.7% strongly agreed, 60% agreed, 11.1% felt neutral, and 2.2% disagreed that the video demonstration was helpful (see Figure 5.14).

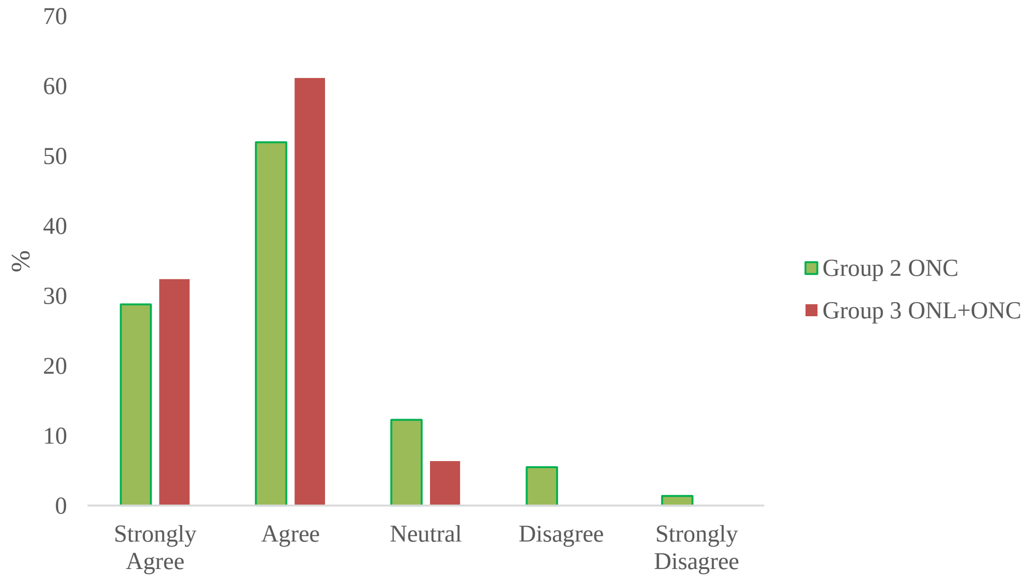


Figure 5.13. Participant responses in user perception survey to question 6a. *Teaching instructions about use of the actual IV pump were easy to understand;* ONC = On-Campus Group 2 (*n* = 73), ONL + ONC = Online + On-Campus Group 3 (*n* = 45).

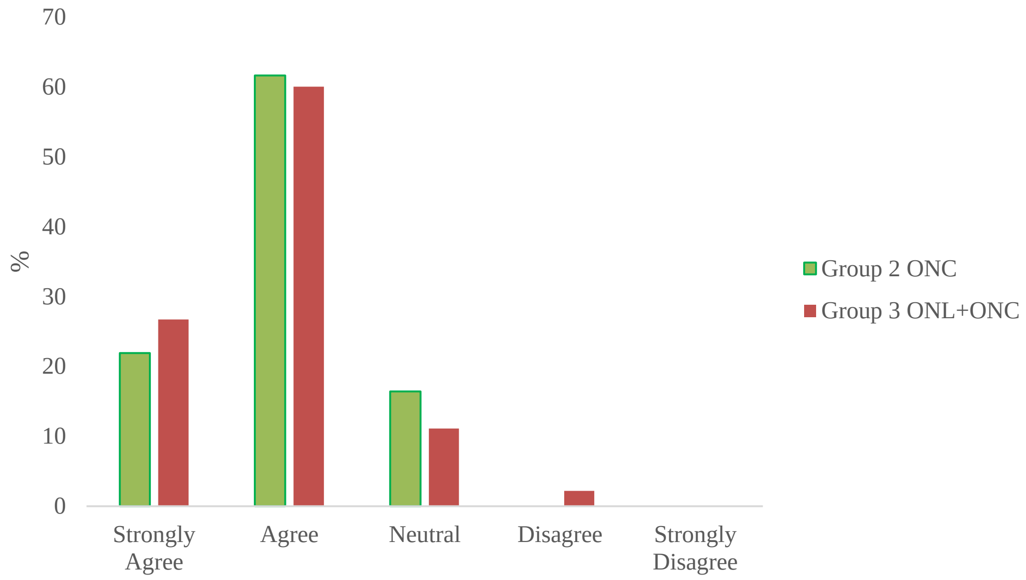


Figure 5.14. Participant responses in user perception survey to question 6b. *Video demonstration about using the actual IV pump was helpful;* ONC = On-Campus Group 2 (*n* = 73), ONL + ONC = Online + On-Campus Group 3 (*n* = 45).

On the question of whether sufficient time was allocated for the in-class education about the actual IV pump, opinion differed within the groups. Among Group 2 (ONC) only 2.7% of participants strongly agreed, 20.5 % agreed, and 20.5% were undecided, whereas 36.8% disagreed and 19.5% strongly disagreed that enough time was allocated, perhaps indicating a preference for face-to-face and “hands-on” time with equipment in the simulated laboratories. Responses from Group 3 (ONL + ONC) were similarly varied, with 6.7% strongly agreed, 20% agreed, 35.6% unsure, 26.7% disagreed, and 11% strongly disagreed (see Figure 5.15).

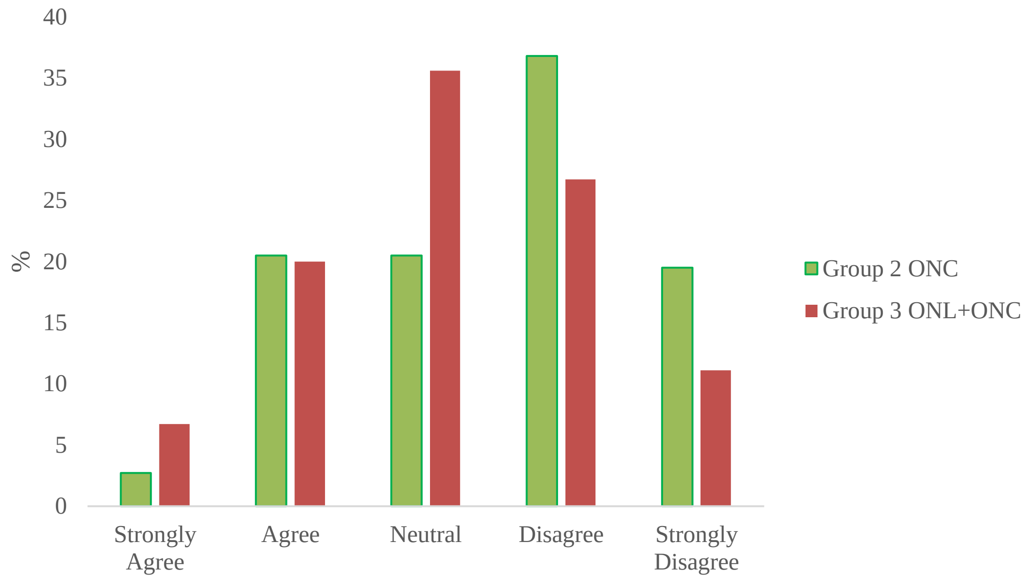


Figure 5.15. Participant responses in user perception survey to question 6c. *Enough time was allocated for instruction;* ONC = On-Campus Group 2 (*n* = 73), ONL + ONC = Online + On-Campus Group 3 (*n* = 45).

The time allocated for practice on the actual IV pump was perceived among the two groups as sufficient. From Group 2 (ONC), 27.4% strongly agreed, 42.5% agreed, 13.7% were undecided, and only 16.2% disagreed that enough time was allocated for practice. Similarly, from Group 3 (ONL + ONC), 15.6% of participants strongly agreed, 40% agreed, 24.4% were undecided, 17.8% disagreed, and 2.3% strongly disagreed that the two-hour class block was sufficient time to practice skills with the actual IV pump (see Figure 5.16).

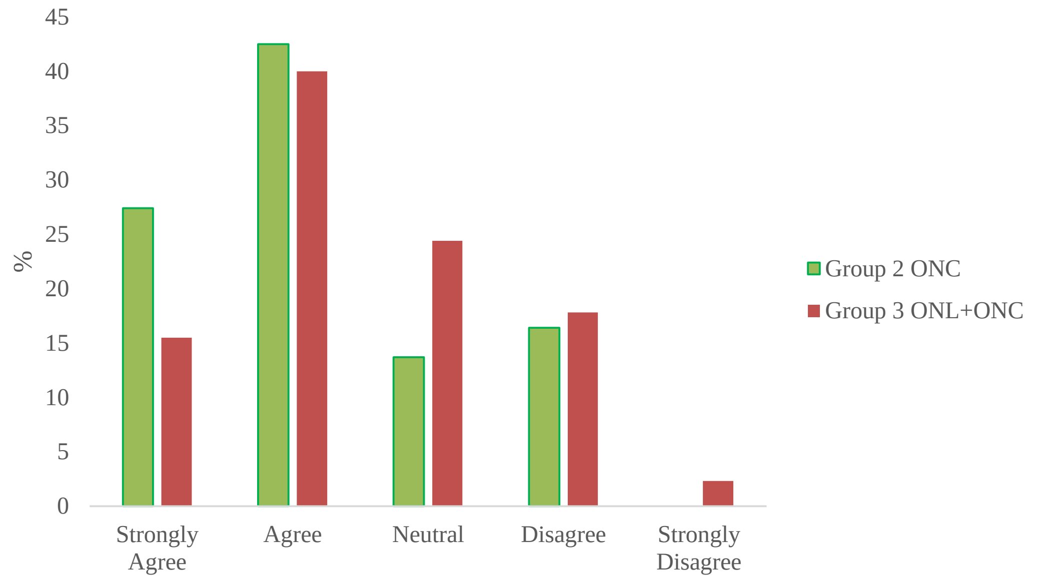


Figure 5.16. Participant responses in user perception survey to question 6d. *Enough time was allocated for practice;* ONC = On-Campus Group 2 (*n* = 73), ONL + ONC = Online + On-Campus Group 3 (*n* = 45).

Regardless of the responses about the education, instruction, training and time allocated to the actual IV pump, a large percentage of participants from both groups reported feeling confident using the actual IV pump. Group 3 (ONL + ONC) reported more confidence, with 80% either strongly agreed or agreed, compared to 61.7% of Group 2 (ONC) who either strongly agreed or agreed to feeling confident using the actual IV pump. A total of 27.4% of participants from Group 2 (ONC) felt neutral, whereas 9.6% disagreed and 1.4% strongly disagreed about feeling confident using the actual IV pump. From Group 3 (ONL + ONC), fewer participants were undecided (17.8%) and only 2.2% disagreed to feeling confident (see Figure 5.17).

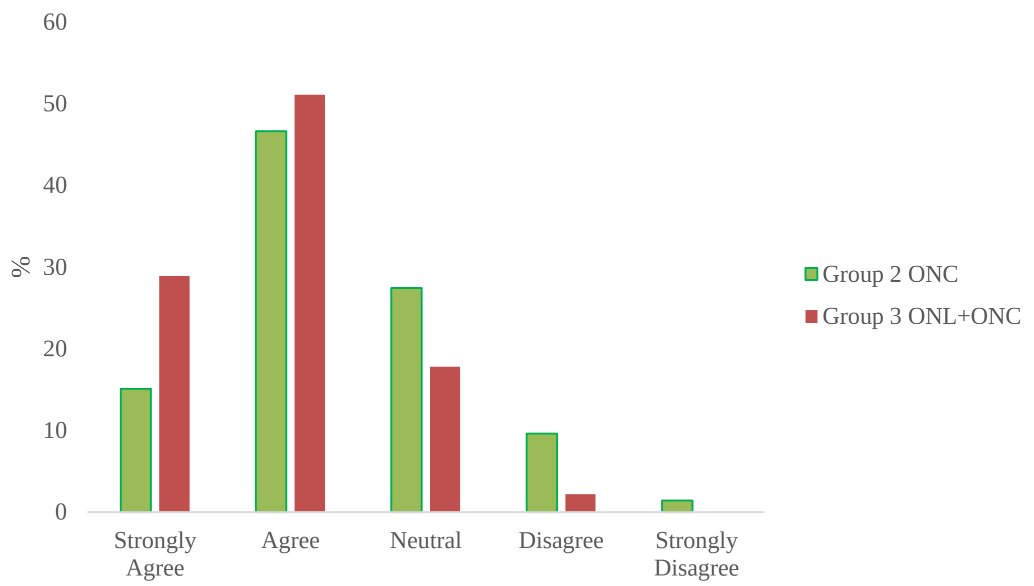


Figure 5.17. Participant responses in user perception survey to question 6e. *I feel confident using the actual IV pump;* ONC = On-Campus Group 2 (*n* = 73), ONL + ONC = Online + On-Campus Group 3 (*n* = 45).

Results of the qualitative analysis showed common themes, with many favourable thoughts about the online IVPE captured in the user perception survey. The themes that were identified were realistic features, convenience of access, and ease of use. Participants from Group 1 (ONL) and Group 3 (ONL+ ONC) were asked to indicate what they thought were the best features of the online IVPE. Eighty-two percent (*n* = 87) of participants from these groups responded, mostly about how realistic the features were and the likeness of the online IVPE to an actual IV pump. Other common themes included positive comments about accessibility and how easy it was to use.

From Group 1 (ONL), 27% of participants (*n* = 13) commented on the realistic features. This theme was supported with statements such as "*It's basically the same as the real thing," "strong features of the online IV pump is that it looks very similar to the actual pump and it makes the same sounds as well. The online IV pump is a great teaching tool," "It actually shows where everything is and sounds like a real pump."* Another participant added *"It exposes the external students on* *how the real IV pumps look like and how to operate it. It is very helpful to those who haven't seen it before, like me."* These were encouraging comments from a group who had only just used the actual IV pump for the first time in the assessment activities prior to completing the survey. Among Group 3 (ONL + ONC), a total of 68% of participants (*n* = 39) made a comment, of which nine commented about the realistic nature being the best feature of the online IVPE with statements such as "*Just like the real thing," "Virtually identical to pump,"* and that *"It was clear and easy to use and also very realistic."*

Another common theme throughout the content of statements was about the accessibility of the online IVPE. For example, from Group 1 (ONL) 21% of participants (*n* = 10) thought the best feature was having the ability to access the online IVPE from home. It was evident how accessibility for external students was so important and was obviously appreciated by them, with comments such as: "*Having an online pump to use anytime with scenarios," "It was very clear – good graphics and great to do it from home," "Real use of a pump at home. Good to use as external student and to brush up on skills,"* and *"Easy for the external students to practice online and got to use it before coming to residential school."* Group 3 (ONL + ONC) had 21% of participants (*n* = 8) who stated similarly "*The best feature about the IV pump was that I can use it whenever applicable*," "*We can do it anytime we are free*," and that it was "*easy to practice on, especially at home*."

There were a number of written comments made by participants in relation to the theme how easy the online IVPE was to use. This was certainly considered a favourable feature of the technology. From Group 1 (ONL), 21% of participants (*n* = 10) made these sorts of statements; "s*aves time and easy to practice*," "*best features were the well reproduced dials and easy to follow prompts,"* "*it was very* *clear*," "*the pump is a great learning tool – user-friendly*." Similarly, 21% of Group 3 (ONL + ONC) participants (*n* = 8) commented "*easy to practice on especially at home," "it was easy to use and colourful," "the instructions were easy to understand and helpful in lab,"* and that *"it was easy to work out the rate and run it."*

Some of the remaining positive comments referred to the actual functions and specific properties of the online IVPE such as the prompts, warning signals, sounds and alarms. The case study scenarios were favoured and the learning mode was mentioned as a helpful feature. These sorts of comments included "*great opportunity to learn especially via distance – well done!*" and simply "*great work,*" which was encouraging feedback.

When asked to indicate what features of the online IVPE could be improved, 66% of participants from Groups 1 and 3 combined (*n* = 70), responded with a written comment. Albeit brief, 57% of these comments (*n* = 40) were either, "*nothing*," "*none*," "*nil*," "*not sure*" or something to that effect. Among the other written comments, a common feature identified as in need of improvement related to including some function on how to load the IV tubing or giving set into the actual IV pump. Eleven percent (*n* = 8) felt it was worth mentioning as a possible improvement. Many participants had difficulty with that specific activity and, among the RAAT scores, it received the most number of zero points among all participants regardless of group membership, and often added considerably to completion time. Naturally, loading or inserting tubing is a feature of all physical infusion devices in health care delivery, but the online IVPE is not interactive technology *per se*, and the functions for use are either touch screen or mouse activated. This is discussed as a limitation of the online IVPE in Chapter 7, in the overall discussion and suggestions for future directions of the research.

The final question in the survey, asked of all participants regardless of group membership, related to greater use of online technologies for educating nursing students in the use of laboratory equipment. As shown in Figure 5.18, in Group 1 (ONL) 94.6% indicated "yes" and 5.4% indicated "no," in Group 2 (ONC) 87.7% indicated "yes" and 12.3% indicated "no," and in Group 3 (ONL + ONC) 93.3% indicated "yes" and 6.1% indicated "no." These responses showed overwhelming support among participants that online resources be used as a way of demonstrating laboratory equipment in a nursing program. It was interesting to note that more participants in the groups who had access to the online IVPE (Group 1, ONL and Group 3, ONL + ONC), responded positively to the notion of future online resources than Group 2 (ONC) participants, who had no access to the online IVPE.

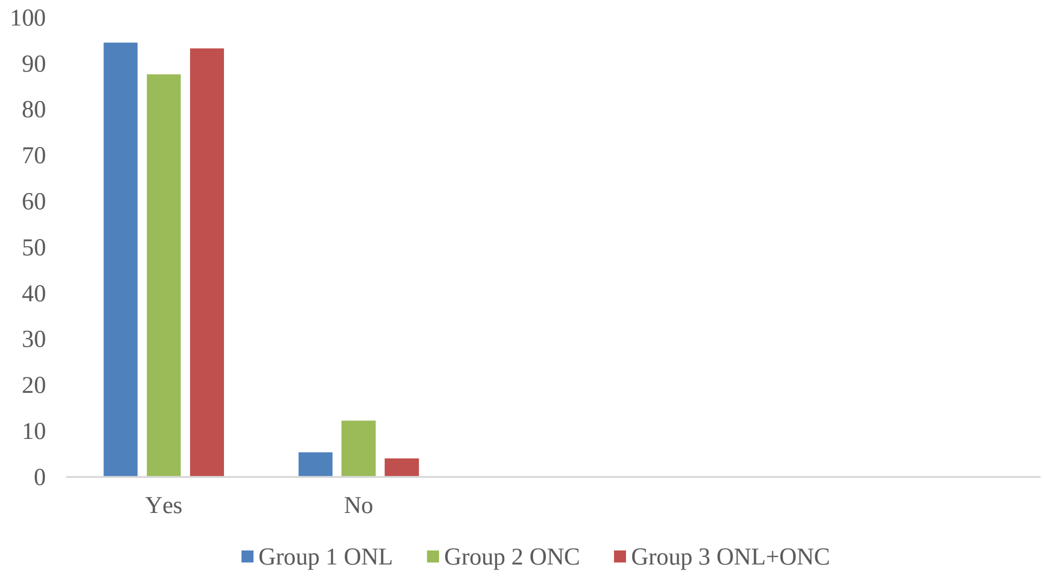


Figure 5.18. Participant responses in user perception survey to question 7. *Would you like to see greater use of online technologies for educating nursing students in the use of laboratory equipment*? ONL = Online Group 1 (*n* = 54), ONC = On-Campus Group 2 (*n* = 73), ONL + ONC = Online + On-Campus Group 3 (*n* = 45).

5.5 Summary of Stage 3

In summary, the results from Stage 3 suggested on a number of fronts that the online IVPE could be considered equivalent, or as good as the real thing, when it comes to simulated training on clinical equipment for nursing students. This was confirmed in the results whereby, in support of H0, there was no significant difference in the assessment score achieved on the RAAT between Group 1 (ONL) and Group 2 (ONC).

What was particularly evident from the results, was that use of the online IVPE in addition to the actual IV pump appeared to improve performance in using an actual IV pump. In support of H1 and H2, not only did the combined group score significantly better but finished the activities significantly faster than the other two groups. Superior performance from Group 3 (ONL + ONC) was evident across a number of activities. For example, Activity 1B (turning on the actual IV pump) and Activities 1D and 1E (setting the rate and volume to be infused) which indicates that using a combination of technologies has benefits for student learning. This supports the concept of blended learning as a mode of delivery in health disciplines. Furthermore, it supports the notion that the training of some clinical skills can be transferred from the hands-on simulated laboratories to the computer screen.

The positive results achieved in this stage of the research support the introduction of online education technologies for nursing students, and support the notion that the development of additional online technologies should be a consideration for the future. It is uncertain, however, whether the competence necessary for operating an actual IV pump is likely to be retained from one semester to the next semester of study. Stage 4 investigated the retention of clinical skills acquired by nursing students after an extended break from the classroom.

Chapter 6

Stage 4 – Competency Retention Evaluation

6.1 Introduction

Stage 4 was the final stage of the research and evaluated the retention of competency using the actual IV pump with the same group of participants recruited in Stage 3. Stage 4 was conducted in the subsequent semester to Stage 3, approximately 26 weeks later. Academics, clinicians and nursing students alike often comment that students appear to retain little in the way of laboratory equipment competency and confidence when subjected to an extended break from practice. Having the online IVPE available for use throughout the period of time when no face-to-face classes are offered, such as between Semester 2 of one year and Semester 1 of the following year, would provide a practical solution to this perceived problem. Such a scenario would offer a great advantage for nursing students, who could continue to practice with the online technology and so maintain their skill and levels of confidence in using clinical equipment.

Stage 4 was designed to assess between-group differences in relation to the retention of knowledge and competence in using an actual IV pump. More specifically, the aim of Stage 4 was to establish whether the group of participants instructed on both forms of IV pump technology retained greater knowledge and competency during a 26-week break from classes. Such evidence would add strength to the notion that using an online IV pump, in addition to the traditional teaching and learning on an actual IV pump in a simulated laboratory, produces more enduringly competent, and therefore potentially safer, graduates entering the nursing profession.

6.2 Aims and Hypotheses

The aims for Stage 4 were to establish and evaluate the retention of competency using the actual IV pump among the same sample of nursing students recruited in Stage 3, one semester later. Specifically, to determine on which form of technology, or a combination of both, did participants achieve better learning outcomes after 26 weeks of no exposure to the equipment. The learning outcomes of participants were operationalised in terms of the activity assessment scores that reflected their competence using the actual IV pump. The same assessment tool, the RAAT, along with other methods previously described, were again used for the purposes of Stage 4. The hypotheses tested for Stage 4 were:

H0: There will be no significant differences in assessment scores at the 26-week follow-up between Group 1 (ONL) and Group 2 (ONC);

H1: Participants in Group 3 (ONL + ONC) will demonstrate significantly better retention of competence, as assessed by RAAT, than Group 1 (ONL) and Group 2 (ONC) participants in a 26-week follow-up assessment;

H2: There will be a significant inverse relationship between assessment completion time and assessment scores, whereby participants who complete the assessment faster will tend to score higher.

6.3 Methods

Level of competence among the participants from Stage 3 who used the online IVPE, an actual IV pump or a combination of the two were assessed via a series of activities performed on the actual IV pump, using the same quasi-experimental design. This stage of the research can be referred to as the longitudinal component of the research (Nagy et al., 2010), meaning that the intervention had been administered in the previous stage (Stage 3), so the same variables were measured in the same way as they were in the previous stage, following a pre-determined period of time, to test for changes to learning outcomes.

The same three participant groups were maintained for Stage 4. Group 2 (ONC), the control group, received the traditional educational in-class, face-to-face training on an actual IV pump. Group 1 (ONL) and Group 3 (ONL + ONC) received the intervention, training on the online IVPE. A statistical comparison was made of the learning outcomes between the groups after the extended and pre-determined period of time (see Figure 6.1).

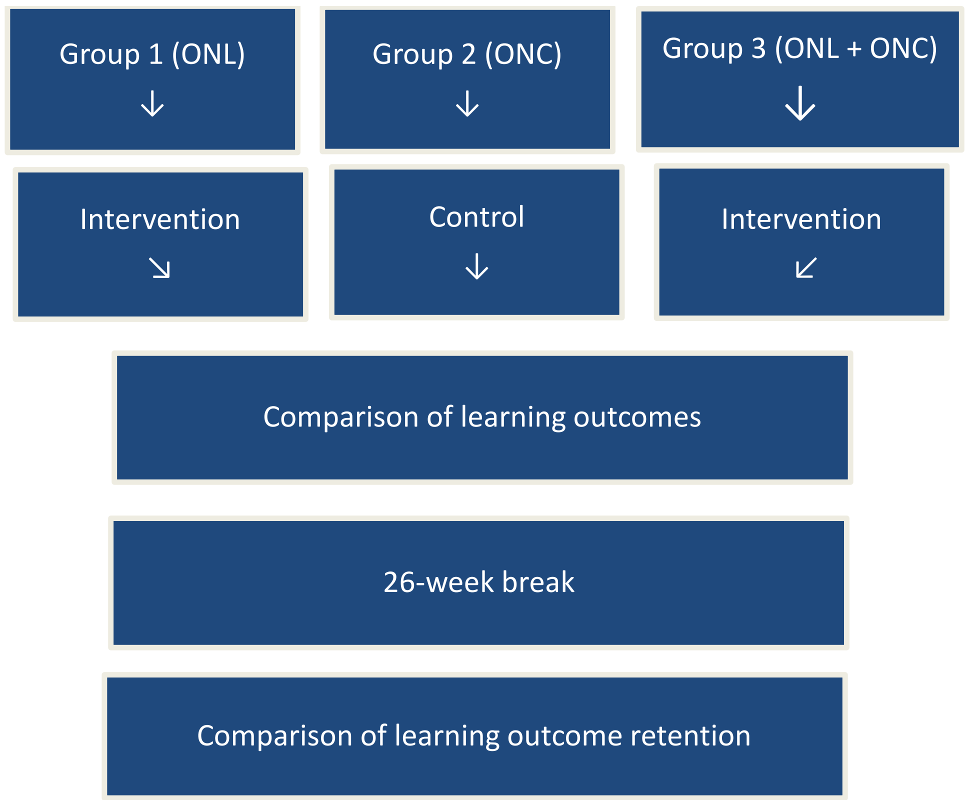


Figure 6.1. Research design for stage 4.

Outcome measures were assessed using the same direct method of assessment, the OSCE, which provided a measure of level of competence by observing participants' use of the actual IV pump. There were no changes in the tools or procedures in the methodology for Stage 4, other than the period of time when the assessment occurred and the exclusion of the user perception survey. The RAAT, the clinical assessors, and the assessment criteria were unchanged for this stage of the research. The assessment activities for all participants were conducted in Week 1 of the following semester. This was to prevent exposure to any forms of the IV pump technology in the simulated nursing laboratories after the semester was underway.

6.3.1 Participants. Participants for Stage 4 were recruited from the same sample of nursing students used in Stage 3 and group membership was retained. Not all participants from Stage 3 progressed through to the next course of study, which was a slightly more complex simulated laboratory course within the undergraduate nursing program. Some participants either did not pass the medications course from the previous semester or chose a non-standard progression through the program and were not present at the time of assessment. Participants for Stage 4 were 102 nursing students, who completed all assessment activities. Final group numbers were:

Group 1: online only (ONL, n = 34)

Group 2: on-campus only (ONC, n = 38)

Group 3: online and on-campus (ONL + ONC, n = 30)

The sample for this stage included 13 male and 89 female students. Participants were grouped by age: 18–24 yr. (n = 57), 25–34 yr. (n = 31), and 35–44 yr. (n = 14). There were 40 international students and 62 domestic students included in this sample.

Although no access to actual IV pumps or the online IVPE was provided during the 26-week retention period, some participants had been on clinical placement during the retention period and had been exposed to actual IV pumps, creating a potential confounding variable. Participants who had been on a clinical placement during the retention period (*n* = 21) and those who had exposure to actual IV pumps during the placement (*n* = 18) were evenly distributed among the three groups, reducing any confounding impact. This potential confound will be addressed further later in the chapter (see Table 6.11).

6.3.2 Assessment of Competence. The direct measure for this evaluation of competency retention involved establishing the learning outcomes for groups of nursing students performing the standardised set of activities on an actual IV pump. Participants were observed performing the activities from the RAAT, which were same set of activities that had been performed previously by each participant. Learning outcome assessment activities on the actual IV pump, the assessors, and the assessment marking criteria remained the same as in Stage 3. The user perception data in relation to the education and training, best features, improvements, and level of confidence using the technologies was already analysed, and therefore this measure was not repeated in Stage 4.

Most participants had no access or exposure to actual IV pumps and no participants had exposure to the online IVPE between their initial assessment in Stage 3 and the 26-week follow-up assessment for Stage 4. A check on the LMS for the course, *Medications, Theory and Practice,* confirmed that no participant had accessed teaching material pertaining to the IV pump during the retention period.

The activities on the RAAT directly reflected the teaching and learning objectives in the course material from the previous semester. All participants were assessed on their retained level of competence with an actual IV pump using the OSCE method. Three of the four assessors from the previous stage were used in this final stage of research (all still independent university academics and blind to group membership). Using the same assessors in this stage ensured consistency with the

OSCE method and the use of the marking criteria from one stage to the next. Adequate inter-rater reliability between the assessors had been demonstrated in Stage 3 of the research.

Assessment of competence on the actual IV pump again required participants from each group to perform the activities from the RAAT. A documented medical order was provided for the participants. The standardised set of activities on the RAAT were presented in a sequential step-by-step process as if preparing an IV infusion for a patient: Activity 1(a) Select 1000mL sodium chloride and check the order provided, 1(b) Turn on the IV pump, 1(c) Load the IV giving set into the IV pump, 1(d) Set the rate at 83mL, 1(e) Set the volume to be infused (VTBI), and 1(f) Start the infusion. Activity 2 asked the participants to list the six rights followed by Activities 3 and 4 which required participants to program into the actual IV pump a variety of rates and volumes from the problem-based medication calculations using the formula that had been taught in the IV pump module in the previous semester. The final activity (5) was to switch off the IV pump. Level of competency for each activity was scored on a numerical Likert-type scale and included a legend of descriptions and behaviours matching performance. The same marking criteria from Stage 3 was provided to the assessors for this Stage of research.

6.3.3 Procedure. To aid in participant retention in this final stage of research, reminders about the follow-up assessment were presented on the course LMS just prior to the beginning of semester, 26 weeks after the initial assessment on the actual IV pumps. Most participants had progressed through to the next simulated laboratory course. Participation, as per the information for participants and participant consent form from Stage 3 (see Appendix L) was retained for this next stage.

A small number of participants from Stage 3 had enrolled and completed a practical or clinical placement between semesters during the 26-week break. Of these participants, some had exposure to actual IV pumps during their care of patients in health care settings. On the other hand, some had no IV pump exposure as they were working in either community or aged care environments. All of these participants were easily identified, and were invited to complete the final assessment, and whether or not they were exposed to IV pumps was recorded. This was a consideration and is reported in the results section.

In the first week of semester no information about IV pumps or the online IVPE was provided on the course LMS sites. The assessment activities for the participants, regardless of mode of delivery of training, occurred in the first week of the semester. In the assessment week for Stage 4, all forms of the IV pump were removed from the laboratory classrooms, including the online IVPE program from computer desktops.

Participants from Group 1 (ONL), Group 2 (ONC) and Group 3 (ONL + ONC) completed identical assessment activities (listed on the RAAT), on the same actual IV pump, based on what they had learnt 26 weeks previously. Assessments were again scheduled to take approximately 15 - 20 min for each participant, which was the average time achieved in Stage 3. The OSCE assessments measuring the level of competence retained on the actual IV pump were conducted during class time in the simulated nursing laboratory classes for all participants present from Group 2 (ONC) and Group 3 (ONL + ONC). Group 1 (ONL) participants, from the external cohort, were assessed during their residential school, which occurred approximately 26 weeks after their initial assessment during residential school for the previous semester.

The OSCE assessors had access to the list of participants from Stage 3 and arrangements were made to locate them during class time. Participants were called out from their laboratory classes individually to perform the activities listed on the RAAT with the actual IV pump. The assessors were instructed not to communicate or assist the participant's performance in any way, other than allowing the participant to move onto the next activity if there was evidence of inability to preform to activity, at which point the score allocated was 0. Start and completion time were recorded and the maximum total number of points for all activities totalled 80 points.

Following completion of the RAAT, assessors recorded whether each participant had been on a clinical placement during the 26-week retention period and, if so, whether they had any exposure to an IV pump. Assessors reported that most participants were anxious about the extended period of time since they had used an actual IV pump. The assessors reassured participants that their performance, time taken, and scores achieved would not be reflected in any way in their grades for the course. Once data collection was completed after Stage 4, all participants were invited to use the online IVPE, both online from home and on the computer systems situated in the simulated nursing laboratories.

6.3.4 Data Analysis. Comparison of assessment scores between Group 1 (ONL) and Group 2 (ONC) determined whether instruction using the online IVPE was equivalent to traditional in-class instruction for retention of competence in the use of the actual IV pump 26 weeks following the cessation of practice. Once again, Group 3 (ONL + ONC) was included to address the question of whether using the online IVPE in addition to in-class instruction on the actual IV pump was associated with superior retention of competence 26 weeks later.

For the quantitative analysis, the dependent variables were the RAAT total scores, participant practice time, and completion time. The independent variable of group membership was the same as in Stage 3: Group 1 (ONC), Group 2 (ONL), and Group 3 (ONC + ONL). Descriptive statistics for the three groups were calculated and between-group comparisons were conducted using single-factor ANOVA and Tukey post-hoc comparison tests. The effects of gender (male, female), age group (18–24 yr., 25–34 yr., 35–44 yr.), and residency (domestic, international) on retention of knowledge were tested using the same inferential tests. A between-group comparison between participants who had exposure to IV pumps during the 26-week break compared to those who had no exposure, was also conducted. Pearson correlation analysis was used to test relationships among the dependent variables. Probability analyses were augmented with calculation of effect sizes using Cohen's d, where 0.2 represents a small effect, 0.5 a moderate effect, and 0.8 a large effect. As no user perception surveys were administered, analysis of qualitative was not applicable in this stage.

6.5 Results

Prior to analysis, the dataset was checked for missing and out-of-range values and necessary corrections were made. The normality of the data was checked prior to group comparisons being made. Scores on the RAAT ranged from 20–78 (M = 67.9, SD = 8.4). Although the distribution of scores showed slight skewness towards the upper end of the scale, as was the case in Stage 3, this deviation from a normal distribution was not significant (see Figure 6.2). Time to completion ranged from 114–1380 sec. Completion times were normally distributed (see Figure 6.3).
All assumptions underlying the statistical procedures used were confirmed prior to analyses being conducted.

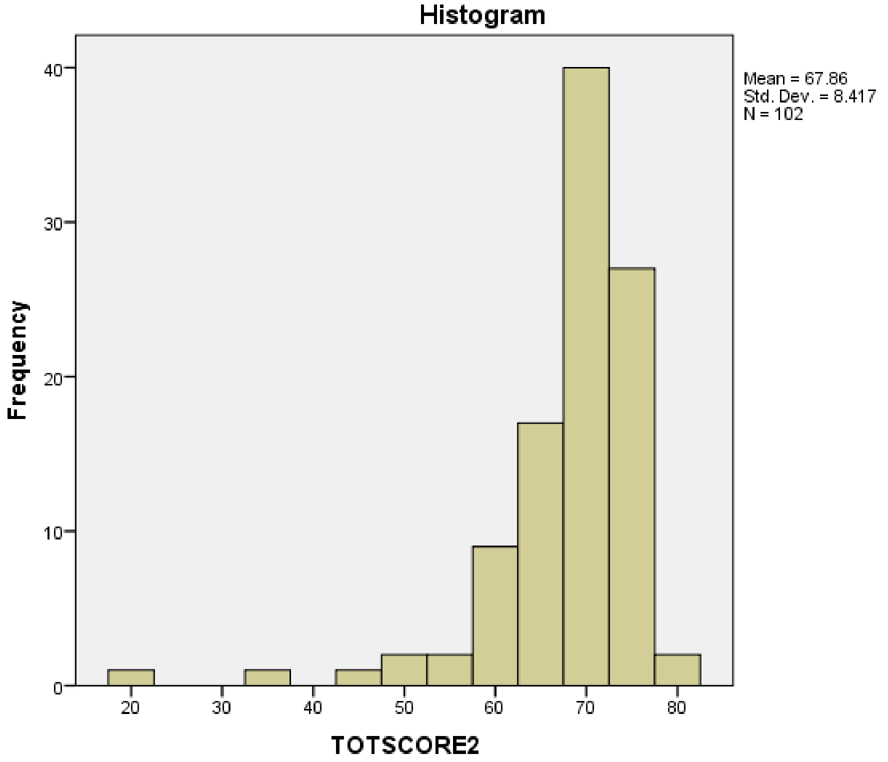


Figure 6.2. Histogram showing distribution of RAAT scores among 102 participants.

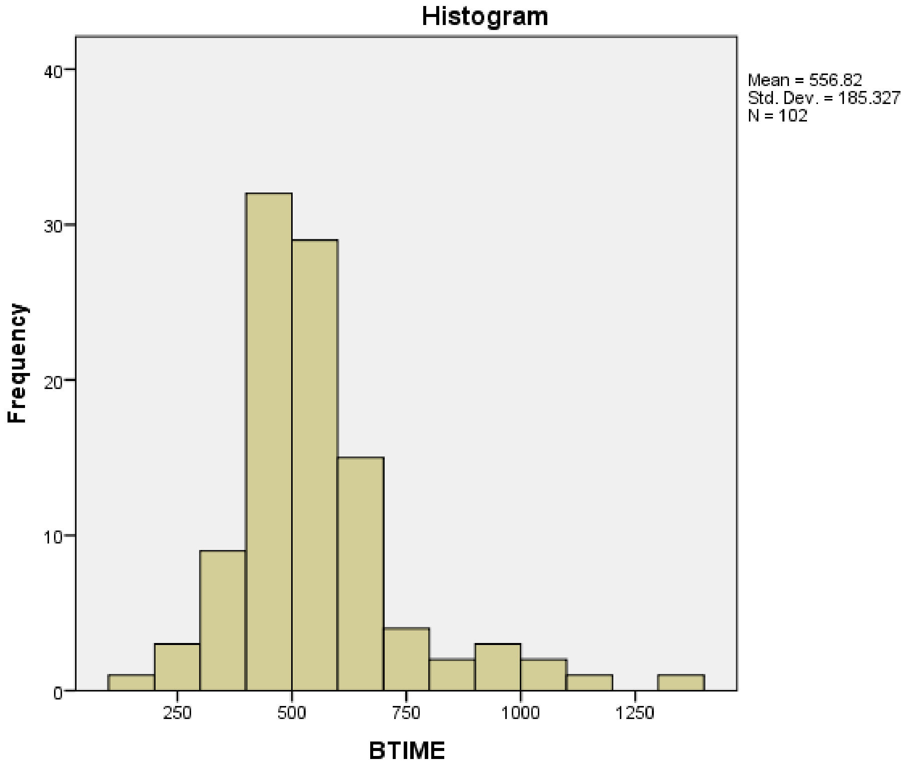


Figure 6.3. Histogram showing time to completion among 102 participants.

Comparison of RAAT scores between Group 1 (ONL) and Group 2 (ONC) determined whether instruction using the online IVPE was equivalent to traditional in-class instruction for preparing the students in the use of the actual IV pump after 26 weeks of no exposure to IV pump technology. It was hypothesised (H0) that there would be no significant difference in learning outcomes of these two groups after an extended period of time. It was also hypothesised (H1) that Group 3 (ONL + ONC) participants would perform significantly better than Group 1 (ONL) and Group 2 (ONC) in assessment scores after the 26-week break.

The results from Stage 4 showed no significant between-group differences for assessment scores, although the trend was the same as for Stage 3, with Group 3 (ONL + ONC) performing best and Group 2 (ONC) performing worst (see Table 6.1). Although between-group differences in RAAT scores were not significant, a meaningful difference of moderate magnitude (d = .55) was shown between Group 3 (ONL + ONC) and Group 2 (ONC). Group 1 (ONL) performed better than Group 2 (ONC) but not significantly so, although the effect size was small-to-moderate (d = .37). This supported H0, demonstrating that the retention of competence in using the actual IV pump having trained on an online IVPE was just as effective (in fact, somewhat more effective) as having trained in the traditional face-to-face manner.

The results also showed that Group 3 (ONL + ONC) completed the assessment activities significantly faster than Group 1 (ONL) and Group 2 (ONC; see Table 6.1). Consistent with H2, a highly significant inverse relationship was found between time to completion and assessment score ($r = .77$, $p < .001$), indicating that participants who performed best on the RAAT tended to complete the assessment faster, whereas those who performed more poorly tended to take longer to complete the assessment. Group 2 (ONC) participants generally took longer to complete the assessment activities than the other two groups and also scored the least number of total points on the RAAT. Despite this trend, it is interesting to note that participants in Group 2 (ONC) showed improvement in RAAT performance overall from Stage 3 to Stage 4 (see Figure 6.4). In fact, all groups showed at least marginal improvement in competency from Stage 3 to Stage 4, despite the 26-week period of no exposure to the IV pump technologies. The scale of improvement did not differ significantly between groups.

Table 6.1

IV Pump Statistics by Training Group (N = 102)

Variable	Group	*M*	*SD*	$F_{2,17}$	*d*	Sig. Group Differences
Assessment Score	ONL	68.7	5.9	2.77	0.37 0.24	N.S.
	ONC	65.5	11.5		0.55 0.37	N.S.
	ONL + ONC	70.0	5.0		0.55 0.24	N.S.
Completion Time (sec)	ONL	568.9	136.6	8.55***	0.82	ONL>ONL + ONC
	ONC	627.2	216.8		0.96	ONC>ONL + ONC
	ONL + ONC	454.0	144.2		0.82	ONL + ONC<ONL
					0.96	ONL + ONC<ONC

Note. Maximum Assessment Score = 80; ONL = Online group (*n* = 34), ONC = On-Campus group (*n* = 38), ONL + ONC = Online + On-Campus (*n* = 30); N.S. = Non-Significant; *** $p < .001$.

Figure 6.4. Longitudinal analysis of RAAT scores over time for three training groups.

In Stage 4, as for Stage 3, no significant between-group differences in total assessment scores or time to completion were found for age group (see Table 6.2) or gender (see Table 6.3). However, results showed that across the three groups as a whole, domestic students scored significantly higher in the RAAT during this retention study compared to international students (see Table 6.4). Domestic students were significantly over-represented in Group 1 (ONL) and under-represented in Group 3 (ONL + ONC; $\chi^2 = 6.15$, $p < .05$), even though participants had been randomly allocated to groups in Stage 3 and group membership remained the same for Stage 4. The under-representation of higher-performing domestic students in Group 3 (ONL + ONC) suggests that the observed benefit to competence of training on both an actual IV pump and an online IVPE may be an underestimate of the true benefit.

Table 6.2

IV Pump Statistics by Age Group (N = 102)

Variable	Age Group (yr)	*n*	*M*	*SD*	$F_{2,176}$	*p*
Assessment Score	18-24	57	67.9	8.9	0.84	N.S.
	25-34	31	68.2	7.9		
	35-44	14	67.1	2.1		
Completion Time (sec)	18-24	57	546.3	197.8	0.34	N.S.
	25-34	31	560.7	185.0		
	35-44	14	556.8	132.4		

Note. Maximum Assessment Score = 80; N.S. = Non-Significant.

Table 6.3

IV Pump Statistics by Gender (N = 102)

Variable	Gender	*n*	*M*	*SD*	$F_{2,176}$	*p*
Assessment Score	Female	89	68.0	7.2	0.16	N.S.
	Male	13	67.0	14.7		
Completion Time (sec)	Female	89	554.3	172.8	0.13	N.S.
	Male	13	574.3	264.0		

Note. Maximum Assessment Score = 80; N.S. = Non-Significant.

Table 6.4

IV Pump Statistics by Residency Status (N = 102)

Variable	Residency	*n*	*M*	*SD*	$F_{2,176}$	*d*
Assessment Score	Domestic	62	69.4	6.0	5.17*	0.45
	International	40	65.6	10.9		
Completion Time (sec)	Domestic	62	529.8	155.8	3.50	0.37
	International	40	598.8	219.1		

Note. Maximum Assessment Score = 80; *$p < .05$.

To gain a more detailed picture of between-group differences in retention of competence over time, it was necessary to look in detail at each specific activity. Activity 1 (B1) was comprised of six tasks, labelled B1A–B1F (see Table 6.5). After checking that the chosen IV fluid corresponded with the medication order, the next five tasks were concerned with physically handling and programming the actual IV pump. There were no significant differences between groups on four of the six tasks in Stage 4. There was, however, a significant group difference in Activity B1C. When asked to load the IV giving set into the actual IV pump, Group 3 (ONL + ONC) out-performed Group 2 (ONC) with this task. In Activity B1E, Group 1 (ONL) and Group 3 (ONL + ONC) performed this task significantly better than Group 2 (ONC) meaning that participants who used the online IVPE scored higher when setting the VTBI (see Table 6.5).

Activity 2 (BA2) required participants to recall the “6 Rights” which showed no significant group differences, meaning that all groups performed equally well on this task (see Table 6.6). Activity 3 (see Tables 6.7, 6.8) and Activity 4 (see Table 6.9), which required participants to perform medication calculations with IV fluid rates and then program the actual IV pump, also showed no significant between-group differences. The final task on the RAAT (B5), turning off the IV pump, showed no significant between-group differences, meaning that all groups performed this task with the same level of competence (see Table 6.10).

Table 6.5

RAAT Activity B1 Scores by Training Group (N = 102)

Variable	Group	*M*	*SD*	$F_{2,176}$	*d*	Sig. Group Differences
B1A	ONL	2.1	1.9	1.34		N.S.
	ONC	1.8	1.8			N.S.
	ONL + ONC	1.4	1.7			N.S.
B1B	ONL	3.4	0.9	2.69		N.S.
	ONC	3.2	1.0			N.S.
	ONL + ONC	3.7	0.5			N.S.
B1C	ONL	1.7	1.3	3.80**		
	ONC	1.6	1.4		0.69	ONC<ONL + ONC
	ONL + ONC	2.5	1.2		0.69	ONL + ONC>ONC
B1D	ONL	3.7	0.4	2.08		N.S.
	ONC	3.4	1.2			N.S.
	ONL + ONC	3.7	0.5			N.S.
B1E	ONL	3.7	0.6	4.66**	0.50	ONL>ONC
	ONC	3.2	1.4		0.52	ONC<ONL + ONC
					0.50	ONC<ONL
	ONL + ONC	3.7	0.5		0.52	ONL + ONC>ONC
B1F	ONL	2.4	1.1	1.71		N.S.
	ONC	2.6	1.2			N.S.
	ONL + ONC	2.9	0.7			N.S.

Note. B1A=Select 1000mL Sodium Chloride & Check An Order; B1B=Turn On The IV Pump; B1C=Load The IV Giving Set Into The IV Pump; B1D=Set The Rate At 83mL/Hr; B1E=Set The Volume To Be Infused (VTBI); B1F=Start The Infusion. ONL = Online Group 1 (*n* =34), ONC = On-Campus Group 2 (*n* = 38), ONL + ONC = Online + On-Campus Group 3 (*n* =30); N.S. = Non-Significant;** $p < .01$. Only significant *d*-values are reported.

Table 6.6

RAAT Activity B2 Scores by Training Group (N = 102)

Variable	Group	*M*	*SD*	$F_{2,176}$	*p*
BA2	ONL	5.6	0.8	2.76	N.S.
	ONC	5.3	0.6		N.S
	ONL + ONC	5.9	0.3		N.S.

Note. B2= Say The 6 Rights. ONL = Online Group 1 (*n* =34), ONC = On-Campus Group 2 (*n* = 38), ONL + ONC = Online + On-Campus Group 3 (*n* =30); N.S. = Non-Significant.

Table 6.7

RAAT Activity B3A Scores by Training Group (N = 102)

Variable	Group	*M*	*SD*	$F_{2,176}$	*p*
B3A1	ONL	3.4	1.1	0.10	N.S.
	ONC	3.3	0.9		N.S.
	ONL + ONC	3.3	1.0		N.S.
B3A2	ONL	3.5	0.9	0.20	N.S.
	ONC	3.3	1.1		N.S.
	ONL + ONC	3.7	0.8		N.S.
B3A3	ONL	3.9	0.6	.05	N.S.
	ONC	3.8	0.7		N.S.
	ONL + ONC	3.9	0.3		N.S.
B3A4	ONL	3.4	0.7	0.71	N.S.
	ONC	3.4	0.8		N.S.
	ONL + ONC	3.5	0.7		N.S.

Note. 3B1=Medication Calculation Infuse 1000mL Sodium Chloride over 24 Hours; 3B2=Set The Rate; 3B3=Set The VTBI; 3B4= Start The Pump. ONL = Online Group 1 (*n* =34), ONC = On-Campus Group 2 (*n* = 38, ONL + ONC = Online + On-Campus Group 3 (*n* =30); N.S. = Non-Significant.

Table 6.8

RAAT Activity B3B Scores by Training Group (N = 102)

Variable	Group	*M*	*SD*	$F_{2,176}$	*d*	*p*
B3B1	ONL	3.8	0.7	0.61		N.S.
	ONC	3.7	0.8			N.S.
	ONL +ONC	3.8	0.5			N.S.
B3B2	ONL	3.8	0.4	0.34		N.S.
	ONC	3.6	0.9			N.S.
	ONL + ONC	3.7	0.8			N.S.
B3B3	ONL	3.9	0.6	0.77		N.S.
	ONC	3.8	0.7			N.S.
	ONL + ONC	3.9	0.3			N.S.
B3B4	ONL	3.4	0.7	0.55		N.S.
	ONC	3.4	0.8			N.S.
	ONL + ONC	3.5	0.5			N.S.

Note. 3B1=Medication Calculation Infuse 1000mL Sodium Chloride over 6 Hours; 3B2=Set The Rate; 3B3=Set The VTBI; 3B4= Start The Pump. ONL = Online Group 1 (*n* =34), ONC = On-Campus Group 2 (*n* = 38), ONL + ONC = Online + On-Campus Group 3 (*n* =30); N.S. = Non-Significant. Only significant *d*-values are reported.

Table 6.9

RAAT Activity B4 Scores by Training Group (N = 102)

Variable	Group	*M*	*SD*	$F_{2,176}$	*d*	*p*
4B1	ONL	3.8	1.0	1.15		N.S.
	ONC	3.5	1.2			N.S.
	ONL +ONC	3.7	1.0			N.S.
4B2	ONL	3.9	0.7	3.42		N.S.
						N.S.
	ONC	3.4	1.3			
	ONL +ONC	3.9	0.3			N.S.
4B3	ONL	3.6	1.2	0.52		N.S.
	ONC	3.3	1.4			N.S.
	ONL +ONC	3.6	1.1			N.S.
4B4	ONL	3.5	0.5	1.70		N.S.
	ONC	3.4	0.9			N.S.
	ONL +ONC	3.7	0.7			N.S.

Note. 4B1 = Medication Calculation Infuse 500mL Sodium Chloride over 2 Hours; 4B2 = Set Rate; 4B3 = Set VTBI; 4B4 = Start IV Pump. ONL = Online Group 1 (*n* =34), ONC = On-Campus Group 2 (*n* =38), ONL + ONC = Online + On-Campus Group 3 (*n* =30); N.S.= Non-Significant. Only significant *d*-values are reported.

Table 6.10

RAAT Activity B5 Scores by Training Group (N = 102)

Variable	Group	*M*	*SD*	$F_{2,176}$	*d*	*p*
B5	ONL	2.0	0.2	0.9		N.S.
	ONC	1.0	0.4			N.S.
	ONL + ONC	2.0	0.2			N.S.

Note. B5= Turn Off The IV Pump. ONL = Online Group 1 (*n* =34), ONC = On-Campus Group 2 (*n* =38), ONL + ONC = Online + On-Campus Group 3 (*n* =30); N.S.= Non-Significant. Only significant *d*-values are reported.

As mentioned previously, some participants (*n* = 21) had been on clinical placement in a health care facility between Stage 3 and Stage 4, which had the potential to bias the results had they been using the same IV pump on which their competence was to be re-assessed. Of these participants, 18 had exposure in one form or another to an infusion device, either observing or physically using an actual IV pump, although it was clarified that none had observed or used pumps that were the same as those used in the simulated laboratories on campus. Notably, these 18 participants were spread almost equally among the three groups. In Group 1 (ONL), six participants had seen or used actual IV pumps on placements, in Group 2 (ONC) seven participants had done so, and in Group 3 (ONL + ONC) five had some exposure to actual IV pumps, during the 26week break between Stage 3 and Stage 4. This distribution suggests that any effect of exposure to infusion devices on clinical placement would not have influenced one group more than the others. As shown in Table 6.11, there was no significant between-group differences in RAAT scores among those who had used an IV pump during the retention period. The results in Table 6.12 show that those participants who had used an IV pump during the retention period, regardless of group membership, performed significantly better on the RAAT than all other participants who were not exposed to IV pump technology (see Table 6.12). This was a logical finding and one that did not affect the overall comparison of the online IVPE and actual IV pump. Rather than being perceived as a limitation of the present research, instead this finding supports the benefit of clinical experience in the "real world."

Table 6.11

Participants Exposed to IV Pumps during 26 Week Break (n = 18)

Variable	Group	*n*	*M*	*SD*	$F_{2,15}$	*p*
Assessment Score	ONL	6	73.3	2.6	2.2	N.S.
	ONC	7	71.4	4.1		
	ONL + ONC	5	75.4	1.5		

Note. Maximum Assessment Score = 80; ONL = Online Group 1 (*n* = 6), ONC = On-Campus Group 2 (*n* = 7), ONL + ONC = Online + On-Campus Group 3 (*n* = 5); N.S. = Non-Significant.

Table 6.12

RAAT Scores for Participants Exposed to (n = 18) and Not Exposed to IV Pumps during 26 Week Break

Variable	Group	*n*	*M*	*SD*	$F_{2,100}$	*p*
Assessment Score	Pump	18	73.1	3.3	4.1	.003
	No Pump	84	66.7	8.8		

Note. Maximum Assessment Score = 80

6.6 Summary of Stage 4

Compared to previous stages of the research, there were relatively few statistically significant between-group differences found in Stage 4. In support of H0, there was no significant differences in assessment scores at the 26-week follow-up between Group 1 (ONL) and Group 2 (ONC), pointing to the equivalence of training on the online IVPE compared to traditional training using an actual IV pump. H1 was not supported, in that overall assessment scores of Group 3 (ONL + ONC) were not significantly higher than the other two groups. It should be noted, however, that the combined group were the best performers on the RAAT and showed a moderate effect size over Group 2 (ONC; d = 0.55) and a small effect size over Group 1 (ONL; d = 0.24). The better performance of Group 3 (ONL + ONC) was particularly evident in Activity B1C (loading the IV giving set into the IV pump) and Activity B1E (setting the volume to be infused).

In support of H2, a significant inverse relationship was found between time to completion and assessment score (r = .77, p < .001), confirming that participants who performed best on the RAAT completed the assessment faster, and those who performed poorly tended to take longer to complete the assessment. Group 2 (ONC) participants generally took longer to complete the assessment activities than the other two groups. It is very encouraging for nurse educators that the participants demonstrated excellent retention of knowledge and skill from one semester to the next. Indeed, all groups scored at least marginally better in Stage 4 than they had in Stage 3.

With quasi-experimental designs, the limited control over participants raises the possibility of potential confounding variables. In Stage 4, it was not possible to prevent all participants from gaining some exposure to IV pump technology during the 26-week retention period. Before the research commenced, careful planning of the research design and data collection phases occurred, taking into account student enrolments patterns. The initial indication was that the first year undergraduate nursing students invited to participate would have an enrolment pattern that would not allow a clinical placement to be undertaken between Stage 3 and Stage 4 of the research. However, with a flexible-delivery program, some students took on clinical experience hours due to non-standard progression, an ongoing shortage of clinical placements (hence taking whatever was on offer), or requests for specific placements granted independently of the research project. Hence, exposure to IV technology during clinical placement became a potential confounding variable, but one that could be readily assessed (see Tables 6.11 and 6.12) and accounted for statistically. Between-group comparisons with and without the participants who had been exposed to IV technology on their clinical placements during the 26-week retention period, produced essentially the same results and hence the dataset was retained intact.

In summary, Stage 4 was designed to assess the retention of competence in the skill of using an actual IV pump, to evaluate the equivalence of receiving training face-to-face in a simulated laboratory or via the online IVPE, and to establish whether the group of participants instructed on both forms of IV pump technology retained greater knowledge and competency during a 26-week break. It was encouraging that competency was retained intact across all three groups. The on-campus and online groups showed comparable retention of competence, and the combined group performed the best, significantly so in the case of some activities included in the RAAT. Such evidence adds strength to the notion that using an online IV pump, in addition to the traditional teaching and learning on an actual IV pump in a simulated laboratory, produces more enduringly competent, and therefore potentially safer, graduates entering the nursing profession.

Chapter 7

General Discussion

7.1 Overview of Key Findings

This chapter begins with a summary of the key findings followed by a discussion of potential applications of the results, especially as they relate to clinical education practices. The chapter continues with a discussion of limitations identified in the research and recommended future directions in this space. Throughout this discussion, although findings from Stages 2 and 3 are frequently summarised and discussed collectively, the findings from Stage 3 should clearly be given greater weight than the results of Stage 2 in consideration of much larger sample size used in Stage 3 and the improved methodology that was implemented.

The research produced the following key findings in the order in which they were reported:

1. In Stage 1, an online IV pump, replicating an actual IV pump commonly used by undergraduate nursing students, was conceptualised, developed and implemented as an emulated computer program for online training purposes.
2. In Stages 2 and 3, there were no significant differences in learning outcomes between groups of undergraduate nursing students who trained on the online IVPE compared to those trained using an actual IV pump in the classroom.
3. In Stages 2 and 3, significantly better learning outcomes were evident from the undergraduate nursing students who trained on both forms of the IV pump.

4. In Stage 3, undergraduate nursing students in the groups who used the online IV pump technology were able to perform most of the functions required in setting up and running an actual IV pump significantly faster than those who trained only on an actual IV pump in the classroom.
5. In Stages 2 and 3, almost all undergraduate nursing students agreed that they would like to see more nursing laboratory equipment transformed into online educational technologies.
6. In Stages 2 and 3, a large majority of undergraduate nursing students favoured the online IVPE for reasons such as freedom of accessibility, ease of use, and similarity to an actual IV pump.
7. In Stages 2 and 3, a large majority of undergraduate nursing students felt confident in using the IV pump technology on which they had trained.
8. In Stage 4, although not a significant difference, better learning outcomes were achieved by those who were trained on both forms of the IV pump after 26 weeks of no exposure to the technology. The combined group performed the assessment activities significantly faster than the other two groups.
9. In Stage 4, all three groups showed excellent retention of competency in using the actual IV pump after a 26-week period. In fact, all groups showed improved performance on the RAAT.
10. As an educational resource for undergraduate nursing students, the online IVPE in combination with the traditional face-to-face training protocol produced better learning outcomes and, therefore, may promote safer, more competent undergraduate nursing students heading into the real world of professional clinical practice.

7.2 Implications of Key Findings

7.2.1 Key Finding 1. *In Stage 1, an online IV pump, replicating an actual IV pump commonly used by undergraduate nursing students, was conceptualised, developed and implemented as an emulated computer program for online training purposes.*

The first key finding is that undergraduate nursing students were able to practice online with a realistic computerised version of an IV infusion pump, following the development and refinement of the online intravenous pump emulator (IVPE). Flexibility, access, providing meaningful tasks and convenience, are desirable elements for students when studying, particularly by distance through online delivery mechanisms (Bennett & Lockyer, 2004). The successful development and implementation of an online IVPE was a step in the right direction for the students (Bowtell et al, 2013) in an external program of study. Having access to an online version of an IV pump was shown to contribute to increased knowledge and skills of students infusing IV fluids and medications, and represents the first of its kind in the nursing profession.

The collaborative process, integrating a multidisciplinary team of engineers and nurses, jointly recognised the value of the concept and the contribution the online IVPE could make, not only in a university nursing program, but to graduates entering the workforce. It was also recognised that existing clinicians in need of revision in skills could also benefit from such technology. The concept enthused and produced many willing participants to undertake evaluations and, in turn, improve the learning outcomes for groups of undergraduate nursing students.

Among the well-established theories and concepts that informed the research process, Rogers' diffusion of innovations theory (2003) appeared to be particularly relevant, especially though the initial stages of the research. In the preliminary development stage of the online IVPE, it was important to consider the advantages of the technology for clinical outcomes, compatibility with the nursing program and other educational resources, the complexity of the innovation, and the relative ease or difficulty of evaluation during a medications course. Acceptance is another challenge when introducing change to a population or a group of individuals (Rogers, 2003). To help maximise the participants' understanding and commitment to the trial, the online IVPE was promoted with information about its use as a beneficial innovation that would enhance their clinical performance.

Once implemented, it was evident from the user perception surveys that the participants were willing to adopt the innovation. Participants generally perceived the online IVPE as advantageous, describing its usefulness, effectiveness, user friendliness, and their satisfaction with it as a distance education technology (see Appendix Q), that enhanced simulated clinical experience (Bowtell et al., 2012). As a result, it seemed feasible to take the next step and introduce the online IVPE into the course for evaluation.

Introducing a new computer technology into a course of study at tertiary level comes with the reality that the users will be adult learners. An educational concept that helped to guide the transferability of the online IVPE to the participants was derived from the principles of andragogy (Knowles, 1975, 1980). Andragogy proposes that adult learners are most interested in learning topics and concepts that have immediate relevance to their work. It was not difficult to promote the online IVPE as an opportunity where students could develop and master skills using an essential everyday clinical resource. Furthermore, the online IVPE included problem-centred applications that could potentially drive and motivate the adult learner (Knowles et al., 2005). Therefore, its implementation was also informed by SDT insofar as the methods used were designed to fulfil the basic psychological need to develop feelings of competence, autonomy and relatedness as a part of the learning process (Deci & Ryan, 2002). The focus of the original design not only included ease of use and simplicity, but also included problem-based concepts particularly through case study scenarios. The problem-solving activities were seen as elements for building on down the track in more advanced courses of study within the program and were also considered for scenarios in which clinical reasoning forms part of the assessment.

The preliminary stage of the development and implementation was a critical step for successfully introducing the online concept into a course of study and effectively disseminating information and instructions about its use. The focus of the research has largely been on the recipients of this technology, and Salmon’s (2012) model of teaching and learning (see Figure 2.2) helped inform the creation, presentation and delivery of the educational material that supported the technology. What transpired was a change from traditional educational delivery to online delivery, which naturally required different pedagogical approaches (Redmond, 2011). First and foremost, it was essential for all concerned to have an understanding of the online environment, especially with respect to having the necessary computer and technical skills to access and use the information effectively (Redmond, 2011; Salmon, 2012).

With respect to *Medications Theory and Practice*, this was a first year course for up to 300 nursing students, some on campus and some external, some inexperienced, some with degrees, some technologically savvy school leavers, some computer illiterate mature-aged mothers and fathers, and some international students with English as their second or third language. The challenge of communicating effectively in order to engage all online learners should not be underestimated, including the need for experience and expertise to support the students' learning styles and personal characteristics through the process (Salmon, 2012).

7.2.2 Key Finding 2. *In Stages 2 and 3, there were no significant differences in learning outcomes between the groups of undergraduate nursing students who trained on the online IVPE compared to those trained using an actual IV pump in the classroom.*

The second key finding showed that training on one or other form of IV pump technology was comparatively equal. The students, whether exposed to just the online IVPE or just the actual IV pump, demonstrated similar learning outcomes, as evidenced by similar RAAT scores and time to completion of the assessment activities. Hence, the instructional material embedded in the online IVPE program, the learning mode, resource page, image gallery and assessment mode was demonstrably equivalent to the traditional face-to-face, in-class instruction and "hands on" training with the actual IV pump.

The fact that there was no statistically significant difference between these two groups when it came to using the actual IV pump, suggests either that training with the online IVPE was in some way more effective or that the learning styles of online only students were different to the on-campus only students. This relates to the fact that online only had not previously seen or used the actual IV pump prior to the assessment activities and yet their learning outcomes were the same as on-campus only group who had completed all their training on an actual IV pump. An important consideration here is that online only students who worked independently in front of a computer were more reliant on self-direction to access, engage and complete the tasks, than in a laboratory classroom filled with background noise and a range of potential distractions, making it more difficult to stay focused. Possibly the on-campus only students in class did not pay adequate attention to the instructions given about the actual IV pump, whereas to progress through the steps of the online IVPE, instructions must be followed accurately. Beneficial learning behaviours, such as self-motivation or enthusiasm, may have emerged from online only due to the novelty effect of a “first of its kind” online education technology.

Another important consideration is that the students participating in the online only group were studying externally, meaning they generally relied heavily on online educational materials. The literature has reported that some external (distance) students get a sense of “feeling left out” or disadvantaged (Mayville, 2007) and not being “ahead of the game” compared to on-campus students. Hence, their motivation and willingness to perform well in classes on campus tends to increase. Moreover, external students like to be prepared before attending residential school activities, which may be another reason for their equivalent performance when using the actual IV pump.

A more obvious explanation for the equivalence of training using the IVPE to the traditional training method is that the preparation, design and delivery of the instructions and resources for the online IVPE were just as effective from a learning and teaching perspective as the traditional face-to-face method of delivery. The user perception survey results support this explanation, indicating that regardless of the type of IV pump technology encountered, it was generally agreed that the training provided was adequate, including the time spent on practice. Most of the students in the online only group and the on-campus only group agreed that they felt confident using the IV pump regardless of the mode of training. An important implication of this finding is that the online IVPE program, delivery instructions and other resources to participants, can be considered to be equivalent to face-to-face training with the actual IV pump in a simulated nursing laboratory. This adds to the body of evidence that a combination of teaching methods, referred to as blended learning, is both beneficial and effective. The teaching of clinical skills, previously confined to a classroom, is now commonly presented online in various ways (Billings & Halstead, 2013) and for the most part these are producing positive outcomes for nursing students.

7.2.3 Key Finding 3. *In Stages 2 and 3, significantly better learning outcomes were evident from the undergraduate nursing students who trained on both forms of the IV pump.*

The third key finding in Stages 2 and 3 supported the hypothesis that the groups of students who used both forms of IV pump technology would achieve significantly better assessment scores with the actual IV pump activities than the participants who were trained on just one or the other technology. Furthermore, groups exposed to the online version performed the assessment activities significantly faster than on-campus only students. Online education in nursing combined with face-to-face teaching has been shown to produce positive results for nursing students (Hudson, 2014). As discussed in relation to the previous finding, training on the online IVPE was equivalent to face-to-face training. It makes sense, therefore, that training on a combination of both forms of the IV pump would take the development of competence a step further, and this did indeed occur. Significantly better learning outcomes were achieved by the combined group than the other two groups in Stage 2 and Stage 3 of the research. This was most evident in activities involving medication calculation for IV fluid orders and changing rates and volumes to be infused on the actual IV pump. Presumably, this occurred because the online IVPE had additional case studies imbedded in the emulation for guidance and practice purposes, and these participants also received the face-to-face instruction in the laboratories. There were no additional case study activities provided to the on-campus only students. In saying that, on-campus students, through the traditional teaching practices were directed to additional resources where more activities could be sought for practice and revision purposes. In Stage 2, the combined group spent extra time practicing on the online IVPE and outperformed the other two groups in AAT scores, verifying that having the online IVPE in addition to actual IV pumps is advantageous to learning outcomes for undergraduate nursing students.

When it comes to medication preparation and administration, getting the medication calculation right is critical. Continuous education and competency testing have been identified as key elements in error prevention when calculating medication doses (Sulosaari et al., 2012; Wright, 2012). Teaching medication formulas and calculations is inherent in medication courses for undergraduate nursing programs. Teaching strategies for nursing students, highlighted in recent reviews, promoted a variety of practices. These included traditional numeracy education, computer-assisted programs, online activities and practical simulations, which all reported positive outcomes related to performance and student satisfaction (Harris et al., 2014; Sears et al., 2010; Sherriff et al., 2012; Stolic, 2014; Weeks et al., 2013). The training for the combined group was consistent with these review findings, where they received traditional simulated training in conjunction with access to an online program. Furthermore, with medication errors linked to incorrect use of IV pumps and the corresponding potential to cause harm (Husch et al., 2005), having unlimited access to online medication case studies and activities with an online IV pump will logically contribute to medication error reduction.

This finding, where participants who used both the actual IV pump and the online IVPE were more competent in its use and functionality, supports the provision of additional online educational resources for repeated practice of skills anywhere and at any time, rather than just in a classroom. Therefore, the present findings bring encouragement to designers and developers of online educational resources worldwide, particularly in the world of health care. In our modern world, informed and perhaps even controlled by mobile devices and influenced by social media, applications of online educational technologies are in no way isolated to desktop and laptop computers. As a matter of priority, the education of these skills by academics and other education providers, must become easily accessible to the students of health care disciplines via their mobile devices of choice, especially the ubiquitous mobile phone and tablet.

7.2.4 Key Finding 4. *In Stage 3, the undergraduate nursing students in the two groups who used the online IV pump technology were able to perform many of the functions required in setting up and running an actual IV pump significantly better than those who trained only on an actual IV pump in the classroom.*

The fourth key finding showed there were several activities on the actual IV pump where the online only group and the combined group significantly outperformed the on-campus only group. This finding demonstrates that the emulated version of the IV pump, through its realistic characteristics, sounds, features and case studies, contributed to superior clinical performance. This further reinforces the potential advantage of developing emulated versions of other common clinical equipment and associated learning materials, for the benefit of nursing students, students in related health disciplines, and those already working as health professionals. Those disciplines that could particularly benefit from augmenting traditional hands-on simulated training with online training methods include nurse practitioners, paramedics, medical students, radiographers, physiotherapists, occupational therapists and pharmacists, among others (George et al., 2014).

Other than medication calculations, assessment activities where the two groups with access to the online IVPE performed significantly better included turning on the actual IV pump, setting the rate, and setting the VTBI parameters. Each of these activities, although straightforward, have additional prompts that are required to be activated in the process. When using the online IVPE, if the prompts are not responded to in the correct way, the program will not move forward. Troubleshooting alerts, even though identical to those seen on the actual IV pump, may be more apparent to IVPE users. On-campus only users in the simulated laboratory, if encountering a technical problem, could request the assistance of the tutor who was present to assist during the face-to-face training. In some respects, having someone available to take corrective action for you, may detract from the clinical reasoning processes involved in making clinical decisions. Using both forms of the IV technology and having increased exposure to the procedures led to better outcomes in many facets of the assessment activities.

One assessment activity where the online only group were significantly outperformed by the on-campus only and combined groups was in loading the IV giving set or tubing. This has been identified as a limitation of the emulated online IVPE program and perhaps one that can be resolved through further technological engineering. To aid all participants to learn how to load the IV giving set, a video demonstration was produced and provided both on the LMS and the Resource Page for access from the online IVPE program. This finding highlights the issue of how to best develop specific tasks and skills that require dexterity, coordination and precision, which can only be effectively mastered with hands-on practice. Delivering a blended education to nursing students, incorporating both online and face-to-face training, may hold the key to closing the theory-practice gap for nurse education and clinical practice (McCutcheon et al., 2014).

The on-campus only group significantly outperformed the other two groups when it came to the first assessment activity; select 1000mL of sodium chloride and check the order provided. During the assessment procedure in Stages 2, 3 and 4 of the research, a litre flask of sodium chloride, a simulated fluid order featuring the necessary and legal patient detail requirements and an armband, were provided. This finding suggests that checking the physical components of commencing an IV infusion became second nature to the participants exposed only to the physical equipment in the simulated laboratories. Perhaps the online version for training created some complacency with respect to the physical and real-life aspects of preparing an IV infusion for administration.

7.2.5 Key Finding 5. *In Stages 2 and 3, almost all undergraduate nursing students agreed that they would like to see more nursing laboratory equipment transformed into online educational technologies.*

The fifth key finding was that a large majority of participants agreed that they would like to see more laboratory equipment, commonly used in the simulated nursing laboratories, transformed into online educational technologies. In the user perception surveys from Stages 2 and 3, in response to the statement "*Would you like to see greater use of online technologies for educating nursing students in the use of laboratory equipment?*" there was resounding support in the affirmative. Almost all participants responded yes, except a small percentage of on-campus only participants (see Figures 4.22 and 5.18). The small percentage who did not support additional online technology may reflect the strong preference of some students for teacher-led direction (Levett-Jones, 2005), a lack of confidence with technology (Hader, 2013), or perhaps simply a preference for the company and socialisation inherent in a classroom setting. On the other hand, given that the large majority supported additional technology development, further consideration and discussion is warranted, especially as recent research has provided additional support for online education of nursing students (Hudson, 2014).

The scope to develop other clinical laboratory equipment into emulated designs via RAL, has enormous potential for providing benefits for the training of undergraduate nursing students as well as students from other healthcare disciplines. Teaching of clinical skills, normally confined to a classroom, is becoming a common computer-based activity where students view digital programs and interactive material that present essential skills and clinical concepts (Billings & Halstead, 2013). Students engaging in web-based information technology to learn clinical skills has become a common feature of contemporary nursing programs (Veredas, 2014).

Educators need to be mindful that it has been reported in nursing studies that students, associate feelings of inadequacy and isolation about studying by distance (Mayville, 2007). Whereas, there are many positive findings related to distance and online education. Some of the reported positives include; enhanced critical thinking skills and empowerment (Hyde & Murray, 2005; Patterson et al., 2012), improved clinical reasoning skills (Kenny, 2002), and convenience and accessibility (Mancuso-Murphy, 2007). Furthermore, it has been reported that distance education for nursing programs is a viable option and should remain as an alternative to on-campus education (Patterson et al., 2012).

University students of all disciplines are becoming more autonomous adult learners with the shift to more distance and online education (Lewis & Price, 2007). Technology plays a vital part in the delivery of content and resources to students, and clinical skills are no exception. This finding is particularly encouraging and the future is promising for any student studying by distance.

7.2.6 Key Finding 6. *In Stages 2 and 3, a large majority of undergraduate nursing students favoured the online IVPE for reasons such as freedom of accessibility, ease of use, and similarity to an actual IV pump.*

The sixth key finding included comments from participants about ways in which tertiary institutions strive to enhance learning and teaching processes, which is fundamentally characterised by flexibility, accessibility, and greater success for students. Again, the number and quality of statements provided voluntarily in response to the open-ended questions in the user perception surveys, warrants highlighting in the discussion of findings. The verbatim comments to support this finding can be found in Appendices J and Q.

It can be interpreted from the responses that the development of a unique online educational technology, for the purpose of improving the quality of education for undergraduate nursing students at a regional university, was seen as successful by the students. This was achieved through a team approach initially via collaboration between two disciplines with common educational principles and goals. The priority of replacing physical or actual simulated laboratory equipment with an online computerised version of an IV pump, required input both from clinicians in the field and technicians familiar with the requirements for advancement in skill competency

(Ginns & Ellis, 2007). Designing simple, yet meaningful, effective and realistic educational technology to be delivered online and freely accessed and used by students, whether on or off campus, was the goal and the end result. Eighty-two percent (*n* = 87) of participants from the online only and combined groups noted how realistic the features were and the likeness between the online IVPE and an actual IV pump. Comments such as "*Virtually identical to pump", "It is easy to work out rate and run it. Accordingly it was very helpful while it makes the alarm, it will let the nurse know about if they are doing anything wrong", "The case studies and diagrams",* and *"Presenting realistic case studies was good*" reflect the perceived usefulness of the technology.

Education at a tertiary level must bridge the theoretical and practice gap with the dissemination of high quality information, and nursing is an exemplary discipline in this regard. One of the driving forces behind the project related to offering undergraduate nursing students, who were not on-campus regularly or who were studying externally, equal opportunities to access content and resources. Clear evidence emerged from the research that will play a part in improving learning outcomes and clinical skills for nursing students. Indeed, based on the findings of the present research, the online IVPE has been implemented as a regular feature of the undergraduate nursing program, and other clinical equipment has been identified as candidates for online emulation.

7.2.7 Key Finding 7. *In Stages 2 and 3, a large majority of undergraduate nursing students felt confident in using the IV pump technology on which they had trained.*

The seventh key finding showed that a large number of participants felt confident using the online IVPE and the actual IV pump following the allocated instruction and training. The period of learning time was the same for the online only and on-campus only groups. It has already been discussed, teaching of nursing skills through traditional means and providing the option to engage with online technology as an additional learning method for skills, increases confidence (McCutcheon et al., 2014). Evidence from the literature provides no doubt that simulation training of clinical procedures and skills strengthens confidence (Blum et al., 2010; Lundberg, 2008) and adding online practice to supplement this training has proven benefits. Transferring this confidence from the classroom to clinical settings, is a target achievement for both educators and students.

As well as level of confidence, participants demonstrated a generally positive perception of the training, instructions and time spent with both forms of IV technology. There were no statistically significant between-group differences within these responses, which indicates that participants were equally satisfied and gained similar confidence whether trained on the actual IV pump or the online IVPE. Lack of confidence impedes the acquisition of knowledge and the ability to make decisions (Lundberg, 2008), so building and promoting confidence in a student's clinical performance through simulation training exercises is vital in its application. It has been suggested that to maintain confidence with increasing complexities in technology, educators should regularly evaluate these technologies to ensure their compatibility and effectiveness when preparing nursing students for clinical practice (Smith & Roehrs, 2009). Kaddoura (2010) supported this assertion among new nursing graduates who reported that simulation had helped them to achieve learning outcomes through problem-solving and critical thinking but above, all else it improved confidence for clinical practice (Samawi et al., 2014).

As the world of technology evolves rapidly, it is important to avoid an oversupply of clinical skill-based technology that overshadows the importance and significance of hands-on experiences. For students of healthcare disciplines, the benefits of real-life practical experience is influential in building confidence (Patterson et al., 2012), but combining it with online educational technology cannot be overlooked with respect to boosting the confidence of a practitioner (McCutcheon et al., 2014). This notion is consistent with the current finding that a large majority of participants felt confident using both the online IV pump and the real thing. For academics of healthcare and other practical disciplines, such as engineering, this is an encouraging finding.

7.2.8 Key Finding 8. *In Stage 4, although not a significant difference, better learning outcomes were achieved by those who were trained on both forms of the IV pump after 26 weeks of no exposure to the technology. The combined group performed the assessment activities significantly faster than the other two groups.*

The eighth key finding within the project was shown in Stage 4, the retention study. After 26-weeks without exposure to IV technology, the combined group showed better retention of competency. Although the between-group difference in overall RAAT scores was not significant, there was some statistically significant between-group differences among the specific activities that comprise the RAAT. First, the combined group performed significantly better than the other two groups when loading the IV giving set or tubing into the actual IV pump. As this was one of the more difficult assessment tasks, it could be interpreted that the combination of training, face-to-face and online, led to greater retention of this hands-on skill. This is consistent with the findings of Bloomfield and colleagues (2010) who reported significantly better knowledge and retention in the skill of hand washing among a group of nursing students who used computer assisted learning resources combined with conventional teaching methods (Bloomfield et al., 2010). Furthermore, Hansen (2011) reported that the combination of simulation, hands-on practice, and use of a mobile device to view a skill, resulted in improved competence and better retention of knowledge and skill (Hansen, 2011).

In addition to the traditional hands-on training, the combined group had access to a video demonstration on the LMS and on the online IVPE about how to load the IV tubing. Video instruction, which might be regarded by some as outdated technology, should still be recognised as a valid form of technology-assisted educational resource in nursing (Brydges et al. 2010, 2012; Hansen, 2011; Holland et al., 2013). Results of the user perception survey from the online and combined groups were strongly in favour of the video instructions to assist in the training of loading the IV tubing into the actual IV pump.

The online only group performed the VTBI task significantly better than the other two groups in Stage 3, and also maintained this superiority in Stage 4. This may be related to the alert, embedded into the online IVPE after Stage 2, which appeared when an inappropriate VTBI was programmed. For example, if 1000mL of volume was ordered, the user was required to set VTBI less than 1000 at approximately 900mL. If the user programmed > 900 mL an alert was activated indicting "Over Limit! Program VTBI 10% less than what is being infused." These unique features of the online IVPE, may very well have facilitated the superior performance after 26-weeks of no exposure.

Finally, it was demonstrated that the on-campus only group, although outperformed by the other two groups at both time points, showed the greatest improvement in RAAT scores from Stage 3 to Stage 4. This finding may point to the effectiveness of the initial simulation training in the laboratories. In support of this notion, Abe and colleagues (2013) showed that nursing students repeating skills over and over in simulated laboratories was the most effective strategy for retention of knowledge. However, the on-campus only group performed the assessment activities significantly slower than the other two groups. This may reflect a tendency to take more care in order to avoid errors but also may indicate lower confidence in their own ability. In fact, in the results of the user perceptions from Stage 2, the on-campus group was the only group to indicate that they were not confident or were unsure about their level of confidence in using the actual IV pump. This was reflected again in Stage 3, where almost 40% of the on-campus students either felt unconfident or undecided about level of confidence in using the actual IV pump.

7.2.9 Key Finding 9. *In Stage 4, all three groups showed excellent retention of competency in using the actual IV pump after a 26-week period. In fact, all groups showed improved performance on the RAAT.*

The ninth key finding showed that excellent retention of knowledge, indicated via the consistency of RAAT scores from Stage 3 to Stage 4, was evident for all three groups. This demonstrates that the online IVPE was just as effective as the traditional classroom face-to-face method of training for developing and retaining competency in using the actual IV pump. This finding, where the RAAT scores remained consistent across the groups after a 26-week period of no exposure to the actual IV pump, demonstrates equivalence in the education received by the participants. Nursing studies that have evaluated retention of knowledge and skills after a time period, typically associate retention outcomes with the type of training initially received. For example, better retention of knowledge and skill has been reported in cases where the training involved a combination of hands-on and online resources (Ackermann et al., 2007; Bloomfield et al., 2010; Hansen, 2011) and the current results were consistent with this literature.

Overall, regardless of the initial education and training methods and IV technology used, excellent retention of competence in using the actual IV pump was evident among all groups, which is an extremely encouraging finding for nurse educators, and for the effective transition of nursing students to clinical practice. The following conclusions can be surmised from the finding. First, it can be concluded that the use of either online or face-to-face training was successful in developing and retaining competence in using an actual IV pump, but a combination of the two methods was superior. The message to nursing educators is that the way to optimise acquisition and retention of competency in the skills of nursing students is to implement a combination of face-to-face and online educational technologies into courses of study.

7.2.10 Key Finding 10. *As an educational resource for undergraduate nursing students, the online IVPE in combination with the traditional face-to-face training protocol produced better learning outcomes and, therefore, may promote more competent undergraduate nursing students heading into the real world of professional clinical practice.*

The tenth key finding summarised the implementation and evaluation of the online IV infusion pump as an educational technology, and in combination with an actual IV pump assisted in producing better learning outcomes. An evidence-based approach was applied to evaluate whether an online IV pump could be considered as a viable education resource for undergraduate nursing education. The concepts of feasibility, appropriateness, meaningfulness, and effectiveness (included in the Joanna Briggs Institute model of evidence-based health care), were considered and established throughout the project (Lockwood et al., 2014; Pearson et al., 2005). It is concluded that the feasibility (i.e., the extent to which an activity is practical and practicable), appropriateness (i.e., the extent to which an intervention is apt in a situation), meaningfulness (i.e., the extent to which an intervention is positively experienced) and effectiveness (i.e., the extent to which an intervention achieves the intended effect) of the online IVPE has been established by the present research. Therefore, a credible evidence-base has been demonstrated to support the benefits of the IVPE to clinical practice.

Not only is the online IVPE influential with respect to improving the practical and mechanical skills of using an actual IV pump, but with the addition of case studies and assessment tools imbedded into the program, students can simultaneously apply some clinical reasoning skills. Improving professional clinical practice by applying clinical reasoning may be a key factor in preventing patient harm (Lapkin et al., 2010; Levett-Jones et al., 2009). Hsu and Hsieh (2014) also demonstrated that this method of combining educational strategies enhances the metacognitive ability in comprehension, critical reasoning, and various other positive educational experiences for nursing students (Hsu & Hsieh, 2014). Hence, the conceptualisation and development of emulated clinical equipment at this level may have a bright future for academics embarking on similar research projects, clinicians accessing, practicing and utilising online programs for educational purposes, and patients in hospital receiving competent and safe care from students and university nursing graduates. These findings add to the body of literature regarding equivalence of online nurse education compared to traditional methods, informs the viability of online or external nurse education at universities and elsewhere, and supports the validity of an emulated version of a globally-used piece of clinical equipment, the IV infusion pump.

Safe and correct medication administration should be inherent in nursing education (Anderson & Townsend 2010) particularly for maintaining competent clinical practice. With the regular updates and changes to policy and procedures associated with medication administration and technology, nurses must always be vigilant regarding safe practice. There are processes in place to uphold safe and quality health care delivered by nurses and to reduce errors (ACSQHC, 2013). However, even with stringent quality control strategies in place, evidence still points to inexperience and knowledge deficits contributing to mistakes in medication administration in hospitals worldwide. Having consistent educational support with online resources available is one way to offer continuous educational activities, to ensure that skills and levels of competency never become unsatisfactory. Having access to an online IVPE during the many weeks of clinical practicum could enable student nurses to not only revise the use of technology but also the administration process for IV fluids and medications. Having the ability to update the information in the online IVPE program promotes quality control in current trends and practices in medications. The key findings all point to evidence that the online IVPE is a high-quality educational resource for undergraduate nursing students to assist in using an actual IV pump.

7.3 Application of Key Findings to Clinical Practice

Ongoing education of skills and procedures leads to improved practice in all facets of clinical nursing. It appears likely that internet-based simulation will play a major role in nursing curricula during the next decade and beyond (Cant & Cooper, 2014). It seems reasonable to argue, therefore, that the online IVPE should be applied to the practice of teaching student nurses in tertiary institutions. Including the online IVPE into course content and as a summative assessment piece may enhance the motivation and self-determination of nursing students in addition to developing competence (Harlen et al., 2002).

It is apparent from feedback received from industry partners in healthcare, that nursing students are sometimes inadequately equipped with clinical reasoning skills and competency with clinical equipment and procedures (Cottrell & Donaldson 2013). Generally, nursing students are prepared for their clinical experiences in simulated laboratories where the education and training of clinical skills is demonstrated by the tutor and practiced by the students. Perhaps simulation alone is not enough. When this method of education and training is enhanced with computer-based technology, the results are more positive. The online IVPE can easily form part of the activities in the simulated laboratories, especially if there are not enough actual IV pumps available for the number of nursing students in a course of study. It is a matter of students having access to a device from which the online IVPE program can be accessed. It can be concluded, therefore, that the online IVPE can easily and cost-effectively play a part in simulation activities that prepare nursing students for their clinical experiences.

Unlimited access to the technology during breaks between semesters could enable student nurses to maintain their IV pump skills and also practice the administration process of IV fluids along with medication calculations. Even though good retention of skill using the actual IV pump was demonstrated when there was no IV pump exposure, one can only surmise that continuous use would produce even better level of competence, confidence and retention.

One rationale for the research was to address how education can be provided effectively to nursing students studying the program externally, or by distance. It is mandated that the content delivered to these students be equivalent to that delivered to a full-time, on-campus student. The online IVPE is an example of how equipment used in the simulated laboratories can be transferred online to distance students. Using the online IVPE and other emulated equipment, the aim of producing, as realistically as possible, the online education of clinical skills and techniques fundamental for nursing students to transfer into clinical practice on the wards, can be achieved.

There is the capacity for the online IVPE to be a source of professional development. A recent study comparing the knowledge and skills of evidence-based practice procedures between nursing academic staff from a tertiary institution to clinical staff members in a hospital, showed that the academics demonstrated superior knowledge of evidence-based practice (Upton et al., 2015). It was reported that the academics demonstrated superiority probably due to greater accessibility to online resources and research findings via technology (Upton et al., 2015). Therefore, the online IVPE could be applied in the professional development of RNs to acquire extra educational support with skills and use of clinical equipment for IV infusions.

7.4 Limitations

The first limitation was the small sample size used in Stage 2. Even though the results of Stage 2 clearly pointed to, for example, the equivalence of online and face-to-face instruction for developing competence in the use of an actual IV pump, the small sample of 20 participants left a question mark against the reliability of Stage 2 results. Hence, it was critical that the study was replicated with a much larger sample, as completed in Stage 3, which greatly strengthened the rigour of the online versus face-to-face comparison. Another minor limitation was that complete random assignment of participants to groups was not possible given that distance students could only be assigned to the online-only group. It is possible that those students who enrol to study nursing by distance education differ on some important characteristics from those who study on-campus, although no significant between-group differences were found related to age, gender or international/domestic status.

Some other minor limitations were present the project, but it is judged that none impacted on the participants in a way that skewed the findings. Accessing the IVPE via RAL was initially problematic due to unwieldy login procedures. Also, during Stage 2, the online IVPE through RAL was not compatible with some computer systems such as Mac devices. To overcome this limitation the program was installed on the desktop computers in the simulated laboratories. The nursing students then had the option of accessing the online IVPE remotely through RAL or, if visiting on-campus could use the program in the simulated laboratories.

Another limitation, again not one that skewed the findings, was that users of the online IVPE could not physically load the IV tubing with the program. This procedural step when using the actual IV pump was difficult for many of the participants to master during the assessment activities in Stages 2, 3 and 4. It was also an issue on which participants commented in the user perception survey, although it was largely overcome with the use of step-by-step instructional videos that demonstrated how to load the IV tubing into the IV pump. As technology continues to advance and these types of programs evolve, the capacity to include such an activity as a physical and interactive feature will grow.

Another issue to highlight in this section is the number of university-wide research studies and surveys being conducted with beginning and first year students at the time Stage 2 was in progress. This may have influenced the willingness of students to participate in additional research and possibly impacted on the recruitment and retention of participants in Stage 2. The students in question were the first cohort of external nursing students in the Bachelor of Nursing program and there was a sense that the adjustment to online delivery was somewhat overwhelming. Some staff and nursing students at the time were still novice to the notion of online teaching techniques and resources and felt flooded with information. Perhaps this created an initial unwillingness to commit to participation in these research activities.

Another limitation was apparent in Stage 4 where some participants gained exposure to IV pump technology during the 26-week retention period, despite careful planning of the research data collection phases. The initial advice was that the first year students invited to participate would not undertake a clinical placement between Stage 3 and Stage 4 of the research. However, with a flexible-delivery program, some students took on clinical experience hours, and gained exposure to IV technology. This became a potential confounding variable, but one that could be readily assessed (see Tables 6.11 and 6.12) and accounted for statistically. As previously reported, between-group comparisons with and without the participants who had been exposed to IV technology on their clinical placements during the 26-week retention period, produced essentially the same results.

7.5 Future Research Directions and Recommendations

The program of research was undertaken primarily with the aim of improving the safety and effectiveness of health care delivery by nurses and, for this reason alone, the present line of research enquiry should be further developed and continued. Ongoing research initiatives are currently being considered for the online IVPE, due to the feasibility of sustaining the program on the university's online learning platform with minimal ongoing cost. Once data collection for the present program of research was completed, all undergraduate nursing students enrolled in laboratory-based courses within the program were given access to and invited to use the IVPE, and the RAL link was embedded into the LMS platform of relevant courses. Monitoring the frequency of use and results of student inputs is possible through the SCADA system technology, so ongoing evaluation of the online IVPE within courses is currently feasible. To commence ongoing investigation into student performance and usage of the online IVPE, additional ethics approval would be required.

Providing improvements to the technology, including updating and adding variety to the case study scenario activities is also ongoing due to the cost-effectiveness of the computer program itself. The data stored within the emulator computer program can potentially become part of the next stage of research. A similar research design and methodology would be implemented; aiming to evaluate the ongoing benefits and any required improvements to the online IVPE in terms of learning outcomes for nursing students as they move in and out of clinical experiences. Furthermore, assessing the competence of the same participants using an actual IV pump during their first clinical placement is also an opportunity for further research on the topic.

As health technology research is an area growing rapidly internationally, contributing to producing safe and competent health care clinicians should always be a priority. Given the scope to develop other clinical laboratory equipment into emulated designs, this area of research has enormous potential for future investigations, and is likely to provide benefits for undergraduate nursing students as well as other health care clinicians. The direction recommended for research to progress in this area, is in the development of an emulated electrocardiograph or ECG machine, and other cardiac monitoring devices. Another systematic and evidence-based research framework could be implemented to evaluate whether an emulated ECG machine and cardiac monitor could improve the clinical performance of nursing students while on a clinical placement. Another potential line of investigation relates to whether an RN could also benefit from accessing this type of online technology. This research could easily extend to the practices of RNs already working in health care facilities.

Implementing the online IVPE into health facilities for use as a continuous educational tool for nursing staff to stay up-to-date with medication administration and infusion device technology should be considered. As new IV medications come in to practice, educating staff about the preparation and administration of anything new is a high priority (Anderson & Townsend 2010). The online IVPE can be used an educational tool to demonstrate new procedures and, at the same time, allow RNs the ability to practice and refresh a competency. Safe and correct medication administration should be included in this area of providing continuous education and ongoing professional development (Anderson & Townsend 2010). Given the emphasis on accessibility in the world of online and distance education, smartphones would be an ideal platform to house this technology. A future direction might be to design an application (or app) of the IVPE for a smartphone or similar device.

Forming partnerships between nursing and engineering disciplines in teaching, learning and research was a successful and progressive move. In the present project, the collaboration between nursing and engineering specialists was important for educators transitioning from one paradigm to another, and also produced a valuable nexus between the different technologies, pedagogies, content and knowledge to promote and support student learning in an online environment. A further recommendation is to continue to build collaborations between disciplines where research and technology have common interests.

7.6 Conclusions

The program of research represents a step forward for online education within the nursing profession. The education of undergraduate nursing students in clinical skills is aligned with patient safety, so no matter how disseminated or taught, it must be relevant, efficient, accurate, and current. The successful development and implementation of an emulated online IV pump for the training of nursing students, in particular for the students studying by distance, was the first of its kind. Furthermore, evidence was provided that an online IV pump, used in addition to traditional hands-on training in a simulated nursing laboratory, may have significant benefits for the development of competence and confidence among nursing students.

With online concepts in education advancing rapidly, comes the realisation for educators in universities and schools, particularly those from hands-on practical disciplines that traditional teaching techniques and styles must evolve to meet the demands of delivering modern nursing education in our society. Although these ideas may be harsh lessons for some, the recipients of online degrees are generally excited and relish the opportunity for the flexibility to study anywhere anytime from whatever digital device they have. Changing teaching methods to meet the clinical performance expectations of the student cohort and reorganising the need to adapt existing content and programs to health care today can be a challenge. Successfully and effectively integrating the essential concepts that align with what is relevant to the student's professional practice is another challenge; a challenge that must be overcome.

As health care and associated equipment advances, naturally education and training is a priority for all clinicians. Universities and other tertiary institutions must continually develop capacity to support the needs of independent and self-directed students and design appropriate programs for awarding professional qualifications. This must entice educators to develop a variety of feasible models, making content easily and freely accessible and crafting teaching and learning systems that promote and support adult learning. Activities, resources and other learning materials, constant student support and information systems, must all work towards developing competency and professional attributes. Online education and remote access to resources cannot be overlooked and must complement traditional approaches. Blended learning provides opportunities for students to become confident, self-directed, critical, and reflective students; work-ready for their profession. University graduates of nursing must demonstrate professional behaviours associated with an educated individual, especially considering that nursing is among the most trusted professions in the world (Cronenwett et al., 2007) so nurse educators owe it to the profession to maintain this reputation.

In conclusion, findings showed that educating nursing students to become competent and confident users of an actual IV pump using an emulated online pump was equivalent to traditional face-to-face training. Moreover, using both forms of IV technology may provide a superior educational strategy for undergraduate nursing students in their quest to be safe and professional clinicians.

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Appendices

Appendix A

Original Ethics Approval: H12REA154

University of Southern Queensland
TOOWOOMBA QUEENSLAND 4350 CRICOS: QLD 00244B NSW 02225M
AUSTRALIA
TELEPHONE +61 7 4631 2300
www.usq.edu.au

OFFICE OF RESEARCH AND HIGHER DEGREES
Ethics Committee Support Officer
PHONE (07) 4631 2690 | FAX (07) 4631 1995
EMAIL ethics@usq.edu.au

Monday, 30 July 2012

Victoria Parker
Faculty of Sciences

CC: Clint Moloney (supervisor)

Dear Victoria

The USQ Fast Track Human Research Ethics Committee (FTHREC) assessed your application and agreed that your proposal meets the requirements of the *National Statement on Ethical Conduct in Human Research (2007)*. Your project has been endorsed and full ethics approval granted.

Project Title	On-line versus on-campus. Learning outcomes for Bachelor of Nursing (BNUR) students using an emulated online intravenous (IV) pump and an actual IV pump as an education resource.
Approval no.	H12REA154
Expiry date	31.12.2014
FTHREC Decision	**Approved with recommendations:** 1) In 3.3 are the participants in stage 2 the same as in stage 1? Otherwise, the total number of participants will need to change. 2) At 6.1, please provide details of agencies participants may contact. It would also be useful to provide a short statement about the debrief procedures in this research project. 3) The Participant Information Sheet also requires the USQ Ethics contact details, as given in the Consent Form.

Please note: the application is approved unconditionally; the recommendations have the status of informal advice which you are not obliged to take note of.

The standard conditions of this approval are:
(a) conduct the project strictly in accordance with the proposal submitted and granted ethics approval, including any amendments made to the proposal required by the HREC
(b) advise (email: ethics@usq.edu.au) immediately of any complaints or other issues in relation to the project which may warrant review of the ethical approval of the project
(c) make submission for approval of amendments to the approved project before implementing such changes
(d) provide a 'progress report' for every year of approval
(e) provide a 'final report' when the project is complete
(f) advise in writing if the project has been discontinued.

For (c) to (e) forms are available on the USQ ethics website: http://www.usq.edu.au/research/ethicsbio/human

Please note that failure to comply with the conditions of approval and the *National Statement (2007)* may result in withdrawal of approval for the project.

You may now commence your project. I wish you all the best for the conduct of the project.

Melissa McKain
Ethics Committee Support Officer
Office of Research and Higher Degrees

Toowoomba • Springfield • Fraser Coast usq.edu.au

Appendix B

Ethics Amendment Approval: H12REA154.1

Dear Victoria

The Ethics Chair has recently reviewed your application for amendments to approved project *On line versus on campus: Learning outcomes for Bachelor of Nursing (BNUR) students using an emulated online intravenous (IV) pump and an actual IV pump as an educational resource (H12REA154)* as stated in your email dated 09.10.2012 The requested amendments have been endorsed and full ethics approval has been granted.

Your amendment approval number is H12REA154.1

Ethics approval for the project expires on 31.12.2014.

The standard conditions of this approval are:

(a) conduct the project strictly in accordance with the proposal submitted and granted ethics approval, including any amendments made to the proposal required by the HREC
(b) advise (email: ethics@usq.edu.au) immediately of any complaints or other issues in relation to the project which may warrant review of the ethical approval of the project
(c) make submission for approval of amendments to the approved project before implementing such changes
(d) provide a “progress report” for every year of approval
(e) provide a “final report” when the project is complete
(f) advise in writing if the project has been discontinued.

For (c) to (e) proformas are available on the USQ ethics website: http://www.usq.edu.au/research/ethicsbio/human

Please note that failure to comply with the conditions of approval and the *National Statement on Ethical Conduct in Human Research (2007)* may result in withdrawal of approval for the project.

You may now implement the amendments. I wish you all the best for the conduct of the project.

Melissa McKain
Manager, Research Integrity & Governance
Office of Research & Higher Degrees
University of Southern Qld
Ph +61 7 46312214
Fax +61 7 46311995
Email melissa.mckain@usq.edu.au

Appendix C

Ethics Amendment Approval: H12REA154.2

Dear Victoria,

The Human Research Ethics Committee Chair has recently reviewed your application for amendment:

HREC Approval Number:	H12REA154.2
Project Title:	Development, refinement and evaluation of an online intravenous (IV) pump emulator

The requested amendments have been endorsed and full ethics approval has been granted as follows:

Amendment approval date:	4 September 2013
Amendment approval:	Change to PIS & Consent, Change of Title and Additional study
Project Expiry date:	31 December 2014

The standard conditions of this approval are:

(a) conduct the project strictly in accordance with the proposal submitted and granted ethics approval, including any amendments made to the proposal required by the HREC
(b) advise (email: ethics@usq.edu.au) immediately of any complaints or other issues in relation to the project which may warrant review of the ethical approval of the project
(c) make submission for approval of amendments to the approved project before implementing such changes
(d) provide a "progress report" for every year of approval
(e) provide a "final report" when the project is complete
(f) advise in writing if the project has been discontinued.

For (c) to (e) proformas are available on the USQ ethics website: http://www.usq.edu.au/research/ethicsbio/human

Please note that failure to comply with the conditions of approval and the *National Statement on Ethical Conduct in Human Research (2007)* may result in withdrawal of approval for the project.

You may now implement the amendments. I wish you all the best for the conduct of the project.

Kind regards,
Samantha Davis
Ethics Assistant
University of Southern Queensland
Toowoomba | Queensland | 4350 | Australia Ph: 07 4631 2690 | Fax: 07 4631 1995 | Email: ethics@usq.edu.au

Appendix D

Information for Participants and Participant Consent Form Stage 2

The University of Southern Queensland

Participant Information Sheet & Consent Form

HREC Approval Number: H12REA154

We would like to invite you to take part in this important research project

Online vs. On-Campus

Learning outcomes for Bachelor of Nursing students using an online intravenous (IV) pump

and an actual IV pump as educational resources

Principal Researcher: Ms Victoria Parker, Lecturer in Nursing & Midwifery

Other Researcher(s): Dr Clint Moloney, Lecturer in Nursing & Midwifery

Other Researcher(s): Dr Les Bowtell, Lecturer in Faculty of Engineering and Surveying

Participation in this project will involve:

- Being allocated to one of three groups that will evaluate a **new online** initiative specifically designed for flexible and external delivery of the BNUR program.
- External participants will use and evaluate an online intravenous (IV) pump, referred to as an emulated pump, from home for 2 hours, commencing week 8. Learning outcomes will observed in a 15-30 min session during the residential school for NUR2000 but **not as an exam**.
- On-campus participation will involve learning to use either the emulated IV pump and/or an actual IV pump for 2 hours, commencing week 7.
- Learning outcomes will observed in a 15-30 min session during class for NUR2000 but **not as an exam**.
- This will **not affect your grades** in any way for NUR2000.
- Participation in the project will provide you with the opportunity to use a **brand new** and innovative online resource.
- There are **no foreseeable risks**.
- Participants who complete their involvement in the project will be entered in a draw to win one of four **$50 cash vouchers**.

Voluntary Participation

Participation is entirely voluntary. If you do not wish to take part you are not obliged to.

If you decide to take part and later change your mind, you are free to withdraw from the project at any stage.

Any information already obtained from you will be destroyed.

Your decision whether to take part or not to take part, or to take part and then withdraw, will not affect your

relationship with the University of Southern Queensland.

Please notify any of the researchers if you decide to withdraw from this project.

Should you have any queries regarding the progress or conduct of this research, you can contact the principal researcher or the ***University of Southern Queensland Ethics Office***:

Ms Victoria Parker
Department of Nursing & Midwifery I Faculty of Sciences I University of Southern Queensland
Email: victoria.parker@usq.edu.au I Phone: 07 4631 2377 I Mobile: 0419 779271

Ethics and Research Integrity Officer
Office of Research and Higher Degrees I University of Southern Queensland
West Street, Toowoomba 4350 I Ph: +61 7 4631 2690 I Email: ethics@usq.edu.au

Consent

Your informed consent is necessary before you can proceed with the research.

I have read this Participant Information and the nature and purpose of the research project has been explained to me.
I understand and agree to take part.

I understand the purpose of the research project and my involvement in it.

I understand that I may withdraw from the research project at any stage and that this will not affect my status now or in the future.

I confirm that I am over 18 years of age.

I understand that while information gained during the study may be published

I will not be identified and my personal results will remain confidential.

Name of participant…………………………………………………………………......

Signed……………………………………………………**Date**………………………

If you have any ethical concerns with how the research is being conducted or any queries about your rights as a participant please feel free to contact the University of Southern Queensland Ethics Officer.

Ethics and Research Integrity Officer
Office of Research and Higher Degrees I University of Southern Queensland
West Street, Toowoomba 4350 I Ph: +61 7 4631 2690 I Email: ethics@usq.edu.au

Appendix E

Online Instructions for Online IVPE Stages 2 and 3

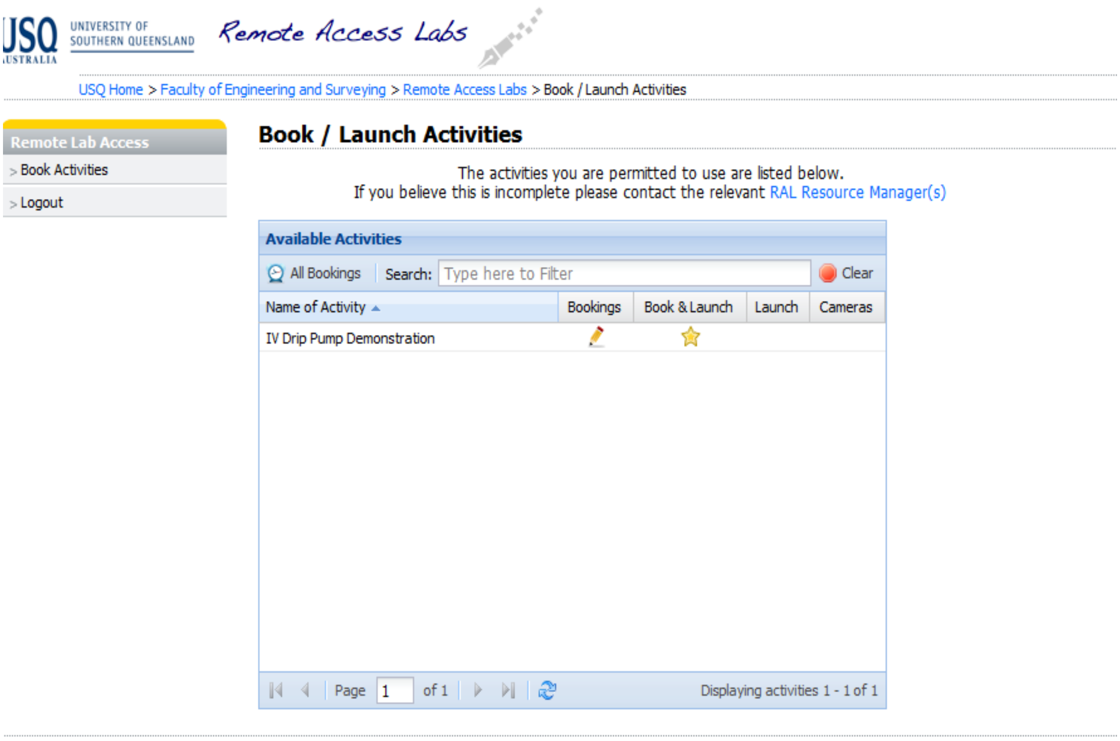
<u>On-Line IVPE instructions</u>

1. **Ctrl + Click or Copy and Paste this link into your browser**

https://ralweb-prd.usq.edu.au/

2. **Enter USQ user name and pass word on The Remote Access Labs page**

3. **Click on Bookings**

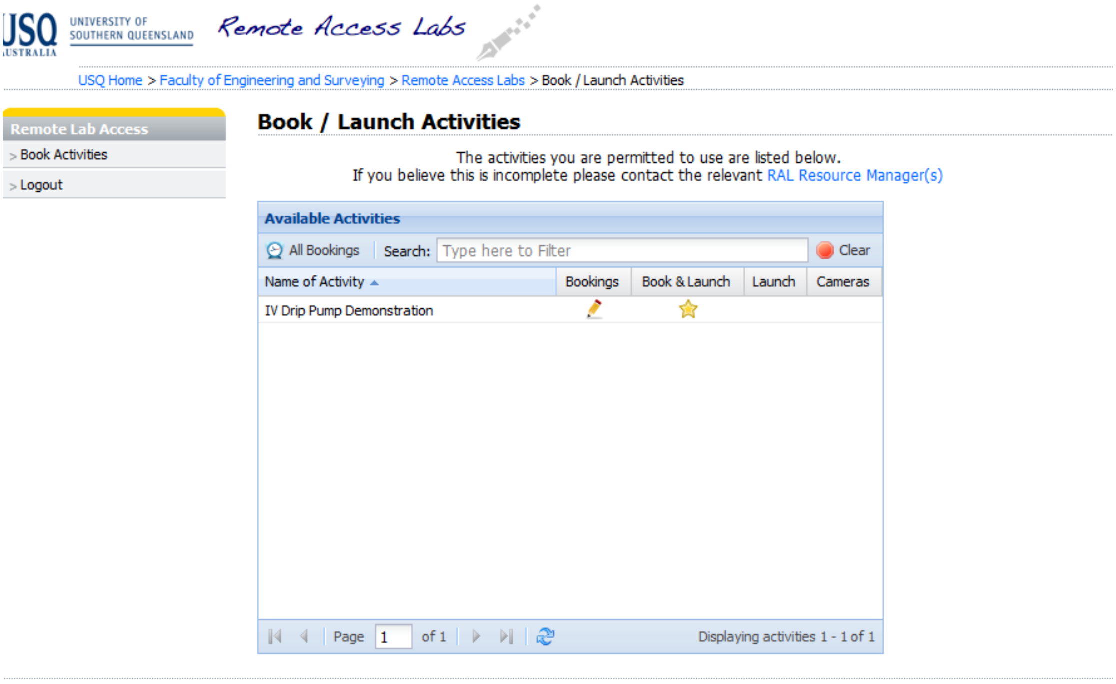


4. **Click on Bookings → Make New Booking →Book a Session for IV Drip Pump Demonstration → Click on suitable time → See message: Booking Completed Successfully**

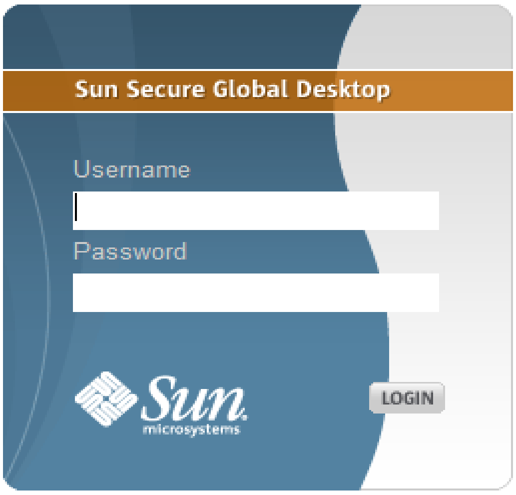
5. **Either exit X screen or Logout and return to step 1 later when it's time to use the pump**

OR if you are booked in straight away:

6. **Click on Launch**

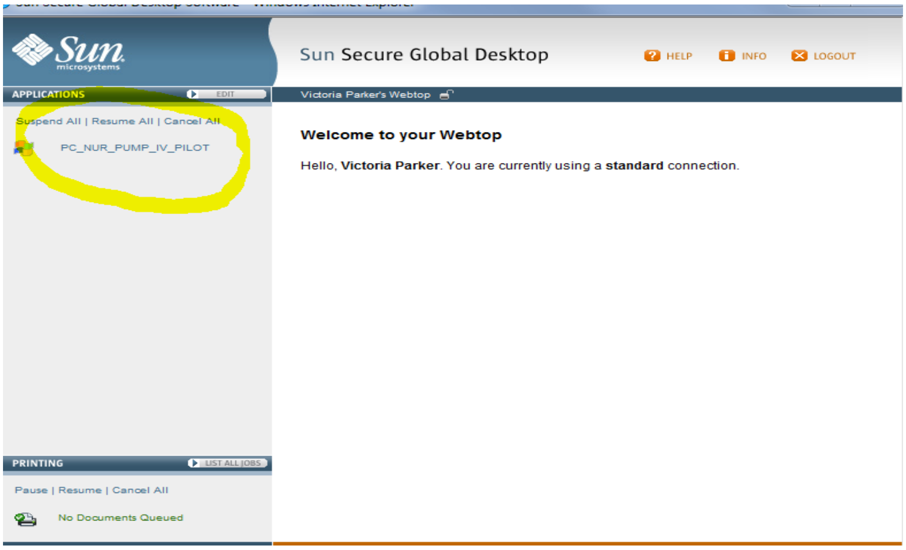


7. **Enter USQ user name and password**

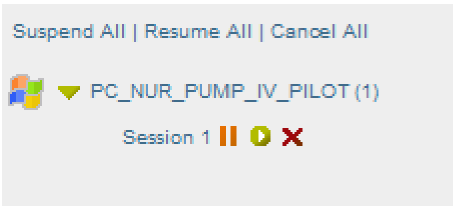


NB. Click "yes" and/or "continue" on any question messages about allowing the program to continue on your computers. It's safe to do so.

8. **Click on PC_NUR_PUMP_IV_PILOT**



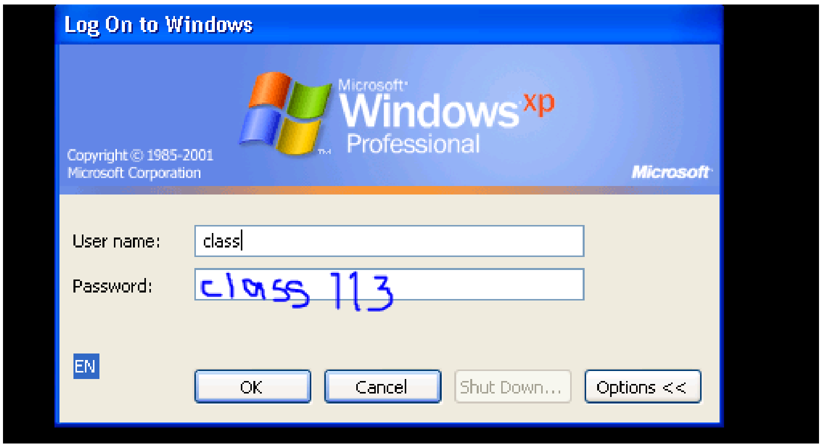
9. **Click on Session or green arrow (resume)**



10. **Ignore the logon message and Click OK**

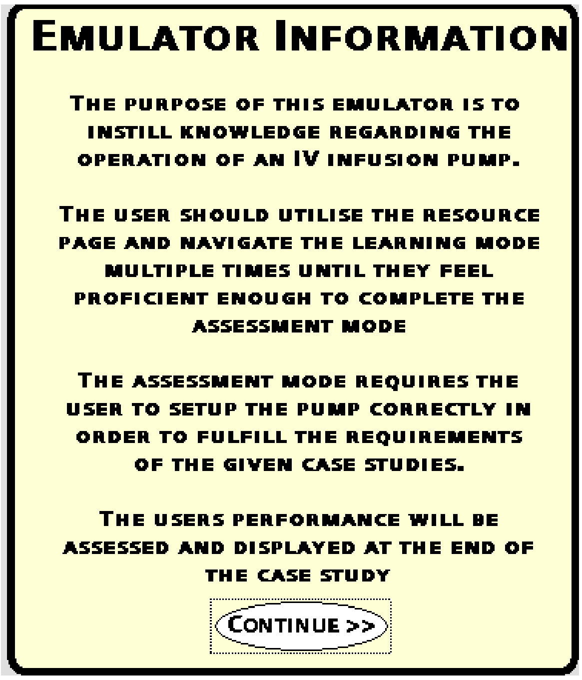
11.User Name: please type class (case sensitive)

12. Password: please type class113 (case sensitive)



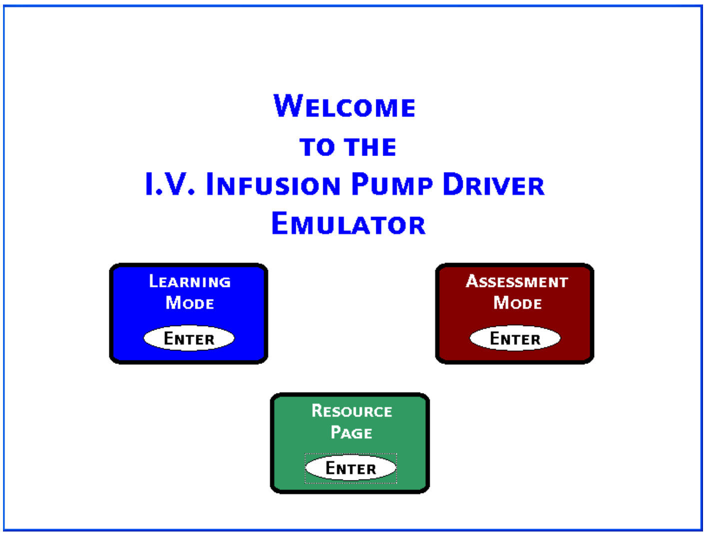
13. Click on USQ IV Pump Emulator

14. Click continue (you may need to hold down the mouse click for a few seconds)



15. Click Enter for Learning Mode or Resource Page and explore your way through the program

(You may need to hold down the mouse click for a few seconds)



WELCOME TO YOUR ONLINE IV PUMP

Contact victoria.parker@usq.edu.au **if you have any problems**

Appendix F

Activity Assessment Tool (AAT) Stage 2

Project Group: ____________ Time started: _____________

Activity 1

a) Select 1000mL Sodium Chloride & prime an infusion set

b) Turn on the IV pump

c) Load the infusion set into the IV pump.

d) Set the rate at 125mL

e) Set the VTBI to an appropriate volume

f) Start the infusion

Activity 2

State 2 causes for a "downstream occlusion."

Activity 3

List the 6 Rights

Activity 4

Program the Rate and Volume on the IV pump according to these medication calculations:

a.) Infuse 500mL Sodium Chloride over 12 hours and start.

b.) Infuse 1 litre Sodium Chloride over 6 hours and start.

c.) Infuse 1000mL Sodium Chloride over 16 hours and start.

d.) Infuse 1000mL Sodium Chloride over 24 hours and start.
e.) Infuse 250mL over 1 hour and start

Activity 5

Pause the IV pump and change the Rate and Volume according to the following order:
A patient's BP has dropped to 80mmHg systolic.
Order: Administer a fluid bolus of 500mL over 2 hours

Activity 6

Cease your patient's IV infusion and turn off IV pump

Appendix G

User Perception Survey Stage 2

QUESTION 1

In which research group were you allocated? **Tick ONE box**

☐ Group 1 (external/online) **GO TO Questions 3, 4, & 5**

☐ Group 2 (on-campus) **GO TO Question 7**

☐ Group 3 (on-campus AND online IV pump) **GO TO Question 2**

QUESTION 2

Group 3 participant, did you use the online IV pump program in addition to the actual pump?

Tick ONE box

☐ YES and for how many hours/min __________Go to **Questions 3, 4, & 5**

☐ No **GO TO Question 7**

QUESTION 3

Rate your agreement to the following statements: Circle either

SA - Strongly Agree A - Agree N – Neutral D – Disagree SD - Strongly Disagree

a) Logging in to the online IV pump was simple	SA A N D SD
b) There were too many steps in the instructions for login and booking into the program	SA A N D SD
c) The emailed instructions about booking into the online IV pump were easy to follow	SA A N D SD
d) There were enough time slots available to book the online IV pump	SA A N D SD
e) Booking to use the online IV pump was straight forward	SA A N D SD

QUESTION 4

Rate your agreement to the following statements: Circle either

SA - Strongly Agree A - Agree N – Neutral D – Disagree SD - Strongly Disagree

a) Learning Mode about the use of the online IV pump was easy to follow	SA A N D SD
b) Resource Page for the online IV pump was helpful	SA A N D SD
c) Image Gallery for the online IV pump was helpful	SA A N D SD

d) Enough information was supplied for Learning Mode	SA A N D SD
e) The Assessment Mode was not easy to work through	SA A N D SD
f) The case studies were excellent learning examples	SA A N D SD
g) Insufficient time was allocated for practice	SA A N D SD
h) I feel confident using the online IV pump	SA A N D SD

QUESTION 5

a.) What were the best features of the online IV pump

____

____

b.) What features of the online IV pump could be improved?

____

____

QUESTION 6

Would you like to see greater use of online teaching technologies for educating nursing students in use of equipment?

Circle YES or NO

THANK YOU FOR YOUR INVOLVEMENT IN THIS SURVEY

GROUP 2 (ON-CAMPUS)

QUESTION 7

Rate your agreement to the following statements: Circle either

SA - Strongly Agree A - Agree N – Neutral D – Disagree SD - Strongly Disagree

a) Teaching instructions about use of the actual IV pump were easy to understand	SA	A	N	D	SD
b) Video demonstration about using the actual IV pump was helpful	SA	A	N	D	SD
c) Enough time was allocated for instruction	SA	A	N	D	SD
d) Enough time was allocated for practice	SA	A	N	D	SD
e) I feel confident using the actual IV pump	SA	A	N	D	SD

QUESTION 8

Would you like to see greater use of online teaching technologies for educating nursing students in use of equipment?

Circle YES or NO

THANK YOU FOR YOUR INVOLVEMENT IN THIS SURVEY

Appendix H

Tutor Instructions for IV Pump Stage 2

At commencement of lab class demonstrate use of IV pump to all students.

Instruct students:

- Wash hands, select equipment, check the order for IV Sodium Chloride 0.9% with another student and prime IV giving set (as per week 5)

Explain and demonstrate:

- Routine IV pump checks
- Press **ON/OFF** button and follow prompts
- Press and hold **Speaker Key** and listen for the sound
- Did you hear the sound? Select **YES or NO**
- Select **New Patient**
- Select **Done**
- Select **Open** and load IV giving set into the IV pump
- Reinforce how the blue key clamp is inserted into IV pump and refer students to video on study desk
- Open roller clamp
- Consult IV order again for rate and volume

Order: 1000mL Sodium Chloride 0.9% over 8 hours

Formula: Volume/Time (hrs)

- **Rate**: 125mL/hr
- **Volume**: 900mL
- Wipe IV bung with alco-wipe
- Flush IV bung with 5mL of Sodium Chloride
- Perform the **6 Rights** of Medication Safety

- Attach IV line to bung and secure with tape
- Select **Primary**
- Select **Start**
- Sign the IV fluid orders and document on fluid balance chart

Students to practice on IV pump for remainder of class.

Appendix I

Marking Criteria Stage 2

Project Group: _____________ Student Number: _________________

How many hours/min did you use the online IV pump? ___________

Start time: ______________

Activity 1

a. Select 1000mL Sodium Chloride & prime an infusion set
b. Turn on the IV pump
c. Load the infusion set into the IV pump
d. Set the rate at 125mL
e. Set the VTBI to an appropriate volume
f. Start the infusion

Circle appropriate score

a.	4	3	2	1	0
b.	4	3	2	1	0
c.	4	3	2	1	0
d.	4	3	2	1	0
e.	4	3	2	1	0
f.	4	3	2	1	0

Score	Statement
4	Perfect
3	Hesitation but achieved
2	Some mistakes but achieved
1	Many errors but achieved
0	Could not perform task

Activity 2 State 2 causes for a "downstream occlusion."

Circle appropriate score

2 1 0

2	2 causes
1	1 cause
0	Could not state a cause

Activity 3 List the 6 Rights

Circle appropriate score

6 5 4 3 2 1 0

Activity 4

Work out the: i) **Medication calculation** program the

ii) **Rate**

iii) **VTBI**

iv) **Start the pump**

a.) Infuse 500mL Sodium Chloride over 12 hours and start.

b.) Infuse 1 litre Sodium Chloride over 6 hours and start.

c.) Infuse 1000mL Sodium Chloride over 16 hours and start.

d.) Infuse 1000mL Sodium Chloride over 24 hours and start.

e.) Infuse 250mL over 1 hour and start.

4 a). Infuse 500mL Sodium Chloride over 12 hours and start.

Circle appropriate score

i.	Calculation	4	3	2	1	0
ii.	Rate	4	3	2	1	0
iii.	VTBI	4	3	2	1	0
iv.	Start	4	3	2	1	0

Score	**Statement**
4	Perfect
3	Hesitation but achieved
2	Some mistakes but achieved
1	Many errors but achieved
0	Could not perform task

4 b.) Infuse 1 litre Sodium Chloride over 6 hours and start.

Circle appropriate score

i.	Calculation	4	3	2	1	0
ii.	Rate	4	3	2	1	0
iii.	VTBI	4	3	2	1	0
iv.	Start	4	3	2	1	0

Score	**Statement**
4	Perfect
3	Hesitation but achieved
2	Some mistakes but achieved
1	Many errors but achieved
0	Could not perform task

4 c.) Infuse 1000mL Sodium Chloride over 16 hours and start.

Circle appropriate score

i.	Calculation	4	3	2	1	0
ii.	Rate	4	3	2	1	0
iii.	VTBI	4	3	2	1	0
iv.	Start	4	3	2	1	0

Score	**Statement**
4	Perfect
3	Hesitation but achieved
2	Some mistakes but achieved
1	Many errors but achieved
0	Could not perform task

4 d.) Infuse 1000mL Sodium Chloride over 24 hours and start.

Circle appropriate score

i.	Calculation	4	3	2	1	0
ii.	Rate	4	3	2	1	0
iii.	VTBI	4	3	2	1	0
iv.	Start	4	3	2	1	0

Score	**Statement**
4	Perfect
3	Hesitation but achieved
2	Some mistakes but achieved
1	Many errors but achieved
0	Could not perform task

4 e.) Infuse 250mL Sodium Chloride over 1 hour and start.

Circle appropriate score

i.	Calculation	4	3	2	1	0
ii.	Rate	4	3	2	1	0
iii.	VTBI	4	3	2	1	0
iv.	Start	4	3	2	1	0

Score	Statement
4	Perfect
3	Hesitation but achieved
2	Some mistakes but achieved
1	Many errors but achieved
0	Could not perform task

Activity 5

Read the following scenario:

A patient's BP has dropped to 80mmHg systolic. You are required to administer a fluid bolus of 500mL over 2 hours.

i) **Medication calculation**

ii) R**ate**

iii) **VTBI** according to the following order:

iv) **Start**

5. Administer a fluid bolus of 500mL over 2 hours

Circle appropriate score

i.	Calculation	4	3	2	1	0
ii.	Rate	4	3	2	1	0
iii.	VTBI	4	3	2	1	0
iv.	Start	4	3	2	1	0

Score	**Statement**
4	Perfect
3	Hesitation but achieved
2	Some mistakes but achieved
1	Many errors but achieved
0	Could not perform task

Activity 6 Cease infusion and turn off IV pump

Circle appropriate score

2 1 0

2	Turned off IV Pump
1	Had trouble but turned off IV Pump
0	Could not turn off IV Pump

Time completed: ______________

Points out of 130: _____________

Appendix J

Qualitative Responses from User Perception Survey Stage 2

Question 5a). What were the best features of the online IV pump?

ID Grp 1	Responses
1	*I was able to practice when I had time*
2	*Easy Instructions*
3	*Visually real-life*
4	*Being able to practice anytime; Great explanations*
Grp 3	Responses
14	*Gaining an understanding of what buttons to press when an what order to load pump, unclamp tube etc., ;The case studies were also useful*
15	*Ease of access*
16	*Good work*
17	*Availability*
18	*Access and use anytime*
20	*Really enjoyed the idea. Great to be able to use anytime*

Question 5b). What features of online IV pump could be improved?

ID Grp 1	Responses
1	*The loading of the line into the pump – more interactive*
2	*The graphics/3D*
3	*Nothing*
4	*Booking in class so I think it should be available anytime and to have to book ;Reliable connection always*
Grp 3	Responses
14	*More videos of someone actually loading the pump such as hanging the actual drug; Overall see no other areas*
15	*Compatibility with Mac*
16	*Nothing*
17	*The login*
18	*Nothing really?*
20	*Loading the tube to be included better in the program*

Appendix K

Online IVPE Assessment Mode Additional Case Study

Case Study 2

Miss Black, aged 38 has been admitted to USQ orthopaedic ward with a compound fracture of her tibia resulting from being hit by a car while crossing the road this morning. She has returned from the operating theatre (OR) and has IV fluids and IV antibiotics ordered.

The doctor has ordered: IV 1000mLs of Sodium Chloride to run over 10 hours (10/24).

1. a.) How many mLs/hr?

b.) What should be the volume to be infused?

The doctor has also ordered: IV Timentin 3.1g to be reconstituted in 13mls of Sterile Water for Injection and diluted in 100mLs Sodium Chloride over 1 hour.

Visit the image gallery to see IV Timentin and a Burette connected to the bag of IV fluid.

2. a.) How many mLs/hr?

b.) What should be the volume to be infused?

Case Study 3

Mr Pink, aged 68, weighs 96kgs, has been admitted to USQ CCU with dyspnoea and atrial fibrillation (AF). His HR is 156/min.

He has been ordered an IV Amiodarone Infusion as follows :

600mgs Amiodarone in 500mLs 5% Dextrose to run at: 0.5mgs/kg/hr for HR between 100 – 160/min.

1. a) How many mLs/hr?

b.) What should be the volume to be infused?

The doctor has ordered the following:

If Mr Pink's HR increases to > 160/min, increase the infusion to: 0.075/kg/hr

2 a.) How many mLs/hr?

If Mr Pink's HR decreases to <100/min, decrease the infusion to 0.25/kg/hr

b.) how many mLs/hr?

If Mr Pink's HR decreases to <60/min, cease the infusion.

Appendix L

Information for Participants and Participant Consent Form Stages 3 and 4

HREC Approval Number: H12REA154 – 2 Stage 3 & 4

We would like to invite you to take part in this important research project

Online vs. On-Campus: Learning outcomes for Bachelor of Nursing students using an online intravenous (IV) pump and an actual IV pump as educational resources.

Principal Researcher: Ms Victoria Parker, Lecturer in Nursing & Midwifery

Other Researcher(s): Dr Clint Moloney, Lecturer in Nursing & Midwifery

Other Researcher(s): Dr Les Bowtell, Lecturer in Faculty of Engineering and Surveying

Participation in this project will involve:

- Being allocated to one of three groups that will evaluate a **new online** initiative specifically designed for flexible and external delivery of the BNUR program.
- Some participants will use and evaluate an online intravenous (IV) pump, referred to as an IV Pump Emulator (IVPE), online for 2 hours per week commencing week 7. Learning outcomes will observed in a 15-20 minute session during class time or residential school for NUR2000 but **not as an exam,** and then again in the following semester.
- Some participants will use and evaluate an actual IV pump for 2 hours commencing week 7. Learning outcomes will observed in a 15-20 minute session during class time for NUR2000 but **not as an exam,** and then again in the following semester.
- Some participants will use and evaluate both the online IVPE and the actual IV pump for 2 hours commencing week 7. Learning outcomes will observed in a 15-20 minute session during class time or residential school for NUR2000 but **not as an exam,** and then again in the following semester.

- This will **not affect your grades** in any way for NUR2000.
- Participation in the project will provide you with the opportunity to use a **brand new** and innovative online resource.
- There are **no foreseeable risks**.
- Participants who complete their involvement in the project will be entered in a draw to win one of four **$50 cash vouchers**.

Voluntary Participation

Participation is entirely voluntary. If you do not wish to take part you are not obliged to.

If you decide to take part and later change your mind, you are free to withdraw from the project at any stage. Any information already obtained from you will be destroyed.

Your decision whether to take part or not to take part, or to take part and then withdraw, will not affect your relationship with the University of Southern Queensland.

Please notify any of the researchers if you decide to withdraw from this project.

Should you have any queries regarding the progress or conduct of this research, you can contact the principal researcher or the ***University of Southern Queensland Ethics Office***:

Ms Victoria Parker
Department of Nursing & Midwifery I Faculty of Sciences I University of Southern Queensland
Email: victoria.parker@usq.edu.au I Phone: 07 4631 2377 I Mobile: 0419 779271

Ethics and Research Integrity Officer
Office of Research and Higher Degrees I University of Southern Queensland
West Street, Toowoomba 4350 I Ph: +61 7 4631 2690 I Email: ethics@usq.edu.au

Consent

Your informed consent is necessary before you can proceed with the research.

- I have read this Participant Information and the nature and purpose of the research project has been explained to me. I understand and agree to take part.
- I understand the purpose of the research project and my involvement in it.
- I understand that I may withdraw from the research project at any stage and that this will not affect my status now or in the future.
- I confirm that I am over 18 years of age.
- I understand that while information gained during the study may be published, I will not be identified and my personal results will remain confidential.

Name of participant…………………………………………………………………......

Signed………………………………………………….**Date**………………………

If you have any ethical concerns with how the research is being conducted or any queries about your rights as a participant please feel free to contact the University of Southern Queensland Ethics Officer.

Ethics and Research Integrity Officer
Office of Research and Higher Degrees I University of Southern Queensland
West Street, Toowoomba 4350 I Ph: +61 7 4631 2690 I Email: ethics@usq.edu.au

Appendix M

Revised Activity Assessment Tool (RAAT) Stages 3 and 4

Student Number: ________________________

Please circle the age that applies to you

18 - 24yr   25 - 35yr   35 - 45yr   over 45yr

Activity 1

a) Select 1000mL Sodium Chloride and check the order provided

b) Turn on the IV Pump

c) Load the IV Giving Set into the IV pump

d) Set the rate at 83mL

e) Set the Volume to be Infused (VTBI)

f) Start the Infusion

Activity 2 List the 6 Rights

Activity 3

Press Stop: Work out these Medication Calculations, program the Rate, VTBI and Start the pump:

Formula: Volume/Time (hrs)

a.) Infuse 1000mL Sodium Chloride over 24 hours and Start

Press Stop

b.) Infuse 1000mL Sodium Chloride over 6 hours and Start

Activity 4

Press Stop and change the Rate and VTBI according to the following order:

A patient's BP has dropped to 80mmHg systolic.

Drs Order: From the IV Fluid running administer a fluid bolus of

500mL over 2 hours and Start.

Activity 5 Turn Off the IV Pump

Appendix N

Revised User Perception Survey Stage 3

QUESTION 1

In which research group were you allocated? **Tick ONE box**

☐ Group 1 (external/online) **GO TO Question 3**

☐ Group 2 (on-campus) **GO TO Question 6**

☐ Group 3 (on-campus AND online IV pump) **Answer ALL Questions**

QUESTION 2

Group 3 participant, did you use the online IV pump off-campus via RAL?

Tick ONE box

☐ YES

☐ No

QUESTION 3

Rate your agreement to the following statements: Circle either

SA - Strongly Agree A - Agree N – Neutral D – Disagree SD - Strongly Disagree

a) Learning mode about the use of the online IV pump was easy to follow	SA	A	N	D	SD
b) Resource Page for the online IV pump was helpful	SA	A	N	D	SD
c) Image gallery for the online IV pump was helpful	SA	A	N	D	SD
d) Enough information was supplied for learning mode	SA	A	N	D	SD
e) The assessment mode was not easy to work through	SA	A	N	D	SD
f) The case studies were excellent learning examples	SA	A	N	D	SD
g) Insufficient time was allocated for practice	SA	A	N	D	SD
h) I feel confident using the online IV pump	SA	A	N	D	SD

QUESTION 4

a.) **What were the best features of the online IV pump**

____

____

b.) **What features of the online IV pump could be improved?**

____

____

QUESTION 5

Would you like to see greater use of online teaching technologies for educating nursing students in use of equipment?

Circle YES or NO

THANK YOU FOR YOUR INVOLVEMENT IN THIS SURVEY

GROUP 2 (ON-CAMPUS) & GROUP 3 (ON-CAMPUS & ONLINE)

QUESTION 6

Rate your agreement to the following statements: Circle either

SA - Strongly Agree A - Agree N – Neutral D – Disagree SD - Strongly Disagree

a) Teaching instructions about use of the actual IV pump were easy to understand	SA	A	N	D	SD
b) Video demonstration about using the actual IV pump was helpful	SA	A	N	D	SD
c) Enough time was allocated for instruction	SA	A	N	D	SD
d) Enough time was allocated for practice	SA	A	N	D	SD
e) I feel confident using the actual IV pump	SA	A	N	D	SD

QUESTION 7

Would you like to see greater use of online teaching technologies for educating nursing students in use of equipment?

Circle YES or NO

THANK YOU FOR YOUR INVOLVEMENT IN THIS SURVEY

Appendix O

Revised Marking Criteria Stages 3 and 4

Student Number: ____________________

Start Timer

Activity 1

a.) Select 1000mL Sodium Chloride & check against the order
b.) Turn on the IV pump
c.) Load the IV giving set into the IV pump
d.) Set the rate at 83mL
e.) Set the VTBI to an appropriate volume (500 – 950mL).
f.) Start the infusion

Circle appropriate score

a.)	4	3	2	1	0
b.)	4	3	2	1	0
c.)	4	3	2	1	0
d.)	4	3	2	1	0
e.)	4	3	2	1	0
f.)	4	3	2	1	0

Score	Statement
4	Perfect
3	Hesitant but achieved
2	Stumbled, some mistakes but achieved
1	Unsure, many errors/omissions but achieved eventually
0	Could not or did not perform task, instructed to move on

Activity 3 List the 6 Rights

Circle appropriate score

6 5 4 3 2 1

Activity 3

Work out the:

i) **Medication calculation** program the

ii) **Rate**

iii) **VTBI**

iv) **Start the pump**

a.) Infuse 1000mL Sodium Chloride over 24 hours and start.

b.) Infuse 1000mL Sodium Chloride over 6 hours and start.

3 a). Infuse 1000mL Sodium Chloride over 24 hours and start.

Circle appropriate score

i)	Calculation	4	3	2	1	0
ii)	Rate	4	3	2	1	0
iii)	VTBI	4	3	2	1	0
iv)	Start	4	3	2	1	0

Score	**Statement**
4	Perfect
3	Hesitant but achieved
2	Stumbled, some mistakes but achieved
1	Unsure, many errors/omissions but achieved eventually
0	Could not or did not perform task, instructed to move on

3 b.) Infuse 1 litre Sodium Chloride over 6 hours and start.

Circle appropriate score

i)	Calculation	4	3	2	1	0
ii)	Rate	4	3	2	1	0
iii)	VTBI	4	3	2	1	0
iv)	Start	4	3	2	1	0

Score	**Statement**
4	Perfect
3	Hesitant but achieved
2	Stumbled, some mistakes but achieved
1	Unsure, many errors/omissions but achieved eventually
0	Could not or did not perform task, instructed to move on

<u>Activity 4</u>

Read the following scenario:

A patient's BP has dropped to 80mmHg systolic, from the IV fluid you have running administer a fluid bolus of 500mL over 2 hours.

i) **Medication calculation**

ii) R**ate**

iii) **VTBI** according to the following order:

iv) **Start**

4. Administer a fluid bolus of 500mL over 2 hours

Circle appropriate score

i) Calculation	4	3	2	1	0
ii) Rate	4	3	2	1	0
iii) VTBI	4	3	2	1	0
iv) Start	4	3	2	1	0

Score	**Statement**
4	Perfect
3	Hesitant but achieved
2	Stumbled, some mistakes but achieved
1	Unsure, many errors/omissions but achieved eventually
0	Could not or did not perform task, instructed to move on

<u>Activity 6</u> Turn off the IV pump

Circle appropriate score

2 1 0

2	Turned off IV Pump
1	Had trouble but turned off IV Pump
0	Could not turn off IV Pump

Time completed (seconds): ______________

Points out of 80: _____________

Appendix P

Revised Tutor Instructions for IV Pump Stage 3

NUR2000 Tutors: Module 7 IV Pumps

NB: Please ensure you provide explanation and demonstration of the functions of an IV Pump within the first 15 min for each of your laboratory groups. Please strictly follow these guidelines as set out below.

At commencement of lab class demonstrate use of IV pump to all students.

Instruct students:

- Wash hands, select equipment and check the order for IV Sodium Chloride 0.9% with another student.
- Ask students to prime IV giving set (as per week 5)

Explain and demonstrate:

- Routine IV pump checks
- Press **ON/OFF** button and follow prompts
- Press and hold **Speaker Key** and listen for the sound
- Did you hear the sound? Select **YES or NO**
- Select **New Patient**
- Select **Done**
- Select **Open** and load IV giving set into the IV pump
- Reinforce how the blue key clamp is inserted into IV pump and refer students to video on study desk
- Open roller clamp
- Consult IV order again for rate and volume

Order: 1000mL Sodium Chloride 0.9% over 12 hours

Formula: Volume/Time (hrs)

- **Rate**: 83mL/hr

Volume: set Volume to be Infused (VTBI) suggest for 10% less than the amount in the flask to prevent air in the line and preparation for next bag of IV fluid

- **Volume**: 900mL OR anything in the range of 500mL – 950mL
- Wipe IV bung with Alco-wipe
- Flush IV bung with 5mL of Sodium Chloride 0.9%
- Perform the **6 Rights** of Medication Safety
- Attach IV line to bung and secure with tape
- Select **Primary**
- Select **Start**
- Sign the IV fluid orders and document on fluid balance chart

Students to practice on IV pump for remainder of class.

Appendix Q

Qualitative Responses from User Perception Survey Stage 3

Question 4a). What were the best features of the online IV pump?

ID Grp 1	Responses
12	*Saves time and easy to manage*
13	*Prompts to assist*
15	*How accurate it is*
18	*How realistic it is to the real pumps*
19	*Easy to understand and work through*
20	*The best was that the pump stopped and beeped when you forgot to do something*
23	*The setting of the rate and volume*
25	*It's easy to use if practice. Right dose or exact dose in time can be given*
26	*Graphics – ease of direction*
27	*Being able to physically set the rates and volumes as if a real pump*
28	*Don't like an online pump*
29	*Allows practice when at home*
30	*Ability to practice anytime*
31	*It's basically the same as the real thing*
32	*Very realistic*
33	*Accurate rate and volume*
34	*It reduces the workload as it a time consuming method for nurses*
35	*Best features were the well reproduced dials and easy to follow prompts*
36	*Visually showing what needed to be done made it easy to understand*
37	*Having an online pump to use anytime with scenarios*
38	*Having no calculations for drops*
39	*It was very clear – good graphics and great to do it from home*
40	*Real use of a pump at home. Good to use as external student and to brush up on skills*
41	*Strong features of the online IV pump is that it looks very similar to the actual pump and it makes the same sounds as well. The online IV is a great teaching tool.*
42	*It actually shows where everything is and sounds like a real pump*
43	*It exposes the external students on how the real IV pumps look like and how to operate it. It is very helpful to those who haven't seen it before, like me.*
44	*The pump is a great learning tool – user-friendly*
45	*Great opportunity to learn especially via distance – well done!*
47	*Proper dose administration and it alarms when you leave it or do something wrong*
48	*The interface was very similar to the real IV pump so when I came to use the real one it was familiar*
49	*Exactly the same as the real machine*
51	*Learning how to use in your own time and then getting more time to practice*
52	*Easy for the external students to practice online and got to use it before coming to residential school*
53	*Enable access to the pump that I otherwise wouldn't have. Great for inexperienced students*

54	*Warnings and checks*
166	*Visual likeness, prompts and sounds*
167	*So realistic*
169	*Prompts were very helpful – easy to use*
170	*The steps to inform you if something is incorrect*
171	*Warning signals*
172	*Building in the rates and volume*
173	*How it prompts you*
174	*The picture was exactly like the real image. If I had more time I would like to play with it more.*
175	*Learning mode was very supportive*
176	*Very similar to actual pump*
177	*The onscreen instructions*
178	*That it is pretty easy to work through*
179	*Being able to work through it on your own, time to play around and figure it out*

Question 4a). What were the best features of the online IV pump?

ID Grp 3	Responses
116	*Just like the real thing*
117	*The sounds, the prompts, the access*
118	*Exactness to the real pump*
120	*Learning how to use an IV pump without the physical resources*
121	*The pop up boxes with tips*
122	*Easy to practice on especially at home and the detailed outline of what I had to do, ease of instructions*
123	*The steps of the 6 rights and all the steps of the IV pump*
126	*Easy to use*
127	*Virtually identical to pump*
128	*It is easy to work out rate and run it. Accordingly it was very helpful while it makes the alarm, it will let the nurse know about if they are doing anything wrong*
129	*The case studies and diagrams. Presenting realistic case studies was good*
130	*It was easy and we do it several times*
131	*Very realistic*
132	*Instructions, images. The things included were helpful for students*
133	*Same as a real pump*
134	*That it was the same as a normal one*
137	*It was good practice*
139	*Great work*
140	*It's accessible*
141	*Hands on and the automatic control sensor*
143	*There was a lot of information and you could practice anytime*
144	*Setting the rate and volume*
145	*The case studies really helped to understand how to calculate and use the IV pump*
146	*The best feature about the IV pump was that I can use it whenever it is applicable*
148	*It was easy to use and it was colourful*
149	*We can do it anytime we are free*
150	*Great*
151	*Instructions were provided step by step*
151	*The instructions were easy to understand and helpful in lab*
153	*Working out the different things the IV pump can do and changing the drip rate*
154	*I was able to practice as the IV pump was not available*
155	*It was clear and easy to use and also very realistic*
156	*It was easy and helpful and exactly like the real one*
157	*All good*
158	*The set up*
159	*When something is not right it will let you know*
160	*Clear instructions*
161	*The best feature was it was good to try it and practice*
163	*The highlighted buttons that prompted you to push them*

Question 4b). What features of online IV pump could be improved?

ID Grp 1	Responses
12	*Explain detail*
15	*Unsure*
20	*Nothing*
23	*Need more scenarios*
25	*Sound should be a bit lower*
26	*Clicking the mouse*
27	*No features that I can think of*
30	*Unknown*
31	*I'm not too sure*
32	*More access to it*
35	*Fairly straight forward and logical. No real need for further improvement*
36	*Change scenarios to complicate it a bit*
38	*Everything ok*
39	*Nothing at this stage*
40	*The ability to fast forward in the scenarios*
41	*When I used the online version there were two instances where it froze up maybe because of the internet connection in the lab*
42	*None*
43	*Maybe clear demonstration on how to insert the tube*
45	*Nil*
47	*According to me - nothing*
48	*The buttons don't always click the first time*
49	*Remove the prompts to help assess knowledge*
51	*Having to drag the line in*
52	*None*
53	*I was quite unsure about inserting the line but that is something that can't be replicated on this and physical experience is best tin that situation*
54	*I would prefer if newer and modern IV pumps were developed electronically.*
166	*None*
167	*Nothing really*
170	*Not sure*
171	*Loading the tube into the pump needs to be clearer*
172	*I'm not sure*
173	*More instructions on how to feed the IV line through*
174	*I found reading all of the instructions took me away from realising what I was actually doing*
175	*No features need to be improved*
176	*Nil*
178	*Nothing really*
179	*Need a real pump to practice on afterwards*

Question 4b). What features of online IV pump could be improved?

ID Grp 3	Responses
118	*None*
119	*A clearer demonstration*
121	*Nothing*
122	*Nothing at all*
123	*Newer looking pump*
126	*N/A*
127	*Nothing really*
128	*Nothing*
129	*Nothing*
130	*Nothing, everything is good*
131	*Nothing really*
133	*Nothing*
137	*Yes*
139	*Nothing*
140	*Time consuming*
141	*The loading bay for the IV tube*
143	*Nothing*
144	*Loading the IV set*
145	*Nothing*
146	*Nothing really, I find the online IV pump pretty good*
148	*Pressing the buttons was hard in some cases*
149	*Nothing, everything seems pretty good*
150	*None*
151	*Instructions could have been given beforehand*
152	*Nothing*
153	*Nothing*
154	*I can't think of anything sorry*
155	*None*
156	*The tubing loading*
159	*More direction with words*
160	*Nothing*
161	*Nothing*
163	*Access*