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The role of simulation-based learning environments in preparing undergraduate health students for clinical practice

Brennen William Mills B.Sc. (HONS) (PUBLIC HEALTH)

This thesis is presented for the degree of Doctor of Philosophy

School of Medical and Health Sciences

Edith Cowan University

2016

Principal Supervisor: Professor Cobie Rudd

Co-Supervisor: Associate Professor Owen Carter

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To **Associate Professor Owen Carter**—I am yet to encounter a person who better understands research in all its glory and subtleties, who provides options where I thought there were none, who provides solutions where I saw only problems, and who comprehends practical applicability where I struggle to see value. What I further appreciate though, something I value far more than access to your knowledge-base, is your friendship.

Earlier when I referenced my family, I made light of the 'interest' they showed in my academic/professional life, as for many not involved in the field, it can often be difficult to interpret or understand our language, our processes and what we value. My father though was different. He was an engineer, a paraplegic from the age of 46, and experienced near-constant pain day-in and day-out in the nerve-endings in his finger-tips, yet that did not deter him from truly wanting to understand what I did, what it meant and why I did it. To my father, **Rick Mills**, unexpectedly losing you in December last year was unquestionably the most tragic time of my life, but the life lessons you embedded so strongly within me saw this thesis through to completion. I cannot thank you enough, and dedicate this accomplishment to you.

ABSTRACT

Experiential learning (EL), whereby students are able to integrate theory with practice, is an essential component of learning for health professionals. Traditionally, EL in the health education context has been achieved through clinical placements (CPs) that see students ‘apprentice’ in real clinical settings. The literature suggests there are a number of factors that diminish a student’s ability to learn in such environments, including limited opportunities to practice, being confined primarily to observation roles as opposed to participate in tasks, being exposed to skills/procedures outside their level of learning/understanding, and institutional learning objectives being secondary to workplace goals. Simulation-based learning environments (SLEs) have been espoused as an effective alternative to traditional CPs, as they provide EL opportunities void of patient risk, and can be targeted to suit the needs of both teacher and learner. While many advocate that SLEs are the logical teaching modality for preparing students to practice in real clinical environments, the fast adoption of SLEs in health education has far exceeded evidence of its effectiveness in comparison to learning occurring via CPs. Research investigating SLEs to date has, for the most part, relied upon subjective measures of student satisfaction, confidence and competence and has utilised single-group analyses providing no yardstick for comparison. The present research sought to explore the value of SLEs for undergraduate health students in comparison to CPs, as well as investigate methods of improving the educational benefit of SLEs.

This thesis is presented as a series of papers (i.e. PhD by publication) addressing the role of SLEs in health education. Study One investigates how social evaluation anxiety (SEA) impacts on performance amongst a sample of final-year nursing students. It was found that through increasing the number of professional actors in a simulation-based clinical scenario, social evaluation anxiety increased to an extent sufficient to detrimentally affect student performance. Thus, the study concluded that students would likely benefit from additional authentic exposures to EL opportunities earlier throughout their curriculum, so as to acclimatise them to real patient and person interaction. Studies Two and Three explore the differences and relationship between SLEs and CPs amongst first-year paramedicine students. The extent to which SLEs provide additional learning benefit in subsequent CPs was first established, followed by evidence suggesting this is most likely attributable to the increased opportunity for repetitive and targeted practice

in SLEs, compared to clinical placement (CP) exposures being reliant on random patient presentation. Studies Four and Five describe how manipulating the simulation-based learning environment (SLE) can enhance or diminish educational outcomes. It was found that removing the instructor from the SLEs lessens student intimidation, promotes ownership over the scenario, and narrows focus toward patient wellbeing, as opposed to instructor assessment. Similarly, it was found that through increasing environmental fidelity, the corresponding increase in psychological fidelity led to an expedited and improved performance of clinical skills.

This thesis provides objective evidence describing the contribution SLEs can make to improved learning outcomes amongst undergraduate health students. The research has important implications for education providers seeking to progress the patient safety agenda by implementing SLEs into their undergraduate programs, as well as to researchers seeking to conduct evaluations of the same.

PUBLICATION LIST

PUBLICATIONS (IN ORDER PRESENTED IN THESIS)

1. **Mills B**, Carter O, Rudd C, Claxton L, O'Brien R. (submitted for second review 30.11.2015) An experimental investigation into the extent social evaluation anxiety impairs performance in simulation-based learning environments. *Nurse Education Today* (Chapter Three of this thesis).
2. **Mills B**, Carter O, Rudd C, Ross N, Claxton L. (accepted for publication 22.07.2015) Clinical placement before or after simulation-based learning environments? A naturalistic study of clinical skills acquisition amongst early-stage paramedicine students. *Simulation in Healthcare* 2015;**10**(5):263–9 (Chapter Four of this thesis).
3. **Mills B**, Carter O, Rudd C, Mills J, Ross N, Ruck J. (accepted for publication 19.04.2015) Quantification of opportunities for early-stage paramedicine students to practice clinical skills during clinical placements compared to an equal dose of simulation-based workshops. *BMJ Simulation and Technology Enhanced Learning (STEL)* 2015; DOI:bmjstel-2015-000040 (Chapter Five of this thesis).
4. **Mills B**, Carter, O, Ross N, Quick J, Rudd C, Reid D. (accepted for publication 06.01.16) The contribution of instructor presence to social evaluation anxiety, immersion and performance within simulation-based learning environments: a within-subject randomised cross-over trial with paramedic students. *Australasian Journal of Paramedicine* (Chapter Six of this thesis).
5. **Mills B**, Carter O, Rudd C, Claxton L, Ross N, Strobel N. The effects of low- versus high-fidelity simulations on the cognitive burden and performance of entry-level paramedicine students: A mixed-methods comparison trial using eye-tracking, continuous heart-rate, difficulty ratings scales, video observation and interviews. *Simulation in Healthcare* 2016; **11**(1):10–8 (Chapter Seven of this thesis).

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LIST OF ABBREVIATIONS

ABBREVIATION	DEFINITION
CI	Confidence interval
CP	Clinical placement
CPs	Clinical placements
CPF	Challenge Point Framework
DP	Deliberate practice
ECU	Edith Cowan University
EL	Experiential learning
HFS	High-fidelity simulation
INR	International Normalisation Ratio
LFS	Low-fidelity simulation
NASA-TLX	National Aeronautics Space Administration Task Load Index
NCSBN	National Council of State Boards of Nursing
SBL	Simulation-based learning
SBME	Simulation-based medical education
SEA	Social evaluation anxiety
SLE	Simulation-based learning environment

SLEs	Simulation-based learning environments
US	United States
USA	United States of America
Bpm	Beats per minute
μg/dL	Micrograms per deciliter

CHAPTER ONE

INTRODUCTION

1.1 THE PROBLEM

Experiential learning (EL), whereby students are able to integrate theory with practice, is an essential component of learning for health professionals [1]. Without physically applying knowledge and skills, students would be unable to practise and reflect on their skills development, be they of a 'hands-on'/clinical or more ethereal/non-technical (e.g. communication, decision-making) nature. Traditionally, EL in the health education context has been achieved through clinical placements (CPs) that see students 'apprentice' in real clinical settings. The literature suggests a number of factors that diminish students' ability to learn in such environments, including: limited opportunities to practise; being confined to primarily observe as opposed to participate in tasks; being exposed to skills/procedures outside their level of learning/understanding; and institutional learning objectives being secondary to workplace goals [2–5]. Further, an ongoing consideration involves patient safety, whereby students are essentially learning by 'practising' on real patients. It is clear that today's patient is more informed and has higher expectations than in previous decades and is therefore less comfortable participating in the teaching of novice health professionals [6]. Also, the greater amount of patients, and the need for clinical settings to treat and discharge patients quickly, means even less attention is paid to facilitating a suitable learning environment for novice learners. These factors, coupled with greater student enrolments, have seen demand for CPs grow to the extent that it now far exceeds supply [7–9].

Simulation-based learning (SBL), which occurs within simulation-based learning environments (SLEs), has been adopted as an effective alternative to traditional CPs, as it provides EL opportunities void of patient risk [10], and can be targeted to suit the needs of both teacher and learner [11, 12]. While many advocate that SLEs are the logical teaching modality for preparing students to practise in real clinical environments, the fast adoption of SLEs in health education has far exceeded evidence of its effectiveness in comparison to learning via CPs. Further, in many cases, instructional and design features of SLEs that best contribute to student learning remain undetermined.

7.2 RESEARCH AIMS

This research seeks to address an overarching research question - To what extent can SLEs prepare students for practice in real clinical settings? This thesis is not designed to provide a definitive answer to this question, but to add to existing evidence. In saying this, the author notes the conclusions from several systematic reviews investigating the effectiveness of SLEs in health education [e.g. 13–20] that the majority of existing evidence pertaining to the use and evaluation of SLEs is typically weak and oftentimes draws unfounded inferences from presented data (to be elaborated on in Chapter Two). Thus, the experiments included in the present thesis attempt to utilise stringent and rigorous methodologies, with appropriately and modestly drawn conclusions based on research findings.

7.2 SIGNIFICANCE OF THE RESEARCH

In answering the research question described above, where this research will potentially make its greatest impact is through the use of a variety of novel, yet objective and rigorously applied measures, as well as the use of equally-dosed comparison groups. This research question has certainly been targeted by researchers in the past. However, a consistent flaw identified from systematic reviews investigating the usefulness/effectiveness of SLEs in health education is the need for more objective, rather than subjective, measures. The reviews describe that published papers regularly associate 'effectiveness' with subjective ratings of satisfaction or self-efficacy. While being able to judge perceived satisfaction does provide indication of the acceptance of the teaching and learning modality (an important consideration) such measures fail to provide evidence suggesting their ability to translate to improvements in learning outcomes. Further, systematic reviews describe the majority of published works as utilising single-group analyses that fail to compare SLEs to any other form of learning, and those that do typically compare SLEs to a didactic or lecture-based intervention.

Studies utilising these research designs would typically fall into the first and lowest level of Kirkpatrick's model of training evaluation (i.e. reactions to the training program) [21]. This research attempts to gather evidence at the second stage of the model—"quantifiable indicators of the learning that has taken place during the course of the training." (i.e. quantifiable improvements in learning outcomes)—findings that likely more accurately gauge the "effectiveness" of a training method compared to any other than self-reported satisfaction, or perceived improvements in confidence or competence.

1.4 CONCEPTUAL FRAMEWORK

This research will test the use of the Challenge Point Framework (CPF) in health education (see section 2.2). The CPF has some criticisms in the literature with some believing the model can be misinterpreted to put too much pressure on novice students too early throughout their learning progression [22]. This PhD seeks to use the model as a predictive framework to aid in the conceptualisation of study results and in the answering of the overarching research question.

1.5 THESIS OUTLINE

This thesis is presented as a series of papers addressing the role of SLEs in health education. The first study demonstrates the importance of providing authentic/realistic EL for undergraduates. The second investigates 'when' SLEs should be undertaken in comparison to CPs. The third study examines the strengths and weaknesses of SLEs and CPs with respect to providing opportunities to practise level-appropriate clinical skills. Studies four and five explore specific aspects of simulation 'fidelity' and how increasing the realism and associated 'stressors' in SLEs impact upon learning and performance at different stages throughout the learning continuum. A logical flow diagram detailing the major finding from each study and how this links with the following study is provided in Figure 1.1.

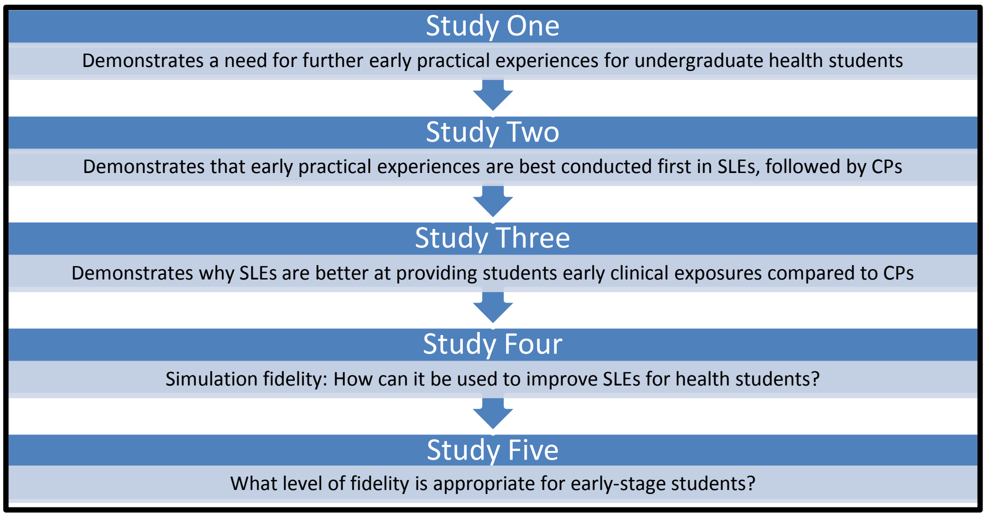

Figure 1.1 Graphical representation of flow between studies

1.5.1 CHAPTER TWO – REVIEW OF THE LITERATURE

The literature review builds the context of the thesis through a comprehensive background of issues related to the thesis and previously published research. It elaborates on the gaps in current knowledge and provides a theoretical rationale for the research.

1.5.2 CHAPTER THREE – STUDY ONE

AN EXPERIMENTAL INVESTIGATION INTO THE EXTENT SOCIAL EVALUATION ANXIETY IMPAIRS PERFORMANCE IN SIMULATION-BASED LEARNING ENVIRONMENTS

The aims of this study are to examine the effects realistic clinical environments have on near graduates' anxiety levels, and, in-turn, if this anxiety impacts on clinical performance.

The study hypotheses are:

- Greater numbers of confederate actors in SLEs will result in higher levels of distress in students.
- Higher distress will result in students' poorer clinical performances in SLEs.

1.5.3 CHAPTER FOUR – STUDY TWO

CLINICAL PLACEMENT BEFORE OR AFTER SIMULATION-BASED LEARNING ENVIRONMENTS? A NATURALISTIC STUDY OF CLINICAL SKILLS ACQUISITION AMONGST EARLY-STAGE PARAMEDICINE STUDENTS

The aims of this study are to investigate the following claims:

- Early-stage CPs facilitate contextualisation of subsequently learned theory.
- Training in SLEs should occur before CPs to ensure students possess at least basic competency.

The study hypotheses are:

- Early-stage students will perceive early CPs as more challenging than SLEs.
- Early-stage students completing SLEs before CPs will evidence better clinical skills learning outcomes than students undertaking CPs before SLEs.

1.5.4 CHAPTER FIVE – STUDY THREE

QUANTIFICATION OF OPPORTUNITIES FOR EARLY-STAGE PARAMEDICINE STUDENTS TO PRACTICE CLINICAL SKILLS DURING CLINICAL PLACEMENTS COMPARED TO AN EQUAL DOSE OF SIMULATION-BASED WORKSHOPS

The aim of this study is to provide evidence for the widely held belief (yet not demonstrated empirically) that SLEs provides a greater number and breadth of opportunities to practise level-appropriate clinical skills compared to the random patient presentations students are exposed to during CPs.

The study hypothesis is that SLEs will provide greater opportunity for early-stage students to practise level-appropriate clinical skills compared to CPs.

1.5.5 CHAPTER SIX – STUDY FOUR

THE CONTRIBUTION OF INSTRUCTOR PRESENCE TO SOCIAL EVALUATION ANXIETY, IMMERSION AND PERFORMANCE WITHIN SIMULATION-BASED LEARNING ENVIRONMENTS: A WITHIN-SUBJECT RANDOMISED CROSS-OVER TRIAL WITH PARAMEDIC STUDENTS

The aim of this study is to investigate the extent to which instructor presence in SLEs impacts on social evaluation anxiety, immersion and performance of early-stage students.

The study hypotheses are, compared to clinical scenarios in SLEs with an instructor present, those with an instructor absent will:

- Decrease students' social evaluation anxiety.
- Increase students' immersion within the task.
- Facilitate better student performance.

1.5.6 CHAPTER SEVEN – STUDY FIVE

THE EFFECTS OF LOW- VERSUS HIGH-FIDELITY SIMULATIONS ON THE COGNITIVE BURDEN AND PERFORMANCE OF ENTRY-LEVEL PARAMEDICINE STUDENTS: A MIXED-METHODS COMPARISON TRIAL USING EYE-TRACKING, CONTINUOUS HEART-RATE, DIFFICULTY RATING SCALES, VIDEO OBSERVATION AND INTERVIEWS

The aim of this study iss to investigate the claim that high-fidelity SLEs are ill-suited to early-stage students due to multiple processing demands typical of high-fidelity simulation (HFS), and that this results in increased cognitive requirement to the extent of 'cognitive overload' leading to poorer learning outcomes.

The study hypotheses are that early stage students undertaking a simulation-based clinical task in HFS compared to low-fidelity simulation (LFS) will:

- Experience greater psychological fidelity (i.e. suspension of disbelief).
- Experience greater cognitive burden.
- Perform the clinical task worse.

1.5.7 CHAPTER EIGHT – SYNTHESIS OF FINDINGS AND CONCLUSIONS

The final chapter seeks to provide an overall synthesis of results presented in the thesis, integrating the major findings from each study and providing an overall summary of the research scope and avenues for future research.

1.5.8 THESIS AS A SERIES OF PAPERS

Edith Cowan University supports the submission of PhD theses that comprise a series of papers prepared for publication. ECU's *Postgraduate Research: Thesis with Publication*, 2012 Guidelines outline that the submitted thesis can consist of publications that have already been published, are in the process of being published, or a combination of these (pg. 2) [23]. These guidelines also state that the number of publications submitted will vary between disciplines and projects, but should be sufficient for the body of work to constitute a substantial and original contribution to knowledge (pg. 2) [23].

This structure has been adopted by the candidate in the submission of this thesis. As such, while the theoretical linking between the studies/papers should be clear for the examiner, each study must be stand-alone in content. Consequently, theses adopting a series of papers approach sometimes result in repetition of literature and methodology from study to study.

1.6 STRENGTHS AND LIMITATIONS OF THE GREATER RESEARCH

While strengths and limitations of each individual study are discussed in their respective chapters, the greatest overarching strengths of this thesis are the use of primarily objective, quantitative measures to answer research questions, as well the use of equally-dosed control/comparison groups. Qualitative data is often used to substantiate, contextualise and explain objective findings.

The most prevalent limitation of the present research that should be acknowledged when interpreting the results is the generalisability of study findings. Each study utilised data from a single cohort of students at one institution (ECU). That is, replication of study findings with other samples and disciplines from other institutions would be necessary to confirm the generalisability of results.

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CHAPTER TWO

REVIEW OF THE LITERATURE

2.1 EXPERENTIAL LEARNING

EL provides learning opportunities for students to obtain and apply knowledge and skills in an immediate and applicable setting [1]. It is contrasted to learning obtained from reading, hearing about, talking about or writing about events, but the student never actually comes into contact with the studied occurrence [2]. The work of Dale in the 1960s concluded that learners actively engaged in their learning retain 90% of what they learn, compared to a retention of 10% of what they learn through reading [3]. EL seeks to link theory and practice by providing direct encounters with the learning event. Thus, previously learnt knowledge can be physically observed or applied in the context of real life settings [4]. Kolb provides a summation of this concept in articulating: "Experiential learning is the process whereby knowledge is created through the transformation of experience" (pg. 41) [2].

A systematic review investigating faculty development interventions that work to improve the knowledge, attitudes and skills of teachers in medical education suggests there is a consensus amongst health and medical educators with respect to the importance of EL in healthcare education to the extent that the approach has become one of the corner-stones of health curricula development [5]. A number of authors suggest the process of applying knowledge, practising skills and receiving feedback is essential to progress from novice to expert practitioners [6-8].

However, during EL exposure, at times the process of linking previously acquired knowledge to practise can be difficult, particularly with students' differing learning styles and progressions [9]. In order for students to contextualise the skills to which they are being exposed, they must have first acquired the appropriate theoretical knowledge or understanding, usually best obtained within the classroom environment through traditional didactic learning settings (i.e. classroom lectures). Should students undertake EL of skills to which they are unfamiliar, learning will suffer and the experience potentially wasted (or at the very least not maximised) [10].

2.2 THE CHALLENGE POINT FRAMEWORK

Guadagnoli and Lee first discussed the application of the Challenge Point Framework (CPF) to skill development in a published paper in 2004 [11]. Since then, the framework has appeared in numerous papers including samples from various populations such as children, geriatrics, patients suffering from Parkinson's disease, rehabilitation patients, golfers and automobile drivers [12–16]. The framework describes a learning model that aligns with a quote from a book entitled "Happiness Hypothesis"- "People need adversity, setbacks, and perhaps even trauma to reach the highest level of strength, fulfillment, and personal development" [17]. While Guadagnoli and Lee acknowledge fully that repetitive practice is considered the most important factor for learning and subsequent improvements in performance, at the core of the CPF lies the notion that best success is derived from overcoming adversity.

The CPF provides a conceptual basis for how and when students should be exposed to EL events throughout their learning progression. It suggests optimal performance is achieved when students are provided with a level of challenge that is difficult but appropriate to their current stage of learning; practice performance becomes suboptimal if the challenge is set too low—leading to low engagement in the task —or too high, leading to 'cognitive overload' (see Figure 2.1) [18]. It has long been established that low task engagement is linked with poorer learning outcomes and knowledge retention [19–21]. However, the influences of cognitive overload on such factors are less clear.

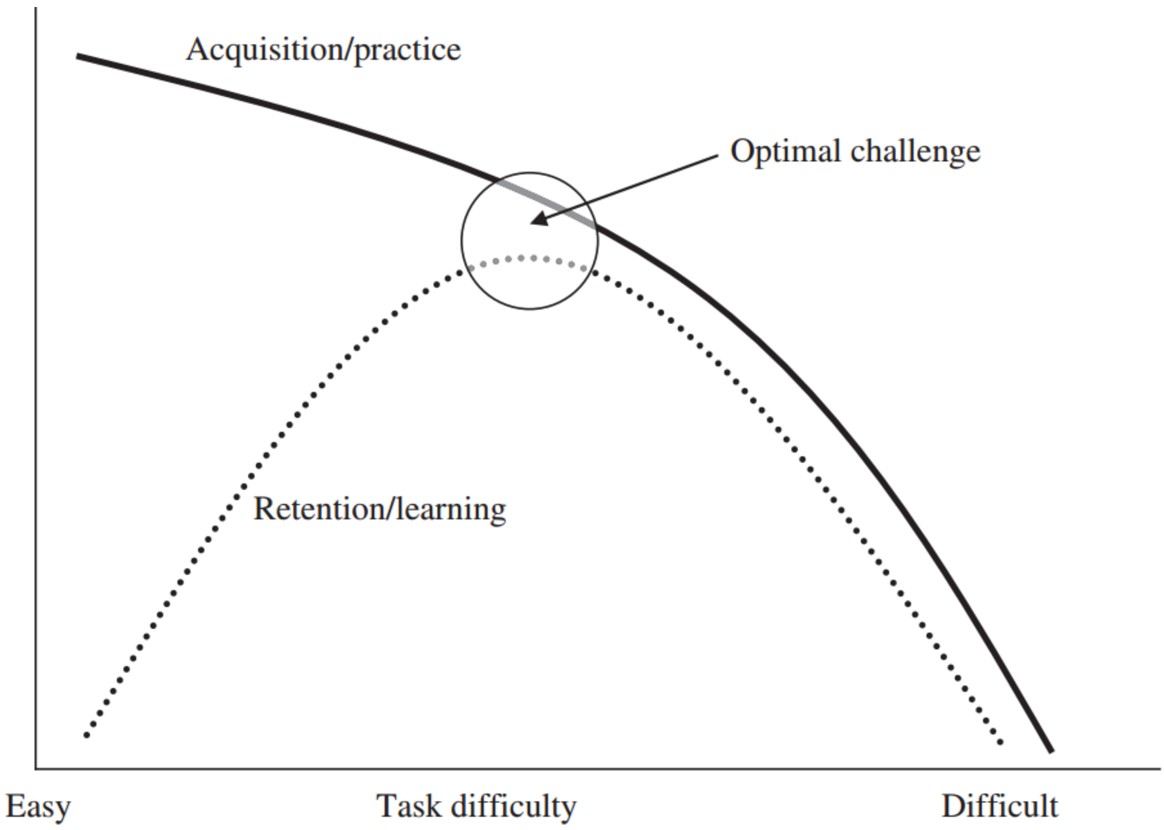

Figure 2.1 Relationship between learning and task difficulty by Guadagnoli *et al*.

Guadagnoli *et al*. suggest the level of 'challenge' associated with performing tasks in experiential health education is dependent on two aspects: (1) the actual physical difficulty of the task being undertaken, and (2) the psychological perceptions of the student [18]. When one or both of these factors exceed the student's current level of competency, be it theoretical understanding or lack of practical experience, the CPF suggests the student will experience a heightened cognitive burden that will impact negatively on learning. Therefore, during the initial stages of learning acquisition, information should be presented in smaller, more manageable units so as to not overwhelm the student. After an introduction to the skill in question, at a later stage of learning, the cognitive system's ability to group and process information improves thus allowing the learner to more efficiently handle more demanding practical experiences without experiencing too high a cognitive burden [22].

There are several ways educators can manipulate either the physical difficulty or psychological perception of a task attempting to align 'challenge' with students' current stage of learning. For instance, with respect to 'physical difficulty', a novice learning a new skill can (and likely should) be presented with performance feedback after each performance, thereby allowing the student to compare their performance with feedback. However, as students become more familiar with the task, feedback can become limited so students can work out the details of their performance for themselves. Another method involves manipulating the quantity of extraneous tasks likely to detract from focus on the central task. For example, early-stage learners can (and again, should) be asked to practise one task at a time, such as suturing or chest compressions. For more advanced learners, it may be fair to expect students to perform a number of skills all at once such as performing an incision, clamping and suturing, or forcing air into an airway, chest compressions and ECG monitoring.

The other factor that educators can seek to manipulate is the perceived psychological consequences associated with their practice performance. For early-stage learners, it would not be appropriate to place any form of 'consequence' on their performance having had no previous experience undertaking the skill in question. However, for more experienced students, say final year students near graduation, it may be appropriate to expose them to the consequences of performing skills incompetently, or at the very least ensure understanding of the implications of poor skill performance, be they patient safety or otherwise.

In essence, the CPF contends that educators should seek to provide sufficient challenges to the learner throughout the stages of their learning progression. Doing so will maximise practice performance and learning retention. However, problems arise when educators are unable to exhibit control over their own teaching practices. While this is less common for didactic teaching methods, it can be a problem when providing EL opportunities, in particular through CPs.

2.3 CLINICAL PLACEMENTS

EL in health has traditionally been dominated by education occurring via CPs. For example, clinical education in nursing is viewed as an integral and essential component of student learning. The Australian National Review of Nursing Education (2002) states "While university programs may skill [sic] students on particular procedures in laboratory situations, the actual exposure to nursing in its various settings is essential to their understanding of the profession and to the development of competence at the beginning practice level for registration” (pg. 59) [23]. The majority of other health professions also support the inclusion of a substantial amount of clinical placement (CP) hours in undergraduate education [24–26].

Results of several qualitative studies uniformly suggest high satisfaction with CP experiences [27–30]. However, some studies identify a number of issues that decrease students’ satisfaction with CP learning, including insufficient opportunities to practise skills, relegation to purely observatory roles, unproductive downtime, poor relationships with overworked preceptors and limited opportunities to practise patient care [25, 31–33]. Further, when considering the application of the CPF to EL in CP settings, exercising control over the events to which students are exposed can be difficult. For example, for early-stage students, exposure to basic clinical skills (e.g. pulse taking) is more appropriate than more advanced skills such as intubation or catheter insertion. To some extent, this can be controlled by sending students to health settings primarily dealing with patient cases of an appropriate level, but the vagaries of random patient presentations mean luck plays some role in whether students receive exposure in alignment with their current level of theoretical and practical capacity [34–36]. Grealish and Trevitt point out that placements occur at workplaces where student learning is secondary to workplace goals, and placements are dynamic in nature such that neither the student nor faculty has control over the type of experience gained [37].

It has been argued that simply sending students on CPs does not assure learning or improved clinical competency [38] with one publication going so far as to suggest CPs can be far from the ‘ideal’ learning environment [37]. Others reiterate the importance of providing CPs ‘at the right time’ to allow practice to complement students’ current theoretical understanding [27]. An obvious solution is to delay sending students on CPs until later in their degrees to maximise theoretical understanding prior to linking theory to practice. However, many argue the importance of ‘vertical integration’ of CPs across all years of undergraduate education as the contextualisation of clinical skills in real-world settings, even basic ones, expedites learning [39, 40]. Others counter that there is no clearly articulated case for vertical integration, nor empirical evidence in its favour [41]. For example, Battersby and Hemmings provide evidence suggesting the quantity of time spent in the clinical area may not be as significant as the quality of the experience and guidance the student receives [42]. Support offered to students in the clinical setting can vary across different CP sites; an aspect often beyond the control of the education institution.

Unfortunately, it is likely these issues are to only become more prominent in the coming years due to the simple fact that the number of students requiring placement continues to increase. The increased demand on global health systems has resulted in more students requiring undergraduate CPs in Australia, to the point that demand now exceeds supply [43–45]. This is often compounded by limited funding for training, staff shortages, limited access to suitable clinical supervisors, limited access to patients and competition for CPs between health care disciplines [46, 47]. Such issues limit the opportunity for students to put into practise previously learnt theory, which some argue has already impacted negatively on the progression from novice to experienced health practitioners, and ultimately threatens to lower levels of professional competence [48–50].

This is particularly alarming when considering the issue of patient safety. There are obvious ethical considerations corresponding to under-qualified practitioners practising on real patients, both pre- and post-graduation. It is suggested that today's average patient is better informed, has greater expectations and no longer wants students 'practising' on them or their children, particularly those involving potentially invasive procedures [51]. However, it is well-recognised that there is great learning benefit derived from the analysis of errors[1] [52], but with errors during early stages of learning not being tolerated by patients in CP settings, this potential avenue for learning is lost.

There is little doubt CPs are a necessary form of EL for health professionals. It is likely this even extends to early-stage students, as early-stage CPs can work to broaden understanding of the greater healthcare system and introduce students to the importance of interprofessional practice [41, 53]. However, the difficulties associated with aligning placements with level-appropriate exposures, a difficult process even without demand for CPs exceeding supply, coupled with patient safety considerations, indicate that we

[1] "*An expert is a person who has made all the mistakes that can be made in a very narrow field*." – Neils Bohr (1885–1962)

should not rely on CPs alone to produce sufficient opportunity for EL. This conclusion is further supported when considering the CPF, suggesting an appropriate level of challenge should correspond with students' increases in competency. Since educators have little control over clinical opportunities students are exposed to on CP it can be exceedingly difficult ensuring exposures align with an appropriate level of 'challenge' (i.e. not too easy or too hard) on CP. Creating new sustainable models for clinical experience that align with the Australian National Registration and Accreditation Scheme requirements is a priority across sectors to increase students' opportunities to gain authentic clinical experience. Simulation-based learning environments (SLEs) are widely suggested as part of the solution.

2.4 SIMULATION-BASED LEARNING ENVIRONMENTS

Some contend simulation has been used in health education for the past 40 years [54] but others argue that clinical simulation has been used in primitive forms for centuries, well before the advent of plastics or computers [55]. However, only in the past 15–20 years has the teaching modality undergone widespread adoption [56]. Innovations in flight simulation, resuscitation, technology, and plastics were essential components adding to the acceptance and adoption of simulation in health education.

Today, SLEs are incorporated to varying degrees in undergraduate curricula for the majority of health professions in Australia mirroring its increasing popularity overseas [56–63]. For example, an audit of n=47 Schools of Nursing/Schools of Nursing and Midwifery with Australian Nursing and Midwifery Council accredited undergraduate/entry to profession nursing programs found 94% of respondents use simulation as a "skills-lab," and almost half (44%) have a dedicated simulation suite with more than half (52%) of those that didn't stating they were intending to develop one [64].

The increased use of simulation in health care training comes from a worldwide shift toward outcome-based education throughout all health professions. This transference originates from attempts by academic institutions to meet quality standards in response to the public's demand for assurances that health professionals are competent to practise at the time of graduation [65].

Simulation has been defined by Gaba as "…a technique, not a technology, to replace or amplify real experiences with guided experiences, often immersive in nature, that evoke or replicate substantial aspects of the real world in a fully interactive fashion." [pg. i2, 56] In the health education context, SLEs aim to replicate real clinical settings through the imitation of real patients, real patient ailments, clinical procedures and clinical settings [66].

Some educators favour SLEs for providing EL opportunities as it can be tailored to align with level-appropriate theoretical knowledge and skill and allow exposure to a consistently wide variety of clinical encounters, some rarely faced during CPs [67, 68]. Thus, an obvious attraction of SLEs is that students can be more assured of practice opportunities 'at the right level' with minimal downtime, without undue risk to patients being treated by students with limited experience. The applications of simulation range from training of routine skills through to critical events training [69, 70] and assessment of competency [71, 72]. Other benefits of SLEs include easy access to EL in a secure, controllable and replicable environment [67] void of patient risk [73] that allows training of both novices and experienced practitioners from multiple health disciplines [74, 75]. Gallagher *et al.* describe simulation-based learning (SBL) as a minimally invasive teaching modality that moves students from inactive observers to hands-on participants but also discusses the limitations to date in simulation-based learning environment (SLE) evaluation research [76].

2.5 SIMULATION-BASED LEARNING ENVIRONMENTS RESEARCH

The clear majority of research that seeks to evaluate the extent to which SLEs provide an effective learning environment for health students has focused on participant perceptions of satisfaction and confidence/self-efficacy [77]. These studies consistently suggest students enjoy SBL [78–81] and result in improvements in students' self-reported confidence [82–85]. While this provides a reasonable indication of students' acceptability of the teaching method, an important consideration, self-report measures are prone to error due to factors such as social desirability bias. Much of the research attempting to quantify improvements in clinical competence also suffers from similar self-reported bias issues; problematic, as the accuracy of students' self-assessments has been questioned with expert faculty ratings suggested to provide a far more reliable indication of clinical competence [86]. Nonetheless, the literature expresses little doubt that simulation can assist students to apply knowledge to clinical contexts and works to close the gap between theory and practice [87]. Perhaps exemplifying this argument is the paper by Weller (cited 247 times according to *Google* Scholar as at 4 November, 2015) who sought to evaluate the use of simulation-based teaching in a medical undergraduate curriculum in the context of the management of medical emergencies [81]. The evaluation consisted of a questionnaire asking 33 medical students to self-evaluate how a simulation workshop improved their mastery of workshop material. Fortunately, Weller was careful not to overstate the implications of her results, admitting the study measures were limited to self-assessment, and lacked a comparison or control group. Weller concluded by stating “it would be desirable to demonstrate that students performed better after a simulation workshop than after an alternative teaching intervention” and “…simulation-based teaching lacks evidence of improved learning outcomes.” (pg. 37) [81].

Comparative studies have begun to emerge that focus on improved clinical competency as opposed to subjective measures of satisfaction, confidence or competence. For example, a meta-analytic review of 14 studies by McGaghie *et al.* investigating the “head-to-head” comparative effectiveness of SLEs and traditional clinical education concluded that the “meta-analytic outcomes favouring SBME [simulation-based medical education] with DP [deliberate practice] are powerful, consistent, and without exception. There is no doubt that SBME is superior to traditional clinical education for acquisition of a wide range of medical skills represented in this study.” (pg. 709) [88]. However, it is important to note that all 14 of the studies included in this review had intervention groups receive additional simulation-based training concerning their target outcome on-top of their regularly scheduled clinical education and compared outcomes to a control group receiving no comparable additional training. This provides an alternate and equally plausible explanation of each of these studies results being attributable to differing training dosages. One can be confident that greater competency improvements in intervention groups were at least somewhat attributable to the intervention as opposed to training effects from baseline to post-intervention assessments. However, a discussion paper by the Chief Editor for *Advances in Health Science Education* Geoff Norman elegantly describes the limitation with this particular research design by stating "Just as we need not prove that something is bigger than nothing, we also do not need to prove that something + something else is greater than something alone." (pg. 2) [89].

Similarly, the majority of other systematic reviews investigating the effectiveness of SLEs conservatively argue that supporting empirical evidence is limited, with few studies utilising objective measures and comparable control groups to indicate improvements in tangible learning outcomes or clinical competencies in comparison to traditional training methods [90–98]. The National Council of State Boards of Nursing (NCSBN) National Simulation Study is one of few studies that is able to make a direct comparison between SLEs and CPs utilising objective measures and comparison groups with equal intervention doses. Nursing students in the USA from 10 undergraduate programs were randomised into a control group and two intervention groups each replacing either 25% or 50% of time in previous years spent in CPs with simulation [99]. No significant differences were found between assessor ratings of clinical competency at the time of graduation between the three study groups, allowing study authors to conclude that substituting up to 50% of CP hours with simulation saw nursing students perform no worse at the time of graduation. Participants were also followed up for their first six months of clinical practice and similarly, no significant differences in preceptors' global ratings of clinical competency were found between study groups. The results of this study provide imposing evidence suggesting SLEs are of comparable educational value to CPs, but further research still needs to be conducted to corroborate and substantiate these findings, as suggested by the majority of systematic reviews reporting on SLE research.

For example, when specifically referring to EL, a systematic review investigating quantitative evidence of medium- to high-fidelity simulation in nursing in comparison to other educational strategies found only nine studies that met their inclusion criteria. Of those nine, none compared SLEs to CPs, instead focusing on forms of didactic, lecture-based teaching, student-group interactions, case studies, or self-learning packages [95]. Another systematic review and meta-analysis summarising the outcomes of technology-enhanced simulation training in health profession education studies concluded that SBL is consistently associated with improvements in knowledge, skills and behaviours, but only in comparison to no other form of intervention [100]. Norman explains “We’ll accept without proof that some education is better than none” (pg. 2) [89], essentially suggesting that comparing “something” (an intervention for example) to “nothing” (or no intervention) contributes little toward evidence of effectiveness, particularly with respect to alternative training methods. This trend seems constant across a number of systematic reviews all reporting a tendency for simulation-based research to conduct single-group analyses that fail to compare simulation to any other form of learning, or of those that do, they fail to compare simulation to any other form of EL, instead focusing on didactic teaching methods [91–96]. A systematic review and meta-analysis of mastery learning for health professionals using technology-enhanced simulation states “no-intervention-comparison studies do little to advance the science of education, and we suggest researchers focus on questions that clarify when and how to use these educational technologies.” (pg. 1185) [90].

With such a rapid adoption by health education institutions to provide EL via SLEs, the suggested lack of empirical evidence supporting the increased use of SLEs for education and training in comparison to previously utilised EL methods is worrisome, particularly when considering the importance of practising ‘evidence-based education’. A discussion paper highlighting the importance of developments in educational methods undergoing stringent evaluation prior to implementation suggests it is “undoubtedly true” a gap exists between educational research and teachers (pg. 111) [101], and that many decisions are “made from sentiment over demonstrated effectiveness, or intuition over evidence (pg. 108) [101].” Along these lines, a paper discussing the future of simulation in health contends the rapid implementation of SLEs exceeds proof of benefit [56]. Without comparative research studies evaluating the relative teaching and learning effectiveness of SLEs opposed to CPs, we are unaware of the effects of substituting time traditionally spent on CPs with SLEs will have on graduating students and their transition into qualified health professionals.

2.6 SIMULATION FIDELITY

Perhaps the greatest value of SLEs is the ability to create scenarios on-demand, essentially meaning that educators are able to exhibit a high level of control over the student’s learning environment to match desired learning outcomes. Arguably the most important aspect of SBL said to assist in the transition from skills learnt in SLEs to real world settings is the degree of simulation 'fidelity' or 'realism' of the skills training. Rehmann *et al*. operationalise simulation 'fidelity' by describing three components: equipment, environmental and psychological fidelity (see Figure 2.2) [102]. Equipment fidelity refers to the extent to which the simulator reproduces the composition of the actual event. When referring specifically to simulation in health education, it refers to how well the functionality and responsiveness of patients, manikins and equipment duplicates real-life settings. Environmental fidelity concerns the extent to which the simulation mimics motion, visual and other sensory cues found in the real setting. Essentially, it concerns the concurrent stimuli competing for the student's attention that would exist in the real world (see Table 2.1) Psychological fidelity refers to the degree to which the student perceives the simulation as being an authentic substitute for the actual task, thereby facilitating 'suspension of disbelief' and 'immersion' within the scenario.

Table 2.1 Environmental fidelity aspects in SLEs adapted from Rudd [103]

- Physical location of simulation
- Visual, auditory and olfactory cues
- Level of interaction with environment
- Authenticity of props
- Sequential nature of scenario versus 'skills station approach'
- Attitude of simulation educator/technicians
- Privacy/unanticipated interruptions/distractions
- Realism of/attention to sensory components

While these three components are inter-related, psychological fidelity is generally considered the most essential requirement for training, as without it students are unlikely to behave as they would in real life, resulting in low translation to post-training settings [104, 105]. Previous researchers suggest psychological fidelity is usually increased by providing high equipment and/or environmental fidelity [70, 106].

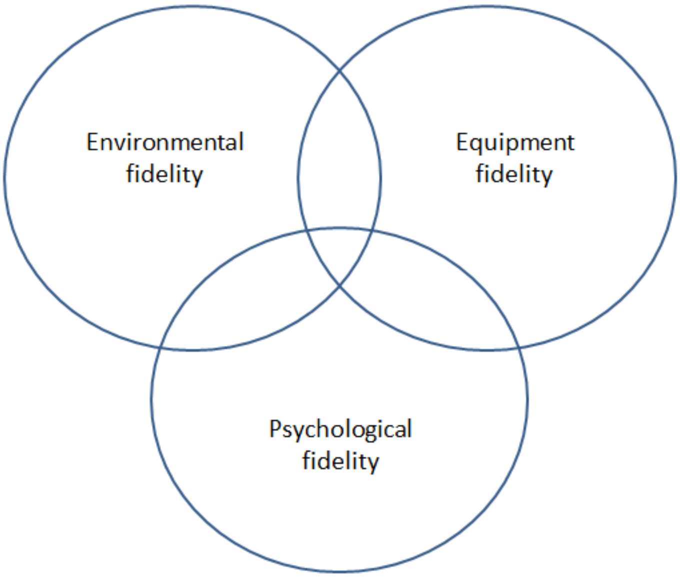

Figure 2.2 Aspects contributing to simulation fidelity by Rehmann *et al*.

These various dimensions of simulation fidelity require educators to make a series of design choices that work best with their target students. The degree to which educators should attempt to replicate the dynamic aspects of real-world environments can (and should) change depending on the desired learning outcomes and the experience of the student. Several commentators recommend a progressive continuum from low- to high-fidelity simulation, where early-stage students learn via low-fidelity simulations (LFS), with minimal environmental distractions until proficiency of a clinical skill is mastered, after which time students should be exposed to increasingly high-fidelity simulations (HFS) with multiple concurrent stimuli that better replicate real-world demands [70, 75]. Wright *et* al. caution against using HFS for early-stage learners whose inexperience makes it difficult to prioritise between multiple environmental stimuli resulting in loss of situational awareness and cognitive overload [107]. Beaubien and Baker exemplify this stance, stating “we implore [educators] to at least explore the use of lower fidelity alternatives, especially during the earliest phases of…skill acquisition” [pg. 55, 70].

These recommendations are consistent with the CPF that predicts optimal learning is achieved when students are provided with levels of challenge that are difficult, but achievable, within their current theoretical understanding [18]. The CPF predicts performance becomes suboptimal if the challenge is set too high, causing cognitive overload—as might be the case for entry-level students in HFS—or set too low, leading to low task engagement, as might be the case for advanced-level students undertaking LFS [18].

2.7 DIFFERENT FORMS OF SIMULATION-BASED EDUCATION AND TRAINING

It has been suggested all simulation in health education can be categorised into five overarching modalities, each involving differing levels of fidelity. These are verbal, standardised/simulated patients, part-task trainers, computer patients and electronic patients [108].

2.7.1 VERBAL SIMULATION

Verbal simulation involves role playing and case studies usually requiring nothing more than a paper and pencil. In case studies, students review previously learnt theory and discuss how these concepts apply to a fictional scenario. They also discuss how they would react differently had they been experiencing the event themselves in real life. Role plays are similar yet slightly more advanced. In addition to discussing potential avenues for improvements, they also re-enact the event [55, 70]. Typically these forms of simulation are classed as LFS and are best utilised for teaching the basics for non-technical skills such as teamwork, communication and clinical decision making (often referred to as human factors). Their strength lies in that they are easy to implement with few resources. However, when viewed in context with the progressive continuum from low- to high-fidelity simulation, and the CPF, it is likely more experienced students will require higher-fidelity simulations to provide optimal level of 'challenge' avoiding low immersion and poor practice performance.

2.7.2 SIMULATED AND STANDARDISED PATIENTS

Standardised and/or simulated patients differ to verbal simulation as they employ the use of live actor-patients and are traditionally used for training of basic, non-invasive clinical skills and non-technical skills such as history taking, communication, professionalism and decision making [55, 109]. Typically, human patients are classed as low- to medium-fidelity (certainly higher than verbal simulation) as patient actors are unable to replicate some of the physiological symptoms and responses of patients suffering from ailments in real life. However, use of human patient actors does have advantages over manikins as they can be trained to give feedback to set cues, and can force students to actively engage with patients. Oftentimes, the terms 'simulated' and 'standardised' patients are used interchangeably throughout the literature [e.g. 110–112], but Adamo contends they have distinct identifiable differences [113]. Standardised patients utilise scripted and consistent content of verbal and behavioural patient responses in reaction to stimulus from students, whereas simulated patients are given artistic licence to improvise, oftentimes drawing on their own experience [113]. Simulated patients are likely more appropriate for SBL as the flexibility associated with improvisation can work to increase authenticity and maintain students 'suspension of disbelief'. Although, depending on the simulation, the level of improvisation required oftentimes requires the expertise of a professional actor, which can substantially increase operating costs. Standardised patients are highly-utilised in assessment of competency in SLEs, where consistent patient responses are important to maintain reliability across multiple student encounters [114–116].

2.7.3 PART-TASK TRAINERS

Part-task trainers also utilise a 'model patient' upon which students can practise. However, rather than actual people, typically they are simple anatomical models of body parts that can or cannot be inflicted with a patient ailment and are used primarily for the teaching of clinical skills. These forms of simulation training are designed to break down aspects of a complex task into several smaller ones. Upon becoming proficient at each subtask, subsequent subtasks can be added until the greater task can be performed in its entirety [117]. Examples of part-task trainers include Resusci Annie for mouth-to-mouth resuscitation or a manikin arm used to train basic skills such as cannulation or venipuncture. Additional bonuses of part-task trainers include that they are relatively cheap compared to full-scale simulators and often more portable meaning practice can occur within a variety of settings (remote or otherwise). While providing a higher level of equipment fidelity than standardised patients, as students can actually perform clinical skills in their entirety, part-task trainers remain associated with low environmental fidelity as educators seek to provide an environment suitable for early exposure to clinical skills void of extraneous information [118]. As per the progressive continuum of simulation, after mastery of the basic skill is achieved on part-task trainers, extraneous stimuli can be inserted into the practice environment (i.e. heightened environmental fidelity) along with more sophisticated working models. In this fashion, part-task trainers can be combined with human patient actors (be it simulated or standardised) to enhance and integrate the communication and psychomotor aspects of a task [75], or even virtual environments, particularly popular for training invasive surgical techniques such as laparoscopy [119].

2.7.4 COMPUTER-GENERATED (VIRTUAL REALITY) PATIENTS

Computer-generated scenarios with virtual patients involve students making diagnostic or clinical decisions, often through student-controlled avatars, in virtual worlds. These can provide an interactive and engaging educational context that work in conjunction with more traditional EL methods [120]. Virtual worlds have the capacity to address the widening gap between supply and demand for authentic EL opportunities with the added bonus of being able to provide education and training without the need for existing infrastructure or prohibitively expensive equipment [120]. Laurillard *et al.* suggest the role of these forms of technology-enhanced learning and teaching is to "enable new types of learning experiences and to enrich existing learning scenarios" (p. 289) [121]. They also suggest that "interactive and cooperative digital media have an inherent educational value as a new means of intellectual expression" (p. 289)[121].

Recent innovations in computer-based education have seen the evolution of 'serious games' that utilise game-based theories of engagement taken from entertainment-based gaming. Thus, students engage as 'players' in their own learning practices through primarily student-directed learning in authentic contexts that address real-world complex problems. Serious games are suggested to enhance motivation to learn through facilitating competition, providing a compelling story and involves problem solving elements that can heighten curiosity [122].

The 2013 Horizon Report (Higher Education Edition) espouses educational gaming as a 'growing field', with a substantial contribution to make to adult learning, and is expected to undergo widespread adoption [123]. It is believed that in the future the flexibility involved with computer programming will allow educators to present wide varieties of controlled stimuli across varying circumstances for multiple skills. It has been suggested that this form of simulation fosters active engagement by students thereby increasing motivation to learn [120]. However, virtual reality environments, at least for now, seem to be best preserved for knowledge acquisition and non-technical skills such as clinical decision making as students cannot easily perform the physical tasks they are undertaking. Current applications see virtual reality training environments being utilised for training in medicine and surgery [124], emergency systems [125, 126], mental health [127] and patient interaction [128].

2.7.5 ELECTRONIC OR SOFTWARE-BASED PATIENTS

The first primitive full-scale human patient simulator (SIM 1) was constructed in the 1960s [54]. SIM 1's facial features included blinking eyes, dilating pupils and a jaw that could open and close. There was some respiratory motion and a heartbeat synchronised with carotid and temporal pulses that was associated (somewhat haphazardly) with a blood pressure [108]. Over the next few decades more sophisticated versions were developed including the Comprehensive Anesthesia Simulation Environment, built in 1986, espoused as being "comprehensive in that it is hands-on and requires actual performance of most interventions using actual equipment." (pg. 387) [63]. By the late 1990s, technology had evolved to include full-body simulators possessing mechanical lungs with physiologic air exchange and ausculatory breath sounds, palpable pulses with corresponding blood pressures and heart-tones, and even limb movements, vocals and automated light-reactive pupils [129]. All these features are controllable by a computer-assisted model of physiologic simulation, allowing drugs and other therapy to be introduced to the manikin resulting in real-time changes in vital signs and medical condition [130]. These applications have now been converted to include pediatric, infant and even neonatal simulators [55].

Electronic patients are typically associated with HFS, particularly high-equipment fidelity, as the 'patient' can demonstrate ailments similar to those occurring in real life and allows practice of intervening skills and procedures with real equipment. By adding additional extraneous cues, such as other health professionals and bystanders, and realistic scenario settings, environmental fidelity can similarly be increased providing a truly HFS, more likely to elicit high psychological fidelity [102].

2.8 SIMULATION FIDELITY RESEARCH

The extent to which simulations should attempt to replicate the dynamic aspects of real-world environments throughout students' learning progression remains contentious. LFS focuses on replicating the essential components of a clinical scenario so as to allow skills to be practised in a safe environment with minimum extraneous distraction, whereas HFS incorporates the use of realistic environments, simulated or standardised patients, or sophisticated and often computerised manikins, other actors and elaborate scripts, generally resulting in increased costs compared to LFS [131, 132].

Given the substantial additional expense of HFS, there is surprisingly little robust research to demonstrate an additional positive effect of HFS on student learning outcomes in comparison to LFS. While it has been convincingly demonstrated that HFS training results in high levels of student satisfaction [98, 133, 134], systematic reviews are consistently critical of the quality of most published research investigating simulation-based learning. This is largely due to the propensity to rely on single-group analyses with no comparison group data or infer benefits of HFS over LFS with comparisons to variants of didactic learning [95, 98, 100]. In addition, Cant and Cooper also criticise most SLE research for relying upon indirect and self-reported measures of improvements in clinical competency [95] that have been shown to vary considerably from ratings by clinical assessors [86].

Given the apparent lack of robust evidence for the effectiveness of HFS training to date, it is difficult to establish when throughout the undergraduate curriculum the use of HFS, as opposed to LFS, is most appropriate. A study by Reischman and Yarandi used paper-based simulations to demonstrate that the development of diagnostic expertise is associated with an ability to focus on highly relevant cues and ignore non-relevant ones [135]. This is generally in line with the views of Maran and Glavin who proposed the progressive continuum of low- to high-fidelity simulation for health profession education [75]. However, while good conceptual arguments were made for the basis of the continuum, being in the form of a discussion paper, little supporting empirical evidence was provided.

The CPF supports this progression of low- to high-fidelity simulation, as it recommends an appropriate level of challenge aligning with student experience to maximise EL [18]. According to the CPF, early-stage students should be provided new information in limited amounts in a controlled practice area, with minimal outside distractions, so as to avoid cognitive overload (i.e. LFS). However, students later in their training should be able to process information more efficiently and therefore are better suited to more dynamic learning environments more closely emulating real-world settings (i.e. HFS). The CPF aligns with other adult learning theories from the health profession literature, such as the information processing theory—which posits that as practitioners become more experienced, processing of information becomes quicker leading to increased clinical decision-making capability [136]. Similarly, the descriptive theory of skill acquisition suggests that with increased expertise an elaborate knowledge-base is compiled into a few high-level concepts, improving the efficiency of short-term memory processing freeing up space for active problem solving [137].

While these theories and frameworks make intuitive sense, their application to simulation-based education in action is largely untested. Beaubien and Baker were able to identify in the literature a number of principles for maximising the effectiveness of simulation as a training tool. However, they comment that due to the published literature on simulation being "extremely fragmented" (pg. i54) they were unable to locate any studies that used multiple types of simulation to train identical or related competencies [70]. It seems that while training practices in simulation are generally supported throughout the literature, they often have little corroborating evidence, and it seems that the progressive continuum of simulation-fidelity is no exception.

However, this is not to say there is no published evidence in support of the continuum. For example, a study by Girzadas *et al.* demonstrated HFS-based assessments are good at discerning novice from experienced emergency medical residents [138]. Similarly, Thompson *et al.* demonstrated that as the fidelity of simulations increases it makes it more difficult for nursing students to separate important clinical symptoms from non-relevant distractors [139]. A directly relevant paper is by Brydges *et al.* who used the ‘scaffolding theory’ to demonstrate that allowing medical students to train through simulations of progressively increasing fidelity led to a superior transfer of clinical skills compared to HFS training only [140]. However, students receiving only HFS-based training undertook approximately half the total training of students receiving a progression from low- to high-fidelity, succumbing the study to ‘dosage effects’ which Norman suggests limits the legitimacy of study findings [89]. Thus, the evidence to date supporting the progression from lower to higher fidelity simulation-based training for undergraduate health professionals requires extension and substantiation.

2.9 SUMMARY

SLEs are popular with students and provide an alternative platform for EL other than the more traditional CP modalities. However, the adoption of SLEs into curricula has far exceeded the evidence of its effectiveness in comparison to CPs. Further studies with more robust measures and equally-dosed comparison groups that demonstrate a quantifiable effect on improving learning outcomes are needed. Furthermore, evidence is lacking suggesting the extent SLEs should attempt to replicate real clinical environments for students at different stages throughout their learning progression. While the CPF would certainly suggest early exposure to realistic environments is beneficial, there is limited empirical evidence to support this contention.

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Due to risk of copyright infringement, the author has requested the following chapters not be included in this version of the thesis:

Chapter Three:

An experimental investigation into the extent social evaluation anxiety impairs performance in simulation-based learning environments

Chapter Four:

Mills B, Carter O, Rudd C, Ross N, Claxton L. (2015). Clinical placement before or after simulation-based learning environments? A naturalistic study of clinical skills acquisition amongst early-stage paramedicine students. *Simulation in Healthcare, 10*(5):263–9. doi:10.1097/SIH.0000000000000107.

Chapter Five:

Mills B, Carter O, Rudd C, Mills J, Ross N, Ruck J. (2015). Quantification of opportunities for early-stage paramedicine students to practice clinical skills during clinical placements compared to an equal dose of simulation-based workshops. *BMJ Simulation and Technology Enhanced Learning (STEL)*, *1*(1), 24-28. DOI:bmjstel-2015-000040. Link to article at http://ro.ecu.edu.au/ecuworkspost2013/1483/

Chapter Six:

Mills, B., Carter, O., Ross, N., Quick, J., Rudd, C., & Reid, D. (2016). The contribution of instructor presence to social evaluation anxiety, immersion and performance within simulation-based learning environments: a within-subject randomised cross-over trial with paramedic students. *Australasian Journal of Paramedicine, 13*(2), 1-8. Article available at: http://ajp.paramedics.org/index.php/ajp/article/view/482/551

Chapter Seven:

Mills, B. W., Carter, O. B., Rudd, C. J., Claxton, L. A., Ross, N. P., & Strobel, N. A. (2015). Effects of Low-Versus High-Fidelity Simulations on the Cognitive Burden and Performance of Entry-Level Paramedicine Students: A Mixed-Methods Comparison Trial Using Eye-Tracking, Continuous Heart Rate, Difficulty Rating Scales, Video Observation and Interviews. *Simulation in healthcare*: journal of the Society for Simulation in Healthcare 11(1), 1-10. doi: 0.1097/SIH.0000000000000119

CHAPTER 8

GENERAL DISCUSSION

8.1 THE RESEARCH PROBLEM RE-VISITED

Increased student enrolments, patient presentations, pressure on clinicians to treat and process patients quickly, and unwillingness of patients to participate in student learning have all contributed to the difficulty associated with sourcing CPs for health students [1–3], let alone ensuring exposures at such placements align with institutional learning outcomes and accreditation standards. In response, many health educators have turned to SLEs to provide EL opportunities for health students. Some argue SLEs are best used to prepare students for CPs by first allowing them to practise skills in a safe environment, before putting them into practice in real clinical settings [4]. However, empirical evidence supporting this postulation is lacking. Furthermore, the extent to which SLEs actually provide increased opportunity for repetitive practice of clinical skills in comparison to CPs is also lacking. Intuitively, with exposures on CPs reliant on random patient presentations, and well-conducted SLEs providing targeted clinical experiences, this contention makes innate sense. However, quantifiable evidence mapping out the degree of variation between the two learning environments would be beneficial for educators planning health curricula.

Some argue that providing opportunities for repetitive practice of clinical skills alone is not sufficient to produce a competent clinician [5, 6]. For example, Littlewood *et al.* argue that early stage CPs can help orientate students to settings in which they will eventually work [7]. Furthermore, students must become comfortable with practising skills on real patients in realistic environments under potentially stressful conditions. Recent years have seen an attitudinal shift toward the expectation of students being competent to practise at the time of graduation [8]. With students no longer having the luxury of 'finding their feet' in the first few months after graduation, authentic experiences during undergraduate training are required to help acclimatise students earlier. Again, with the difficulties associated with locating appropriate CPs, it is likely such authentic experiences are best provided through HFS.

However, particularly amongst early-stage learners, care must be taken to ensure simulations do not exceed students' cognitive capacities. Maran and Glavin propose a continuum of simulation fidelity whereby early-stage students are exposed to SLEs with minimal environmental distractions, instead facilitating students focus purely on application of the underdeveloped skill [9]. However, upon basic mastery of the skill, students can be exposed to increasingly realistic practice environments more closely resembling real life settings. Again though, reflecting the state of the majority of research evaluating the effectiveness of SLEs that utilise single-group analyses and primarily subjective measures [10–12], the evidence in support of this progressive continuum remains in its infancy.

8.2 STUDY ONE

Study One (Chapter Three) aimed to establish the extent to which increasingly realistic clinical environments (delivered via HFS) affects near-graduates' anxiety levels, and the extent this anxiety impacts on clinical performance. Objective physiological measures (HR and cortisol amylase) demonstrated that increasing the number of live standardised patients and actors in the room was associated with higher anxiety amongst stage six nursing students, thus serving as a manipulation check of the studies experimental paradigm. Further, the performance measure, whereby two independent nurse clinical supervisors assessed videos of students undertaking their designated tasks via a structured clinical assessment checklist, demonstrated that the heightened anxiety associated with human patient actors was sufficient to debilitate task performance by a measureable extent. When considering these results in union with the CPF, it is likely the addition of live persons being present in the room facilitated difficulty (or challenge) above 'optimal' levels (see Figure 2.1). This was surprising, given participants were stage six nursing students approaching graduation. Most would expect that by this late stage of the curriculum students would not be so affected by exposure to live persons. These results suggest, at least amongst the study sample, that students would benefit from further practice in realistic settings exposing students to real patient and/or person interaction prior to real world exposures, particularly unsupervised real world exposures. CPs, being the more traditional form of providing EL opportunities is certainly an option. However, issues associated with sourcing appropriate CPs [2, 3], as well as preceptors being unable to allocate sufficient time toward mentorship [13, 14], and the corresponding patient safety implications of exposing students to patients unsupervised and under-qualified, perhaps point to SLEs being the more appropriate avenue to provide such training.

8.3 STUDY TWO

With Study One demonstrating a need for further EL opportunities throughout undergraduate health curricula, Study Two (Chapter Four) aimed to investigate whether such exposures are best conducted first in SLEs followed by CPs or vice-versa. Through this naturalistic study with equally dosed comparison groups, it was demonstrated that while there was some additive benefit of undertaking CPs prior to SLEs (Clin→Sim group), students undertaking SBL followed by CPs (Sim→Clin group) ultimately fared better. This conclusion was based on objective improvements in clinical competency at four time-points over the course of the semester, and the logical assumption that greater improvement stemmed from better learning. Sim→Clin students had the benefit of being able to progressively contextualise skills by first undertaking repetitive practice in SLEs followed by extended opportunities to practise on CPs. Clin→Sim students, having no prior exposure to skills through the SLE workshop, had lower temporal demand scores on CPs (i.e. how hurried or rushed were they throughout their placement). Thus, it is likely Clin→Sim students were unable to participate as much during their CPs and spent more time being idle compared to Sim→Clin students, which would explain the lack of improvement between baseline and post-CPs clinical competency scores for the Clin→Sim group. These results aligned with the intimations of the CPF, suggesting that Clin→Sim students were insufficiently challenged during their CPs leading to poorer learning. It was not until after their completion of the SLE workshop, where students had the opportunity to participate in more hands-on technical skills (i.e. greater and more appropriate ‘challenge’) that competency improvements were noted. Inversely, Sim→Clin students did experience challenge during their CPs more closely resembling appropriate levels, as they had the previous exposure in the SLE workshop necessary to adequately participate.

Thus, this study was able to objectively demonstrate the additive benefit of undertaking SBL prior to attending CPs. While generalisability is limited, as the study included only one cohort from one institution, it does provide a first-step toward an empirical evidence-base justifying the inclusion of SLEs in curricula, if for nothing else, through its additive benefit toward learning on subsequent CPs.

8.4 STUDY THREE

Study Three (Chapter Five) aimed to build on the results of Study Two (Chapter Four) by empirically demonstrating the variation between exposures to practise clinical skills in SLEs and an equal dose of appropriately selected CPs. While activity diaries completed by students on CPs showed students were kept reasonably well-occupied on CPs, direct observation by an independent observer during the SLE workshop demonstrated far greater access to level-appropriate clinical skills than CPs. This result was not surprising, given that exposures on CPs by nature rely on random patient presentation, compared to educators being able to exhibit controlled and targeted exposures in SLEs. Interestingly, the majority of CP exposures were outside students current theoretical underpinnings. So while students did receive some exposures that were directly relevant to what they had learnt in class, the majority of skills had either not yet been covered, or were not at all relevant to paramedicine. When considering these results with the CPF, it is likely these exposures, particularly as participants were early-stage students, did little to contribute towards learning. Unfortunately, demonstrating empirically the extent to which this is true was outside the scope of the study.

Some would argue the purpose of early-stage CPs is not to provide repetitive practice of clinical skills, but to provide general exposures so students can reflect on what they have learnt in the context of the broader health system [7]. Thus, the greater conclusion of this study was that educators should make clear the learning objectives and provide a more appropriate training environment to match. Ericsson *et al.* state the most important factor separating the elite performer from others is the amount of practice one has on a task set at an appropriate level of difficulty, with informative feedback, opportunities for repetition and correction of errors [15]. This study’s results showed that SLEs provide these opportunities more efficiently than CPs.

These results also go toward substantiating the conclusions from Study Two (Chapter Four) which found that first being exposed to SLEs aided in learning occurring in subsequent CPs. However, the causative mechanism explaining ‘why’ this occurred was outside the scope of the study. The results of Study Three (Chapter Five) suggest it is most likely due to SLEs providing more opportunity for repetitive practice of clinical skills. Whilst the majority of skill exposures on CPs were not level-appropriate, it seems that even the small range of skills (n=11) students had high exposure to in SLEs (n=226) did contribute to learning occurring on CPs. This suggests even having not yet undertaken all the skills to which students are exposed on CPs, having an opportunity to achieve basic mastery of some core skills, prior to attending early-stage CPs, could have substantial learning benefit.

8.5 STUDY FOUR

Study Four (Chapter Six) progressed from the issue of learning via simulation and CPs to focusing on how to enhance the SBL experience for students, keeping in mind Maran and Glavin’s continuum of simulation fidelity [9] and the CPF [16]. Specifically the study aimed to investigate the extent a simple manipulation of a LFS, namely the removal of the instructor from the room, can impact students’ anxiety, immersion and performance. While interview data suggested students experienced greater anxiety undertaking a simulation-based exercise in the presence of their instructors, this was only corroborated by peak HR, and not average HR data, thus only providing partial support for the contention that instructor presence increases students’ anxiety. However, both subjective and objective measures provided strong support for the study’s second hypothesis; that students will be less immersed in their SBL exercise in the presence of an instructor. This provided the primary conclusion for the study, as instructor presence had no impact on students’ ultimate performance, other than the speed at which they accomplished tasks. While this could be interpreted as an indirect measure of performance, it is likely this is more reflective of lowered immersion. When instructors were removed from the environment, emulating qualitative data from previous studies [17, 18], students reported heightened focus on the patient, as opposed to split focus between the instructor and patient in the ‘present’ condition. Objective coding data from videos served as a confirmatory check of this finding.

Instructors being present seemed to limit the student’s ability to ‘suspend disbelief’ throughout the scenario instead serving as a constant reminder of being assessed, as opposed to primary focus being on patient wellbeing. The progressive continuum of simulation education, that recommends exposing students to increasingly realistic environments as their learning progresses, would suggest that when it comes time to increasing simulation fidelity, the removal of the instructor from the environment could act as a simple first step, particularly for educators lacking the resources to provide highly realistic environments. Doing so seems to elicit a more ‘natural’ performance from students that more closely resembles how they would work and act in real life. However, instructor debrief and feedback are essential components of SLEs [19, 20]. Thus, it is still important for instructors to view the simulation in some way to allow an accurate commentary on events occurring in the scenario. Not all have access to a simulation suite inclusive of two-way mirrors or live video feed which would allow for immediate viewing and subsequent feedback. Simply videoing scenarios for educators to later view and then provide feedback is an option, but is perhaps less desirable than providing immediate feedback.

8.6 STUDY FIVE

Where Study Four (Chapter Six) undertook a simple manipulation of simulation fidelity (the removal of the instructor from SLEs), Study Five (Chapter Seven) sought to further elaborate by examining what effects a more in-depth manipulation of the surrounding environment would have on student outcomes. In this study, one group had environmental fidelity substantially increased whilst undertaking SBL, and another completing a comparatively LFS. All other scenario factors, including equipment, confederate and patient condition, were kept constant to ensure any between-group differences noted were attributable to environmental fidelity alone. Both objective and subjective measures of psychological immersion, cognitive burden and performance were utilised. Eye-tracking was used to demonstrate that students did attend to extraneous environmental stimuli in the HFS condition, and also showed participants spent more time fixating on equipment in LFS than HFS. When combining these results with interviews and time-to-completion data, it was clear students experienced greater psychological immersion in HFS compared to LFS. Emulating findings from Study Four (Chapter Six) LFS students HR and self-reports suggested greater anxiety in HFS than LFS which was reported to be attributed to the feeling of being assessed from the confederate in the LFS condition. Similarly, students reported a sense of ownership over the scenario in the HFS condition, and were able to narrow focus toward the patient. While in HFS the extraneous stimuli did provide some initial distraction, most were able to recover to the extent that students were more likely to successfully complete the scenario by removing the obstruction (although this result only approached statistically significance).

Taken broadly, it was surprising these early-stage students, having only learnt the required skill during one lab three weeks prior to data collection, performed better (or at least no worse) when exposed to the authentic environmental design of the HFS. While cognitive burden in the HFS was increased (as demonstrated by self-reported measures and corroborated by objective HR data), the study's standardised distractions provided no measureable detriment to performance with students narrowing their focus to the treatment of the patient, as opposed to their being a split focus between the patient and the confederate in the LFS condition. The results of this study exemplify well the learning contentions proposed by the CPF [16]. It seems the challenge provided to HFS students in this study, hypothesised to be too great at the outset, actually fell within appropriate levels. Thus, study investigators were forced to reconsider the resilience of early-stage students, with study results suggesting that it may be educationally beneficial to expose students to HFS soon after basic skill exposure.

8.7 SYNTHESIS OF FINDINGS AND IMPLICATIONS OF THE STUDIES AS A WHOLE

Taken together, the primary results of the thesis in its entirety are as follows:

1. Undergraduate health students would benefit from further exposure to realistic EL opportunities earlier throughout their curriculum. This would likely decrease the extent to which new graduates experience intimidation and social evaluation anxiety (SEA) when dealing with real patients, especially in the company of preceptors.
2. Through providing targeted clinical exposures, SLEs work to prepare students for practice in real clinical settings and enhance learning occurring in subsequent CPs.
3. Removing the instructor from SLEs decreases intimidation and improves task focus without negatively impacting on performance.

4. Once basic clinical skill acquisition has been achieved, exposing early-stage students to HFS, inclusive of substantial extraneous distractions, has considerable learning value.

Globally, these findings add new knowledge to what existing evidence there is substantiating the SLE's ability to contribute to health students' competence to practise in real clinical environments. When considering the presented studies in the context of all simulation-based evaluative research to date, the research adds to a burgeoning list of reviews and studies finding support for simulation as a teaching and learning modality. Where the present research separates itself from the majority of previous investigations is in the novel and primarily objective measures used to test study hypotheses, as well as the essential use of equally dosed comparison groups in assessing the value of SLEs. This thesis successfully provided evidence advocating for SLEs at the second stage of Kirkpatrick's model of training evaluation through providing quantifiable indicators of the learning that has taken place during the course of training, as opposed to the first stage of Kirkpatrick's model concerning subjective reactions to the training (i.e. satisfaction and/or improvements in self-reported confidence or competence) [21]. This thesis provides further evidence to support the continued use of SLEs allowing educators already utilising SLEs to continue doing so with increased confidence. Further, the research will (hopefully) work to influence skeptics of SLEs teaching and learning value.

This thesis was undertaken in response to a call from the literature for comparative studies using more objective measures evaluating SLEs [e.g. 2, 11, 12]. It is not clear why so many previous investigations chose to primarily focus on qualitative or self-reported enquiry and single-group analyses. Such study designs are not uncommon when investigating relatively new interventions or concepts as they can outline basic inherent issues (e.g. is administration of a drug at a certain dosage accompanied by severe side effects?) [22]. However, single-group studies are unable to rationalise a comparative hypothesis (i.e. how does one method of training compare to another, or even no training?). While many investigators evaluating simulation in health have attempted to alleviate this methodological limitation through the inclusion of a control or comparison group, reports in favour of SBL are not surprising when the majority compare SLEs to (1) nothing [e.g. 23, 24–26], or (2) forms of didactic learning that typically fail to provide opportunity for hands-on EL [e.g. 27–29]. Of the few that do compare SLEs to traditional clinical education, the majority fail to provide equal doses of learning between the two environments [e.g. 30].

The present research has attempted to demonstrate empirically the value of SLEs to undergraduate health students, as the rapid uptake of SLEs has far exceeded evidence of its effectiveness [31–33]. Thus, the present research findings, particularly those from studies two and three that demonstrated additional learning benefit from SLEs compared to CPs with respect to early-stage clinical skill acquisition, should aid in alleviating concerns from educators already utilising SLEs to teach undergraduate health students. The results of study five suggest that students can receive these exposures relatively soon after basic skill acquisition. However, this result should be replicated in other samples before educators act fervently on this proposition.

Further, the research can be presented to detractors and traditionalists failing to see value in SLEs; the typical argument being that there is a lack of evidence suggesting the extent to which simulation can or should replace time spent in real clinical settings [34, 35]. Study one demonstrated further clinical experiences early in a health students undergraduate career would be beneficial at the time of graduation, and studies two and three suggested that for early-stage students, time spent in SLEs is likely more beneficial than out on CPs, at least until basic mastery of skills has been achieved in simulation. The present research does not seek to advocate for the full replacement of learning occurring via real clinical settings, though it does suggest SLEs can be a substantial contributor to the effectiveness of an undergraduate health curriculum. Interestingly though, the NCSBN USA-based study did attempt to investigate the impact on students of replacing clinical time with simulation by conducting a large-scale longitudinal, randomised control-trial across 10 sites separating students into groups either receiving normal training, or 25% or 50% of clinical time being replaced by simulation [36]. Study investigators found no differences in clinical competency at the end of the trial based on objective global ratings from preceptors.

Lastly, findings of this thesis endorse the use of the CPF in undergraduate health education. The CPF showed good predictive validity across the five studies and was a valuable tool to aid in the contextualisation and interpretation of study results. Other researchers could consider utilising the CPF to aid in the formulation of study hypotheses surrounding the evaluation of education and training. Further, educators could also consider the value of the CPF when designing education initiatives, as well as wider curricula. It is likely that incorporation of the framework will work to maximise learning output throughout students' ongoing progression.

8.7.1 SNAPSHOT RECOMMENDATIONS

- Health students should receive ample exposure to authentic clinical experiences throughout their undergraduate curriculum.
- Educators should first expose students to clinical experience through SLEs, prior to students attending CPs.
- In order to decrease anxiety, and increase immersion amongst students in SLEs, instructors should remove themselves from SLEs.
- Exposure to HFS has substantial learning value amongst early-stage students, provided students have achieved basic clinical skill acquisition.

8.8 THESIS LIMITATIONS

The strengths and limitations of individual studies present in this thesis are discussed in each corresponding chapter. Thus, this section will focus on research limitations applicable to the greater research findings; the generalisability of results. As mentioned, one of the primary strengths of this thesis is the use of novel objective measures and equally dosed comparison groups. Thus, readers can be assured the study findings are based on impartial and unbiased methodology. However, the stringent application of such study designs and measures can increase resources required to collect data. Accessing and exposing large representative samples to exhaustive procedures can be a costly and resource-intensive endeavor. The studies included in this thesis were designed to meet minimum required effect sizes given limited access to large samples. Repeating these studies with larger samples with differing backgrounds would be beneficial.

Studies utilised four paramedic student cohorts (three first-years, one second-year) and one nursing student cohort (third-year), all from the same educational institution (ECU).

Each of these studies findings could be substantiated through replication with different health disciplines across different institutions. Simulation-based education and research has a strong foothold in nursing education. However, paramedicine, having only recently shifted from a post-employment or internship teaching and learning style to a pre-employment, university-based model [37], is only beginning to document the applicability of SLEs to paramedic education. Further studies utilising other health disciplines, such as medicine, physiotherapy, dentistry, occupational therapy etc., would be beneficial to demonstrate whether study findings are discipline-specific or generalisable to SLEs across all disciplines. For example, in Study One (Chapter Three) stage six (final-year) nursing students performed worse with increasing scenario fidelity, whereas in Study Five (Chapter Seven) first-year paramedicine students preferred HFS. While it is difficult to compare directly between these two studies, as study purposes differed, it could be interpreted that nursing students, for whatever reason, were less equipped to undertake HFS than paramedicine students, thereby limiting generalisability of each individual study's findings to each study sample's respective disciplines. Replication of these studies with other disciplines across multiple sites would address these concerns, as well as those from Pashler and Wagenmakers that suggest there is an unprecedented level of doubt within the field of psychological sciences regarding the reliability of published findings and suggest replication studies work toward alleviating such doubts [38].

8.9 AVENUES FOR FUTURE RESEARCH

As well as undertaking replication studies, a focus of future research involving SLEs should be to continue to shift away from Kirkpatrick's first and lowest level of evaluation (i.e. student's reactions to the training) primarily involving student self-reports of satisfaction and confidence, toward the second level, of SLEs contribution to learning outcomes. While this has been tackled by researchers in the past, the majority of studies seem to have utilised either single-group analyses, comparisons with inappropriate training environments or provide unequal training dosages. It is also recommended researchers utilise, where possible, objective measures when establishing improvement in such outcomes, particularly as research suggests clinicians have a limited ability to accurately self-assess clinical competence when compared to objective assessment [39].

With limited rigourous evidence to date validating the use of SLEs' contribution to learning outcomes, it may be premature to suggest researchers also progress to investigate Kirkpatrick's third and fourth levels of training evaluation, being (3) the measurement of behavior change in real-life settings (i.e. translation of learning outcomes taught through simulation into performance in real-world clinical settings) and (4) the effect of the training on improved quality and reduced frequency and severity of accidents, which, translated into the healthcare setting, includes improvement in patient safety outcomes. Previous research has been conducted investigating the SLEs' impact on these outcomes. For example, Riley *et al.* had obstetricians from one hospital complete an interdisciplinary simulation-based training program accompanied by a didactic workshop, another hospital the didactic workshop only, and had another receive no intervention [40]. A statistically significant improvement of 37% in perinatal morbidity was observed between pre- and post-intervention in the simulation/didactic group. No statistically significant improvement between pre-and post-measures was found for the other two groups. Unfortunately, as with many other published studies in the simulation evaluation literature, no analysis was presented comparing pre/post improvement between conditions, and the study suffered from dosage effects as the full intervention condition consisted of 11 sessions, compared to only a single didactic session, thus providing an alternate interpretation of their data being that the group undertaking more training performed better. However, this limitation notwithstanding, the study did provide some evidence suggesting SBL can translate to improved patient outcomes.

Perhaps the most effective method to gather evidence at the higher stages of Kirkpatrick's training evaluation model would be through longitudinal research whereby participants are randomised into groups undertaking equal dosages of differing training modalities (e.g. simulation vs. CPs) and performance and patient interaction are tracked into the workplace. To succeed, researchers would require substantial planning and collaboration with clinical areas which may prove challenging. However, this would provide the most reliable evidence detailing the benefit of SLEs (other than a systematic review of multiple high level studies) as per the designations of 'levels of evidence' outlined by the National Health and Medical Research Council (NHMRC) [41].

8.10 CONCLUDING COMMENTS

There is little doubt SLEs are popular amongst students but evidence suggesting the extent to which SLEs can contribute to improved learning outcomes remains scarce. This thesis provided evidence of the additive benefit SLEs can have on students' learning outcomes, particularly in comparison to learning occurring on CPs, and also detailed some simple methods educators can utilise to improve educational outcomes in SLEs. It is the author's hope that this research will be instrumental in shifting attitudes towards increased application of SLEs in health within the higher education sector and beyond. This work also provides a blueprint for researchers seeking to utilise more objective measurement of human factors in simulation in health education, along with equally dosed comparison groups demonstrating the accurate value of one pedagogical intervention or method in comparison to another.

8.11 REFERENCES

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APPENDICES

APPENDIX A – CONFERENCE PRESENTATIONS

APPENDIX A – CONFERENCE PRESENTATIONS

APPENDIX A 1 – PAPERS PERSONALLY PRESENTED (MOST RECENT FIRST)

1. **Mills, B.**, Carter, O., Rudd, C., Ross, N. & Claxton, L. Clinical placement before or after simulated learning environments? A naturalistic study of clinical skills acquisition amongst early-stage paramedicine students. *Paramedics Australasia International Conference*, Adelaide, 2–3 October 2015. (Chapter Four of this thesis).
2. **Mills, B.**, Carter, O., Rudd, C., Mills, J., Ross, N. & Ruck, J. Quantification of opportunities for early-stage paramedicine students to practice clinical skills during clinical placements compared to an equal dose of simulation-based workshops—Poster presentation. *Paramedics Australasia International Conference*, Adelaide, 2–3 October 2015. (Chapter Five of this thesis).
3. **Mills, B.**, Carter, O., Ross, N., Quick, J., Rudd, C. & Reid, D. The effect of faculty assessor presence versus absence in paramedicine students' performance in clinical competency assessments. *Paramedics Australasia International Conference*, Adelaide, 2–3 October 2015. (Chapter Six of this thesis).
4. **Mills, B.**, Carter, O., Rudd, C., Claxton, L., Ross, N. & Strobel, N. The effect of low- versus high-fidelity simulations on the cognitive burden and performance of entry-level paramedicine students: A mixed-methods comparison trial using eye-tracking, heart-rate, difficulty scales, video observation and interviews—Poster presentation. *Paramedics Australasia International Conference*, Adelaide, 2–3 October 2015. (Chapter Seven of this thesis).
5. **Mills, B.**, Carter, O., Rudd, C., Mills, J., Ross, N. & Ruck, J. A diary-based comparison of early-stage paramedicine students' opportunities for clinical skills practice during short clinical placements versus the equivalent duration of simulation-based learning environments. *SimHealth Conference*, *Simulation Australia*, Adelaide, 17–21 August 2015. (Chapter Five of this thesis).
6. **Mills, B.**, Carter, O., Rudd, C., Claxton, L., Ross, N. & Strobel, N. Using eye-tracking, heart rate and perceived task difficulty to assess the effects of psychological fidelity on performance of entry-level paramedicine students in low- versus high-fidelity simulations—Poster presentation. *SimHealth Conference, Simulation Australia,* Adelaide, 17–21 August 2015. (Chapter Seven of this thesis).

7. **Mills, B.,** Carter O., Rudd, C., Claxton, L., O'Brien, R. & Strobel, N. To what extent does social evaluation stress impair performance in simulation-based learning environments? *Simulation Network Evening. The Clinical Simulation Support Unit. Department of Health WA*, Perth Australia, 5 August 2015. (Chapter Three of this thesis).
8. **Mills, B.**, Carter, O., Rudd, C., Ross, N. & Claxton, L. (2014) Clinical placement before or after simulated learning environments? A naturalistic study of clinical skills acquisition amongst early-stage paramedicine students. *Simulation Network Evening. The Clinical Simulation Support Unit. Department of Health WA,* Perth Australia, 5 August 2015. (Chapter Four of this thesis).
9. **Mills, B.**, Carter, O., Rudd, C., Ross, N. & Claxton, L. (2014) Clinical placement before or after simulated learning environments? A naturalistic study of clinical skills acquisition amongst early-stage paramedicine students. *ECUlture,* Perth Australia, 3 November, 2014. (Chapter Four of this thesis).
10. **Mills, B.**, Carter, O. & Rudd, C. (2014) The impact of timing of simulation-based learning and clinical practicum on clinical competency. *SimHealth Conference, Simulation Australia*, Adelaide Australia, 25–29 August 2014. (Chapter Four of this thesis).
11. **Mills, B.**, Strobel, N., Carter, O. & Rudd, C. (2013) Determining physiological responses and performance of undergraduate students during varying fidelity simulations. *Simulation Network Evening. The Clinical Simulation Support Unit. Department of Health WA,* Perth Australia, 16 April 2014. (Chapter Three of this thesis).

APPENDIX A 2 – PAPERS PRESENTED ON MY BEHALF (MOST RECENT FIRST)

12. Carter, O., **Mills, B.**, Rudd, C., Claxton, L. & Strobel, N. Determining differences in physiological responses and performance of undergraduate nursing students during simulations with varying patient fidelity. *SimHealth Conference, Simulation Australia*, Adelaide, 17–21 August 2015. (Chapter Three of this thesis).
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APPENDIX A 3 – ADDITIONAL PAPERS UTILISING PHD DATA (MOST RECENT FIRST)

16. Carter, O., **Mills,** B. & Rudd, C. (2015) The concurrent validity of student satisfaction and confidence measures versus instructor assessments of clinical competency: implications for simulation-based course evaluations. *Simulation Network Evening. The Clinical Simulation Support Unit. Department of Health WA,* Perth Australia, 5 August 2015. (Not included in this thesis).
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