THE EFFECTIVENESS OF USING HUMAN PATIENT SIMULATION MANIKINS IN THE TEACHING OF CLINICAL REASONING SKILLS TO UNDERGRADUATE NURSING STUDENTS: A SYSTEMATIC REVIEW

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Samuel Lapkin

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1 Abstract

1.1 Background

Nurses with effective clinical reasoning skills have a positive impact on patient outcomes. Conversely, those with poor clinical reasoning skills often fail to detect impending patient deterioration thus compromising patient safety. Human patient simulation manikins are being used extensively both nationally and internationally in the education of health professionals. There is evidence suggesting that these types of technologies are effective in teaching psychomotor skills and student satisfaction with simulation approaches is generally high. However, the extent to which human patient simulation manikins are effective in the teaching of clinical reasoning skills to undergraduate nursing students is less clear.

1.2 Objective

The aim of this systematic review was to identify the best available evidence on the effectiveness of using whole-body high-fidelity human patient simulation manikin to teach clinical reasoning skills to undergraduate nursing students.

1.3 Inclusion criteria

The review included all randomised controlled trials that assessed the effectiveness of high fidelity human patient manikins in educating undergraduate nursing students. Studies that included health professionals were excluded unless data for nursing students were analysed separately. The primary outcome measure was clinical reasoning, as assessed by methods such as objective structured clinical examinations and questionnaires. Other outcome measures included student satisfaction, knowledge acquisition, and psychomotor skill performance.

1.4 Search strategy

Using a systematic search strategy designed for each database, the following electronic databases were searched for the period 1999 -2009: CINAHL, Cochrane Database, Dissertation and Theses, EMBASE, ERIC, MEDLINE, Ovid database, Proquest Nursing Journals, PsycINFO. Hand searching of the reference lists of included studies and conference proceedings were undertaken to identify further studies.

1.5 Methodological validity

Two independent reviewers' assessed the methodological quality of each study selected for retrieval prior to inclusion using the critical appraisal tool from the Joanna Briggs Institute.

1.6 Data collection and synthesis

Data were extracted from studies using the standardised data extraction tool from Joanna Briggs Institute. Due to the quality of available studies, statistical pooling was not possible and the findings are therefore presented in narrative form.

1.7 Results

Eight studies were selected for inclusion in this review. The results indicate that the use of human patient simulation manikins improves knowledge acquisition and enhanced students' satisfaction with the learning. There is lack of unequivocal evidence on the effectiveness of using high-fidelity human patient simulation manikins in the teaching of clinical reasoning skills to undergraduate nursing students.

1.8 Conclusion

Further research is required to ascertain the effectiveness of the use of human patient simulation manikins as an educational strategy to improve clinical reasoning skills of undergraduate nursing students. The importance of this research is underscored by the potential for patient outcomes to be improved through improved clinical reasoning skills in graduate nurses.

2 Definition of terms

Clinical reasoning

In the nursing literature, terms such as clinical reasoning (CR), clinical judgement, problem solving, decision-making and critical thinking are frequently used interchangeably (Tanner, 2006; Thompson & Dowding, 2002). For the purpose of this review, the term CR will be defined as the process by which nurses collect cues; process the information; come to an understanding of a patient problem or situation; plan and implement interventions; evaluate outcomes and reflect on and learn from the process (Hoffman, 2007; Levett-Jones, et al., in press; Tanner, Padrick, Westfall, & Putzier, 1987).

Fidelity

Fidelity refers to the extent to which the simulation model resembles a live human.

Low fidelity human patient simulation manikins

Low fidelity HPSMs are static models or task trainers primarily comprised of rubber body parts which are used to practice of clinical skills such as intravenous cannulation, urinary catheterisation and basic life support (Issenberg, Gordon, Gordon, Safford, & Hart, 2001; Seropian, Brown, Gavilanes, & Driggers, 2004).

Medium fidelity human patient simulation manikins

Medium fidelity human patient simulation manikins (HPSMs) are full body manikins that have embedded software and can be controlled by an external, hand held device. They have more realism than the low-fidelity HPSMs. An example is Laerdal's Nursing Anne™ with VitalSim capability, a manikin used in nursing education to introduce and develop more complex skills such as auscultation of heart, breath and bowel sounds and identification of life-threatening cardiac dysrhythmias using electrocardiograph (Seropian, et al., 2004).

High fidelity human patient simulation manikins (HPSMs)

High fidelity HPSMs are life sized computerised manikins with realistic anatomical structures and high response fidelity (Alinier, Hunt, Gordon, & Harwood, 2006). They can mimic diverse parameters of human anatomical physiology, for example changes in cardiovascular, pulmonary, metabolic and neurological systems, and have the ability to respond to nursing or pharmacological interventions in real time (Beyea & Kobokovich, 2004; Holcomb, et al., 2002; Nehring, Lashley, & Ellis, 2002; Seropian, et al., 2004). Examples of HPSMs include Laerdal SimMan Universal Patient Simulator (SimMan*TM*) and METI*TM* manikins.

Simulation

Although there are numerous definitions of simulation, the one described by Gaba has been adopted for this review. Gaba (2007) defines simulation as a technique used "to replace or amplify real experiences with guided experiences that evoke or replicate substantial aspects of the real world in a fully interactive manner" (p. 126).

3 Glossary of statistical symbols and terms

Symbol	Term	Description
p	probability value	The probability that a statistical result would occur by chance if a NULL hypothesis was true. When probability values are less than .05, observed scores can be described as “significantly different” since there is a low likelihood of obtaining these observed scores by chance alone.
N	sample size	Total number in sample
SD	standard deviation	A measure of the spread/dispersion of scores around the mean score.
n	sub-sample size	Total number in sub-sample

4 Introduction

Clinical reasoning (CR) is an essential component of competence (Banning, 2008). It is a process that involves both cognition and metacognition (or reflective thinking (Banning, 2008) and is dependent upon a critical thinking ‘disposition’ (Scheffer & Rubenfeld, 2000). Development of CR skills enhances the nurse’s ability to build on previously acquired knowledge and past experiences in order to address new or unfamiliar situations. Nurses with effective clinical reasoning skills have a positive impact on patient outcomes; conversely, those with poor clinical reasoning skills often fail to detect impending patient deterioration thus compromising patient safety (Aiken, Clarke, Cheung, Sloane, & Silber, 2003).

The use of human patient simulation manikins is one strategy that is being increasing adopted by universities to teach clinical reasoning to undergraduate nursing students. A wide range of literature cites the benefits of these types of educational approaches and many assertions have been made in regards to the effectiveness of these methodologies in teaching CR. However, to date there have been no systematic reviews that examine this phenomenon.

The systematic review profiled in this thesis explored the current state of knowledge with regards to the capacity of HPSM to impact nursing students’ clinical reasoning skills. Published and unpublished international research was extracted, appraised, analysed, synthesised and condensed, adhering to the guidelines published by the Joanna Briggs Institute for Evidence Based Practice. This review will be of benefit to academics engaged in utilising HPSM to teach CR, the students engaged in the learning experiences and ultimately the patients who are the recipients of care.

5 Background

Contemporary teaching and learning approaches do not always facilitate the development of a requisite level of CR skills. A recent Australian report described critical patient incidents that often involved poor CR by graduate nurses (NSW Health, 2006). This report parallels the results of the Performance Based Development System, a tool employed to assess nurses' CR, which showed that 70 per cent of graduate nurses in the United States scored at an 'unsafe' level (del Bueno, 2005).

Ideally, opportunities for the development and application of clinical reasoning skills should be provided in 'real' healthcare contexts during the experiential learning that occurs when nursing students undertake clinical placements. In reality, there are a number of barriers to this occurring in a systematic or consistent way. The increasingly complex and unpredictable nature of contemporary healthcare environments (Ravert, 2002; Rhodes & Curran, 2005) and factors such as competing demands for clinical placements (Alinier, et al., 2006), clinical educators that too "often do not have time to think through clinical problems with students" (Aronson, Rosa, Anfinson, & Light, 1997), and ethical constraints that require clinical skills to be developed without potential detriment to patients, limit students' acquisition of CR skills (Bremner, Aduddell, Bennett, & VanGeest, 2006). Collectively, challenges such as these demand a re-examination of the teaching methodologies used for developing nursing students' CR skills in the on-campus learning environment (Porter-O'Grady, 2001).

One strategy that is increasingly being adopted to address the issues outlined above is the use of simulation technologies (Feingold, Calaluce, & Kallen, 2004). Simulation can range in complexity from simple case studies to fully computerised high-fidelity human patient simulation manikins (HPSMs) (Childs & Sepples, 2006). Evidence indicates that the use of simulation achieves quality outcomes where the potential for error and large-scale disaster is high (Weick & Sutcliffe, 2001). Well-known examples are flight simulations in aviation, training exercises in the military, and the development of nuclear power energy (Haskvitz & Koop, 2004; Rauen, 2004).

The first available documented evidence on the use of human patient simulation manikins in clinical education was in 1969 when Denson and Abrahamson used '*Sim One*'™ to supplement the training of anaesthetists (Holcomb, et al., 2002; Peteani, 2004). Since then, various HPSMs have been developed and are broadly classified into three categories based on levels of fidelity; that is low, medium and high-fidelity (Seropian, et al., 2004).

Various systematic reviews have been undertaken to investigate the use of simulation in the education of health professionals. A review undertaken by Laschinger et al.(2008) included critical thinking as an outcome measure in clinical education but did not focus on the effectiveness of using HPSMs for teaching CR skills to undergraduate nursing students. The use of simulation to teach critical thinking was examined in an integrated literature review but did not include nursing students as participants (Ravert, 2002). A systematic review by Issenberg et al. (2005) considered the features of high-fidelity simulation that affected knowledge acquisition by pre and post-graduate medical students but did not include nursing students nor focus on CR. Although these reviews demonstrated the benefits of HPSMs none focused on the effectiveness of using HPSMs in the teaching of CR skills to undergraduate nursing students.

The dynamic nature of contemporary healthcare settings require nursing graduates to assume more complex roles which, in turn, necessitates the acquisition of a requisite level of CR abilities during their undergraduate education (Rhodes & Curran, 2005). Alinier et al.(2006) suggested that in the future, newly qualified nurses will be expected to be competent in handling clinical emergencies such as patient deterioration after having practised mainly with HPSMs. This situation is similar to the aviation industry where pilots are able to fly passenger planes and manage a variety of emergency events after having only practised on flight simulators (Beyea & Kobokovich, 2004). It is essential therefore, that this systematic review fully explores the current state of knowledge regarding the effectiveness of HPSMs in the teaching of CR skills to undergraduate nursing students.

6 Research question

This systematic review was undertaken to answer the following question.

What is the effect of HPSMs on undergraduate nursing students' clinical reasoning skills?

7 Research aim

The aim is of this systematic review was to identify the best available evidence on the effectiveness of using high fidelity HPSMs to teach clinical reasoning skills to undergraduate nursing students.

8 Ethical considerations

This systematic review is part of an Australian Learning and Teaching Council project examining how nursing students' clinical reasoning skills and knowledge application can be enhanced by the effective use of HPSMs and information and communication technology. Ethical approval for this project was obtained from University of Newcastle Human Research Ethics Committee. The systematic review component of the research project posed no risk to any participants as it is based on extraction and analysis of data.

9 Review methods

9.1 Inclusion criteria

The inclusion criteria provided an auditable way of assessing papers that were relevant to the systematic review topic. Papers that met all of the inclusion criteria were retrieved for further assessment of quality. The criteria for including studies in this review were as follows:

9.1.1 Type of studies

The systematic review considered all randomised and quasi-randomised controlled trials (RCTs).

9.1.2 Types of participants

The review included studies where undergraduate nursing students were the participants. Studies that considered health care professionals more generally were excluded unless data for nursing students were analysed separately.

9.1.3 Types of intervention(s)/phenomena of interest

The intervention of interest was the use of HPSMs in undergraduate nursing education.

9.1.4 Types of outcome measures

The primary outcome measure was CR, as assessed by methods such as objective structured clinical examinations (OSCEs) and questionnaires. Other outcomes included student satisfaction, knowledge acquisition, and psychomotor skills in order to provide a broader perspective on the use of HPSMs in nursing education.

10 Search Strategy

To avoid duplication of research, prior to commencing the review the Cochrane Library and the Joanna Briggs Institute databases were searched to ensure that a systematic review on this subject did not currently exist or was not in progress. None of the systematic reviews identified included undergraduate nursing students or focused on CR as a clearly defined outcome measure.

The search strategy aimed to find both published and unpublished studies, limited to English language and restricted to the last ten years. A three-step search strategy was utilised in this review. Initially a limited search of MEDLINE and Proquest was undertaken to help identify the range and type of studies potentially available for synthesis. The initial keywords that were used were: nursing education, nurs*, simulat*, human patient simulator, manikin, clinical reasoning, teaching, and training. A reasonably large number of potential studies were identified and therefore a decision was made to restrict the search to RCTs. This was then followed by an analysis of the text words contained in the title and abstract and of the index terms used to describe the papers.

The second step involved searching electronic databases using several combinations and permutations of key words and index terms identified by the initial literature scoping. Where appropriate, key words were exploded and truncated. Using a defined search and retrieval method, the following databases accessed were for the period 1999 – 2009 and limited to English publications:

1. CINAHL
2. Cochrane Database
3. Dissertation and Theses
4. EMBASE
5. ERIC
6. MEDLINE
7. Ovid database
8. Proquest Nursing Journals
9. PsycINFO

The various electronic databases have different indexing terms hence different search strategies were developed for each search. For a detailed description of the search strategy please see Appendices I and II.

The third stage of the search involved hand searching of studies that met the selection criteria from the following sources

1. The *Journal of the Society for Simulation in Healthcare*, a multidisciplinary publication encompassing all areas of healthcare simulation technology.

2. The *Simulation Innovation Resource Center*, a bibliography facility that offers annotations of publications related to simulation topics.

3. Mednar.com, Conference Proceedings, Dissertation Abstracts, Reports and discussion papers for other 'grey literature'.

The bibliographical software package Endnote^{TM} *Version X2* was utilised to manage all references as it facilitates the importation of references and abstracts from studies obtained by the three strep search process into the Joanna Briggs Institute (JBI) Comprehensive Review Management System (CReMS^{TM}) for assessment of methodological quality. All duplicate references were removed and then assessed against the inclusion and exclusion criteria independently by two reviewers.

11 Assessment of methodological quality

Selected were assessed for methodological validity by two independent reviewers prior to inclusion in the review. For this process, the reviewers used the JBI critical appraisal instrument (Appendix III). Each retrieved study was critically appraised and the methodological quality assessed using the following checklist:

1. Inclusion and exclusion criteria
2. Criteria used to assess outcomes
3. The validity of outcome measurement tools/ instruments
4. Potential for bias in outcome measures
5. Appropriateness of statistical analysis used

12 Data extraction

Data was extracted from the papers included in the review using the standardised data extraction tool from JBI-MAStARI (Appendix IV). The extracted data included specific details about the interventions, participants' demographics, number and reasons for withdrawals and dropouts, study methods and any outcomes of significance to the aim of the review. All results were subjected to double data entry to minimise errors and discrepancies between reviewers were resolved by discussion. Attempts were made to contact authors for any missing data from studies.

13 Data synthesis

It was planned that quantitative papers, wherever possible, would be pooled in statistical meta-analysis. Odds ratio (for categorical data) and weighted mean differences (for continuous data) and their 95% confidence intervals were to be calculated for analysis. Heterogeneity was to be assessed using the standard Chi-square. However, no data was comparable across papers and statistical pooling was not possible.

14 Data analysis

14.1 Description of studies

Approximately 1600 publications were identified by the initial search strategy. After removal of duplicates, the majority of publications were excluded based on the review of the title and abstracts. Thirty-eight were deemed potentially eligible for the review and were selected for full paper retrieval and assessed independently by two reviewers for methodological quality. From these studies only eight met the inclusion criteria and were included in the review. A list of excluded studies and reasons for exclusion are presented in Appendix V.

Of the eight studies, seven were from the United States of America (Brannan, White, & Bezanson, 2008; Hoffmann, O'Donnell, & Kim, 2007; Howard, 2007; Jeffries & Rizzolo, 2006; Radhakrishnan, Roche, & Cunningham, 2007; Ravert, 2008; Schumacher, 2004) and one study from the United Kingdom (Alinier, Hunt, & Gordon, 2004).

The studies used various research designs including multi-site, randomised, pre-test-post-test, experimental design (Howard, 2007; Jeffries & Rizzolo, 2006), randomised pre and post test design (Alinier, et al., 2004; Ravert, 2008; Schumacher, 2004), prospective, quasi-experimental, pre-test and post test (Brannan, et al., 2008), single group pre-test and post-test repeated measure design (Hoffmann, et al., 2007), quasi-experimental post-test (Radhakrishnan, et al., 2007).

14.2 Sample sizes

All of the studies used convenience sampling of undergraduate nursing students. The number of participants ranged from 13 (Radhakrishnan, et al., 2007) to 403 (Jeffries & Rizzolo, 2006) with the average sample size of 104 participants.

14.3 Participants

The participants in of all the studies included for the review were undergraduate nursing students at varying levels of enrolment. Six of the eight studies included in the review gave information on gender and age. All studies included male and female undergraduate nursing students aged between 18 to 45+ years. Numbers of female participants were higher in all of the studies and ranged from 72% (Howard, 2007) to 97% (Ravert, 2008). This is consistent with enrolment patterns in most nursing programs (Sullivan, 2001).

14.4 Interventions

Four studies used SimMan^{TM} (Alinier, et al., 2004; Hoffmann, et al., 2007; Jeffries & Rizzolo, 2006; Radhakrishnan, et al., 2007). The remaining studies (Brannan, et al., 2008; Howard, 2007; Ravert, 2008; Schumacher, 2004) used various HPSMs that met the definition adopted for the purposes of this review.

Five studies (Alinier, et al., 2004; Brannan, et al., 2008; Radhakrishnan, et al., 2007; Ravert, 2008; Schumacher, 2004) compared HPSMs with usual nursing courses. One study compared the outcomes between students exposed to HPSMs of different fidelity levels (Jeffries & Rizzolo, 2006). A study by Howard (2007) compared outcomes between undergraduate nursing students in an experimental group exposed to HPSMs and the control group exposed to a case study. The other study included in the review utelised a pre and poststest repeated measure design to evalaute knowlegde attainment for students participating in a combination of HPSMs and a usual nursing courses Hoffmann, et al., (2007).

15 Methodological quality

All studies were critically appraised for methodological quality. Due to the nature of the studies under review, it was decided to include those with at least six of the ten criteria of methodological quality as determined by the JBI critical appraisal instrument as shown in Appendix I. There was 100% concordance between the reviewers in this respect. One study (Jeffries & Rizzolo, 2006) did not provide any statistical analysis of the results, the other seven studies reported the alpha levels used in the statistical tests.

15.1 Randomisation

All the studies stated that participants were randomly assigned but only one (Schumacher, 2004) reported on the method of randomisation.

15.2 Baseline comparability of groups

Baseline characteristics are essential when assessing comparability between intervention and control groups. Seven studies gave detailed descriptions of baseline comparability relating to age (Alinier, et al., 2004; Bearnson & Wiker, 2005; Ravert, 2008; Schumacher, 2004), gender (Alinier, et al., 2004; Bearnson & Wiker, 2005; Howard, 2007; Jeffries & Rizzolo, 2006; Ravert, 2008; Schumacher, 2004) and prior nursing experience (Alinier, et al., 2004; Bearnson & Wiker, 2005; Howard, 2007; Jeffries & Rizzolo, 2006; Schumacher, 2004). Only one study by Hoffmann, et al. (2007) did not provide any details on the participants.

15.3 Blinded outcome assessment

Due to the nature of the intervention and the studies blinding of the participants and assessors was not possible.

15.4 Outcome assessment

The main outcomes assessed included critical thinking (Howard, 2007; Ravert, 2008; Schumacher, 2004), knowledge acquisition (Alinier, et al., 2004; Brannan, et al., 2008; Hoffmann, et al., 2007; Howard, 2007), cognitive skills (Brannan, et al., 2008); skills performance (Alinier, et al., 2004; Radhakrishnan, et al., 2007), self-confidence

(Brannan, et al., 2008) and satisfaction with the learning experience using HPSMs (Howard, 2007; Jeffries & Rizzolo, 2006).

Various outcome measurement tools were utilised to evaluate the effectiveness of using HPSMs. The outcome assessment tools included Objective Structured Clinical Examinations (OSCEs) (Alinier, et al., 2004), Acute Myocardial Infarction Questionnaire (AMIQ), Likert scale questionnaires and multiple-choice type tests (Brannan, et al., 2008), Basic Knowledge Assessment Tool-6 (BKAT-6) (Hoffmann, et al., 2007), Health Education Systems Incorporated (HESI) exam (Howard, 2007; Schumacher, 2004), Clinical Simulation Evaluation Tool (CSET) (Radhakrishnan, et al., 2007) Simulation Design Scale (SDS), California Critical Thinking Disposition Inventory (CCTDI) and California Critical Thinking Skills Test (CCTST) (Ravert, 2008), Educational Practice in Simulation Scale (EPSS) and Simulation Design Scale (SDC) (Jeffries & Rizzolo, 2006).

16 Results

As a result of limited data reported and different assessment outcome measurements across all of the eight studies meta-analysis was not possible and therefore the report is mainly in a narrative format.

16.1 Critical thinking

Three papers (Alinier, et al., 2004; Howard, 2007; Ravert, 2008; Schumacher, 2004) examined the effectiveness of using HPSMs to develop critical thinking abilities in undergraduate nursing students. The authors reported mixed findings on whether HPSMs improved the critical thinking abilities of students with two of the three studies (Howard, 2007; Schumacher, 2004) showing significant improvement post simulation.

One study (Schumacher, 2004) examined the critical-thinking abilities of beginning baccalaureate undergraduate students by comparing the effectiveness of three different educational interventions namely: classroom, HPSM and combination of classroom and simulation. The researchers used a 60-item customised HESI examination pre and post knowledge test to randomise participants into the three groups. Bonferroni post hoc comparisons were employed to evaluate significant differences between the groups following the educational intervention. Post knowledge results indicated no statistically significant differences ($p > 0.08$) between critical-thinking abilities of nursing students when classroom instructions was utilised to deliver a learning activity. HESI examination scores were higher and statistically significant differences were detected between critical-thinking abilities of nursing students when HPSM or a combination of HPSM and classroom was utilised for a specific clinical scenario ($p \leq 0.002$) (Schumacher, 2004) .

Howard (2007) conducted a randomised, multisite, quantitative, two-group pretest post-test design with 49 students enrolled in diploma and baccalaureate nursing programs from two different nursing universities. The results of this study indicated that the HPSMs group had a significant increase in critical-thinking abilities when compared to the written case study group ($p = 0.051$).

Another study (Ravert, 2008) assessed critical thinking between three groups; namely HPSM, non-HPSM and a control group. The two experimental groups consisted of a non HPSM group (n = 13) that participated in a regular educational process and five enrichment sessions that involved one hour small group discussions , and a second group (n = 12) that was exposed to HPSMs in addition to regular educational process and five enrichment sessions. The control group (n = 15) participated in the regular nursing curriculum with no enrichment sessions. The results demonstrated moderate to large effect size improvements in the critical thinking scores of all the three groups (Ravert, 2008). However, there was no statistically significant difference between the groups.

16.2 Skills performance

Two studies (Alinier, et al., 2004; Radhakrishnan, et al., 2007) evaluated the effect of HPSMs on skill performance. In the first study by Alinier, et al. (2004) second-year diploma of nursing students were assessed pre-intervention by an initial OSCE to determine their baseline clinical and communication skills. The baseline OSCE scores between the two groups were very similar, control group: 49.59 and experimental group: 50.19. Outcomes were assessed at six months in both groups (experimental and control). Although both groups improved their OSCE scores, the scores of the experimental group improved by 13.43% compared to the control group which improved by 6.76%. This result was statistically significant ($p < 0.05$) (Alinier, et al., 2004).

The second study by Radhakrishnan, et al. (2007) used an evaluation tool to objectively measure the effect of HPSMs on various skills levels including the clinical practice parameters of safety, basic assessment, focussed assessment, interventions, delegation and communication skills. Students in the intervention group practiced with HPSMs in addition to their usual teaching/learning method on caring for groups of complex patients while those in the control group had usual teaching/learning alone. The results of this quasi-experimental study with senior baccalaureate nursing students found statistically significant improvements in (a) the interventions group's ability to identify deteriorating patients (a subcategory of safety category; p = 0 .001), and (b) assess vital signs (a subcategory of basic assessment category; p = 0.009) for the intervention group. The control and intervention group's performances did not show any statistically significant differences in any other categories (p > 0.05) (Radhakrishnan, et al., 2007).

16.3 Knowledge gain

In five studies examing knowledge gain (Alinier, et al., 2004; Brannan, et al., 2008; Hoffmann, et al., 2007; Howard, 2007; Jeffries & Rizzolo, 2006) a statistically significant increase in knowledge gain was identified in groups exposed to HPSMs . Brannan et al. (2008) undertook a study to compare the effectiveness of a classroom lecture versus use of HPSM on knowledge gain. The investigators developed a 20-item multiple-choice AMIQ to measure students' knowledge related to the nursing care of patients experiencing an acute myocardial infarction. The results indicated that students who received HPSM instructional methods achieved significantly higher AMIQ post-test scores than those who received the traditional lecture teaching (p = 0.002) (Brannan, et al., 2008).

One multisite study involving 403 undergraduate students compared outcomes among students randomly assigned to one of three types of simulation groups, namely paper and pencil case study, static manikin and HPSM (Jeffries & Rizzolo, 2006). The three groups were provided with the same scenario and worked in groups of four students. The results showed statistically significant differences between pre and post test scores for students in the paper/ pencil group (p <0.001) indicating knowledge gain among students in this group. The other two groups also showed improvement i knowledge gain.

In another multisite, study comparing the acquisition of medical-surgical nursing knowledge students were randomly allocated to either HPSM group or a group that completed a written case study (Howard, 2007). The results were analysed and covariance indicated significant differences in knowledge gain between the two groups as assessed by the HESI Conversion score ($p = 0.18$) and HESI scores ($p = 0.37$) (Howard, 2007).

One study utlised a pre and post-test repeated measure design to evaluate knowlegde attainment of students participating in a combination of HPSM and seven weeks traditional clinical experience Hoffmann, et al. (2007). Participants were assigned to groups and all groups completed seven weeks of traditional clinical experience and seven weeks of HPSMs. Results of pre and post BKAT-6 showed significant improvement at three months post HPSM overall and in the following six subscales: cardiology, monitoring lines, pulmonary, neurology, renal nursing and other ($p < 0.05$). However, there was no statistical difference on the two subscales of endocrine and gastrointestinal nursing.

16.4 Self –reported levels of stress, confidence and judgment

Two studies examined the effect of HPSMs compared to control on students' reported self confidence (Alinier, et al., 2004; Brannan, et al., 2008). Both studies reported that HPSM based intervention did not have any statistically significant effects on perception of stress or confidence of working in a technological environment However, the study by Brannan demonstrated that students in both groups experienced significantly improved confidence level from baseline to six month follow-up and there was no statistical difference between the two groups results.

A third study compared various outcomes between students exposed to HPSM of three different levels of fidelity (Jeffries & Rizzolo, 2006), and identified no significant differences among the three group on self-perceived judgment.

16.5 Student satisfaction with simulation experience

Two studies REF determined student satisfaction with HPSMs. Results obtained in a randomised, multisite, quantitative, two-group pre-test and post-test study by Howard (2007) indicated overwhelming satisfaction with HPSMs experience group when compared with a case study group. The results were as follows: perception of improved critical-thinking abilities (p = 0.070), perceived value (p = 0.001), ability to transfer learning to the clinical setting (p = 0.059), need for inclusion in undergraduate education (p = 0.010), understanding of concepts (p = 0. 010), invoking of nervousness (p = 0.001), decreasing of anxiety in the clinical setting (p = 0.074) and substitution for clinical experiences (p = 0.027). Another study by (Jeffries & Rizzolo, 2006) evaluated student satisfaction between HPSMs and static low fidelity simulation. Students in the HPSMs group reported higher levels of satisfaction with their simulation experience.

17 Discussion

This systematic review was undertaken to investigate the effectiveness of using high fidelity HPSMs in the teaching clinical reasoning skills to undergraduate nursing students. A systematic search of the literature resulted in eight published studies that were eligible for inclusion in this review. The studies included both male and female undergraduate nursing students as participants. The majority of the trials were reported according to the guidelines set out in the Consolidated Standards of Reporting Trials statement, which lists the essential criteria that need to be reported so as to enable readers to determine the validity and reliability of the results. Meta-analysis was limited by the lack of replication studies, thereby reducing the ability to extract definitive conclusions from the studies detailed in this review. The lack of measures of dispersion (e.g. standard deviations) also prevented a meta-analysis from being conducted. As a result, this report is mainly is written in a narrative form. The results in this review should be interpreted cautiously, given the heterogeneity in terms of the follow-up period and the potential for the results of small studies like those reported here, to over or underestimate differences.

17.1 Clinical Reasoning

None of the studies identified for inclusion in this review were specifically designed to evaluate the effectiveness of the use of HPSM on clinical reasoning skills of undergraduate nursing students. However, two outcomes related to clinical reasoning, knowledge acquisition and critical thinking were considered by some of the studies. Five of the studies (Alinier, et al., 2004; Brannan, et al., 2008; Hoffmann, et al., 2007; Jeffries & Rizzolo, 2006) examined knowledge acquisition and three evaluated critical thinking (Howard, 2007; Ravert, 2008; Schumacher, 2004). While knowledge and critical thinking inform clinical reasoning (Levett-Jones et al, in press) the results of these studies are inconclusive in regards to the effectiveness of using high fidelity HPSMs to teach clinical reasoning skills to undergraduate nursing students.

18 Limitations

All studies considered for the review had methodological shortcomings. The reviewed studies used a convenience sampling and generalisations can only be made to populations which share the characteristics of the sample. This is an indication of the enormous challenges inherent in evaluating metaognitive processes such as clinical reasoning and complex technological interventions like the HPSMs; and, although RCTs are considered the golden standard for evidence of effectiveness they can be impractical to execute.

The reviewed studies identified a lack of tested simulation evaluation instruments for accurately measuring clinical reasoning skills. The instruments used to evaluate outcomes in the studies included in the review tested knowledge acquisition more than clinical reasoning. The methods used to evaluate outcome measures clearly demonstrate that there is inconsistent evidence for determining the best instrument to use. With the increase of the use of HPSMs in undergraduate nursing, the ability to evaluate students is essential. Valid, reliable tools to evaluate clinical reasoning skills and other simulation experiences may ultimately improve the assessment of student performance.

Some of the outcome measures were evaluated using self reporting by participants.. Responses obtained in this manner may be subject to social desirability that may bias answers towards more acceptable norms. This data collection method can be unreliable due to issues related to objectivity, completeness and truthfulness (Prion, 2008). In addition, the use of small samples sizes resulted in insufficient power to detect effects of the various interventions on the outcomes (Ravert, 2008).

Only one study (Howard, 2007) provided cost benefit data realted to using HPSMs. As the study was undertaken in the USA it is difficult to generalise the cost-effectiveness of using HPSMs to an Australian setting. Economic modelling is therefore required to inform future decision- making.

19 Conclusion

19.1 Implications for practice

It has been established that nurses with effective clinical reasoning skills have a positive impact on patient outcomes (Aiken, et al., 2003). HPSM have been proffered as an educational methodology that can enhance nursing students' clinical reasoning skills. However, to date, there is lack of unequivocal evidence on the effectiveness of using HPSMs in the teaching of clinical reasoning skills to undergraduate nursing students. This calls for better research to explore this aspect of nursing education. Many of the studies that featured in this review had weak designs, small sample sizes, limited analysis, and were missing important data and details regarding the research methods utilised. Larger more robust pre-test and post-test multisite experimental studies with reliable and valid instruments that measure clinical reasoning in students exposed to HPSMs are needed.

19.2 Implications for research

This systematic review provides a guide to the future priorities for research. These priorities should include the development of reliable and valid outcome measurement tools that can offer direct measurement of clinical reasoning skills. Additionally, given the cost associated with simulation technologies, future studies should undertake a cost-benefit analysis of the use of HPSMs for teaching undergraduate nursing students.

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Appendix I– Search strategy

CINAHL

1. MH Clinical Competence
2. MH cognition
3. MH learning
4. MH thinking
5. MH decision making
6. MH judgment
7. MH problem solving
8. MH psychomotor performance
9. MH Problem-Based Learning
10. AB clinical reasoning
11. or/ 1-10
12. MH Students, Nursing
13. MH Students, Health Occupations
14. MH Education, Nursing
15. MH Education, Nursing, Associate
16. MH Education, Nursing, Continuing
17. MH Education, Nursing, Baccalaureate
18. MH Education, Nursing, Diploma Programs
19. MH Education, Nursing, Graduate
20. MH Nursing Education Research
21. undergraduate nursing student*
22. nursing degree student*
23. or/ 12-22
24. MH Manikins
25. MH Computer Simulation

26. MH Models, Biological

27. MH Patient Simulation

28. MH Models, Anatomic

29. high fidelity patient simulat*

30. 11 and 23

31. 23 and 30

32. limit 31 to (year="1999 -2009")

Cochrane Database of Systematic Reviews

#1	MeSH descriptor **Clinical Competence** explode all trees
#2	MeSH descriptor **Decision Making** explode all trees
#3	MeSH descriptor **Cognition** explode all trees
#4	MeSH descriptor **Learning** explode all trees
#5	MeSH descriptor **Problem Solving** explode all trees
#6	MeSH descriptor **Psychomotor Performance** explode all trees
#7	MeSH descriptor **Problem-Based Learning** explode all trees
#8	(#1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #7)
#9	MeSH descriptor **Students, Nursing** explode all trees
#10	MeSH descriptor **Students, Health Occupations** explode all trees
#11	MeSH descriptor **Education, Nursing** explode all trees
#12	MeSH descriptor **Education, Nursing, Associate** explode all trees
#13	MeSH descriptor **Education, Nursing, Continuing** explode all trees
#14	MeSH descriptor **Education, Nursing, Baccalaureate** explode all trees
#15	MeSH descriptor **Education, Nursing, Diploma Programs** explode all trees
#16	MeSH descriptor **Education, Nursing, Graduate** explode all trees
#17	MeSH descriptor **Nursing Education Research** explode all trees
#18	(#9 OR #10 OR #11 OR #12 OR #13 OR #14 OR #15 OR #16 OR #17)
#19	MeSH descriptor **Manikins** explode all trees

#20 MeSH descriptor **Patient Simulation** explode all trees

#21 MeSH descriptor **Computer Simulation** explode all trees

#22 MeSH descriptor **Models, Biological** explode all trees

#23 MeSH descriptor **Models, Anatomic** explode all trees

#24 (#19 OR #20 OR #21 OR #22 OR (# AND 23))

#25 (#8 AND # AND 18)

#26 (#24 AND # AND 25)

#27 <nothing>, from 1999 to 2009

#28 (#26 AND # AND 27)

Proquest Nursing Journals and Dissertation & Theses (Via Proquest 5000)

#1. ("Clinical Competence"or "cognition" or "learning" or "thinking" or "decision making" or "judgment"or "problem solving" or "psychomotor performance" or "Problem-Based Learning" or "clinical reasoning")
#2. ("Students, Nursing" or "Students, Health Occupations" or "Education, Nursing" or "Education, Nursing, Associate" or "Education, Nursing, Continuing" or "Education, Nursing, Baccalaureate" or "Education, Nursing, Diploma Programs" or "Education, Nursing, Graduate" or "Nursing Education Research" or "undergraduate nursing student*" or "nursing degree student*")

#3. ("Manikins" or "Computer Simulation" or "Models, Biological" or "Patient Simulation" or "Models, Anatomic" or "high fidelity patient simulat*")
#4. #1 AND #2 AND #3
#5. Limit #4 to after 1999

EMBASE

#1. ('Clinical Competence'/exp or 'cognition'/exp or 'learning'/exp or 'thinking'/exp or 'decision making'/exp or 'judgment'/exp or 'problem solving'/exp or 'psychomotor performance'/exp or 'Problem-Based Learning'/exp or 'clinical reasoning.mp') AND [english]/lim AND [humans]/lim AND [1999-2009]/py
#2. ('Students, Nursing'/exp or 'Students, Health Occupations'/exp or 'Education, Nursing'/exp or 'Education, Nursing, Associate'/exp or 'Education, Nursing, Continuing'/exp or 'Education, Nursing, Baccalaureate'/exp or 'Education, Nursing, Diploma Programs'/exp or 'Education, Nursing, Graduate'/exp or 'Nursing Education Research'/exp or 'undergraduate nursing student*.mp' or 'nursing degree student*.mp') AND [english]/lim AND [humans]/lim AND [1999-2009]/py

#3. ('Manikins'/exp or 'Computer Simulation'/exp or 'Models, Biological'/exp or 'Patient Simulation'/exp or 'Models, Anatomic'/exp or 'high fidelity patient simulat*.mp') AND [english]/lim AND [humans]/lim AND [1999-2009]/py
#4. #1 AND #2 AND #3

ERIC

(("NURSING EDUCATION" OR "NURSING" OR EDUCATION, NURSING, BACCALAUREATE) AND ("CLINICAL COMPETENCE" OR "DECISION MAKING" OR "PROBLEM SOLVING" OR THINKING OR JUDGEMENT) AND (MANIKIN OR "COMPUTER SIMULATION" OR "MODELS, ANATOMIC" OR "HUMAN PATIENT SIMULATION" OR "HUMAN SIMULATION TECHNOLOGY"))*

Medline
///Clinical Reasoning///

1. exp Clinical Competence/
2. exp cognition/
3. exp learning/
4. exp thinking/
5. exp decision making/
6. exp judgment/
7. exp problem solving/
8. exp psychomotor performance/
9. exp Problem-Based Learning/
10. clinical reasoning.mp.

////Undergraduate Nursing students////

11. or/ 1- 10
12. exp Students, Nursing/
13. exp Students, Health Occupations/
14. exp Education, Nursing/
15. exp Education, Nursing, Associate/
16. exp Education, Nursing, Continuing/
17. exp Education, Nursing, Baccalaureate/
18. exp Education, Nursing, Diploma Programs/
19. exp Education, Nursing, Graduate/
20. exp Nursing Education Research/
21. undergraduate nursing student*.mp
22. nursing degree student*.mp
23. or/ 12 – 22

///Human Patient Simulation Manikins///

24. exp Manikins/

25. exp Computer Simulation/

26. exp Models, Biological/

27. exp Patient Simulation/

28. exp Models, Anatomic/

29. high fidelity patient simulat$.mp.

30. or/ 24 – 29

31. 11 and 23

32. 23 and 30

33. 31 and 32

34. limit 33 to (english language and yr="1999 -Current" and humans)

Ovid database

1. exp Competence/
2. exp Cognition/
3. exp Learning/ or exp Skill Learning/
4. exp Critical Thinking/ or exp Logical Thinking/ or exp Thinking/
5. exp Decision Making/
6. exp Judgment/ or exp "Clinical Judgment (Not Diagnosis)"/
7. exp Problem Solving/
8. exp Problem Solving/ or exp Learning/ or exp Thinking/ or exp Teaching Methods/ or exp Learning Strategies/
9. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8
10. exp Nursing Education/ or exp Nursing/ or exp Nursing Students/ or exp Nurses/
11. exp College Students/
12. undergraduate nursing student*.mp.
13. nursing degree student*.mp.
14. 11 or 13 or 10 or 12
15. Manikins.mp.
16. exp Computer Simulation/
17. exp Models/
18. exp Models/

19. high fidelity patient simulat$.mp. [mp=title, abstract, heading word, table of contents, key concepts]

20. 18 or 19 or 16 or 17 or 15

21. 9 and 20 and 14

22. limit 21 to (human and english language and yr="1999 - 2009")

PsycINFO

1. exp Professional Competence/ or exp Competence/

2. exp Cognition/

3. exp Learning/ or exp Skill Learning/

4. exp Critical Thinking/ or exp Logical Thinking/ or exp Thinking/

5. exp Decision Making/

6. exp Judgment/ or exp "Clinical Judgment (Not Diagnosis)"/

7. exp Problem Solving/

8. exp Problem Solving/ or exp Learning/ or exp Thinking/ or exp Teaching Methods/ or exp Learning Strategies/

9. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8

10. exp Nursing Education/ or exp Nursing/ or exp Nursing Students/ or exp Nurses/

11. exp College Students/

12. undergraduate nursing student*.mp.

13. nursing degree student*.mp.

14. 11 or 13 or 10 or 12

15. Manikins.mp.

16. exp Computer Simulation/

17. exp Models/

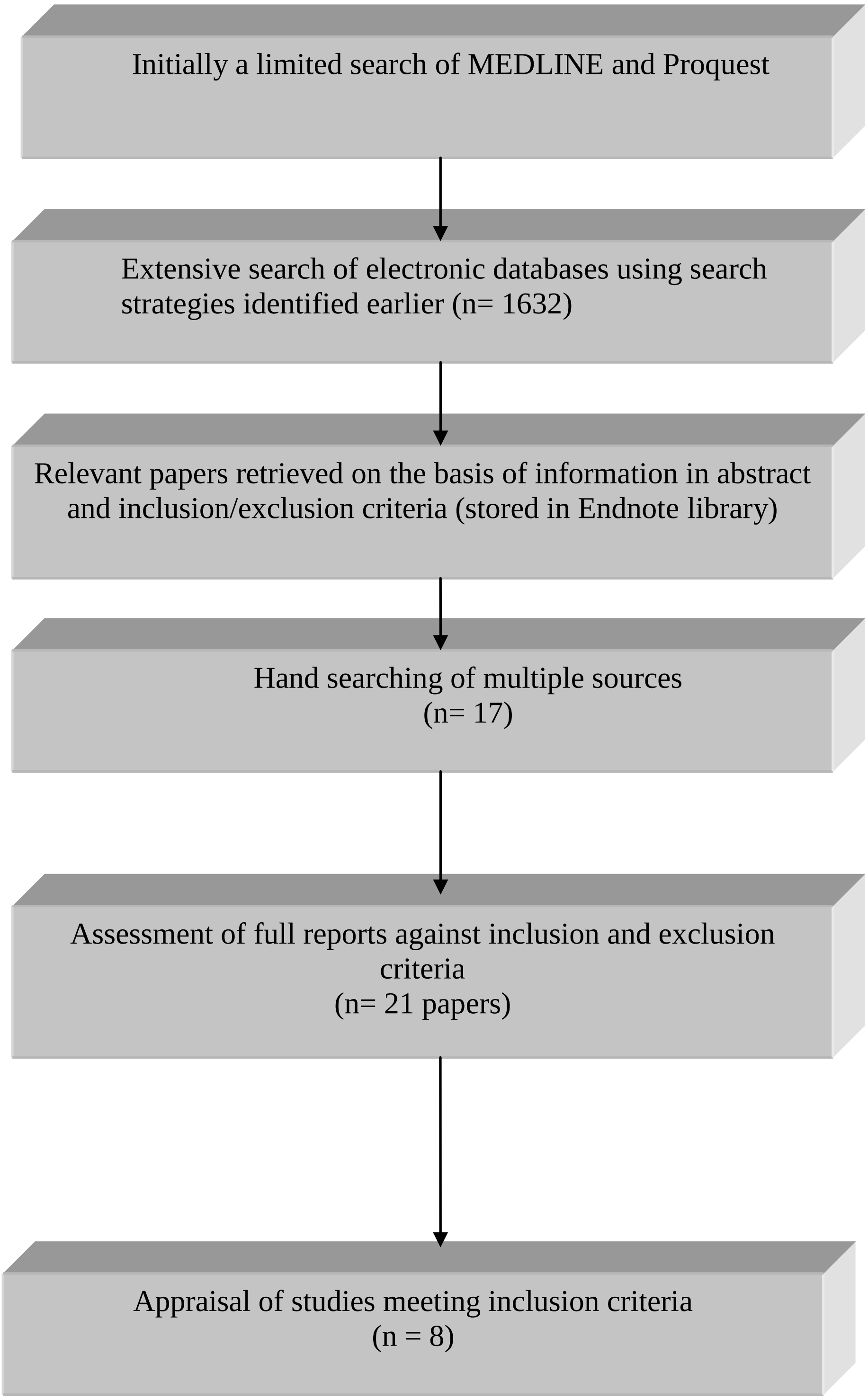
18. high fidelity patient simulat$.mp.

19. 18 or 16 or 17 or 15

20. 19 and 9 and 14

21. limit 20 to (human and english language and yr="1999 -Current")

Appendix II: Summary of the search strategy



Appendix III – Critical appraisal instruments for experimental studies

Assessment for : Name of Assessment

Type: Primary
User: Default
Design: Randomised Control Tables / Psuedo-randomised Trial

	Criteria	Yes	No	Unclear
1)	Was the assignment to treatment groups truly random?	○	○	○
2)	Were participants blinded to treatment allocation?	○	○	○
3)	Was allocation to treatment groups concealed from the allocator?	○	○	○
4)	Were the outcomes of people who withdrew described and included in the analysis ?	○	○	○
5)	Were those assessing outcomes blind to the treatment allocation?	○	○	○
6)	Were the control and treatment groups comparable at entry?	○	○	○
7)	Were groups treated identically other than for the named interventions?	○	○	○
8)	Were outcomes measured in the same way for all groups?	○	○	○
9)	Were outcomes measured in a reliable way?	○	○	○
10)	Was appropriate statistical analysis used?	○	○	○

Include Yes

Reason

Update Cancel

Appendix IV - Data extraction instrument for experimental studies

Extraction Details : Extraction Name - Randomised Control Tables / Psuedo-randomised Trial

Study Information

Method	
Setting	
Participants	
# Participants	Group A: Group B:
Interventions	Interventions A: Interventions B:
Authors Conclusion	
Reviewers Comments	
Complete	No No Yes

Save Details

Appendix V– Excluded studies and reasons for exclusion

Becker, D. E. (2007). *The effect of patient simulation on critical thinking of advanced practice nursing students.* Drexel University Philadelphia.(PhD thesis)

Reason for exclusion: – Participants were not undergraduate nursing students

Beyea, S. C., & Kobokovich, L. J. (2004). Human patient simulation: a teaching strategy. *AORN Journal, 80*(4), 738 -742.

Reason for exclusion: – Participants were not undergraduate nursing students

Cioffi, J., Purcal, N., & Arundell, F. (2005). A pilot study to investigate the effect of a simulation strategy on the clinical decision making of midwifery students. *The Journal of Nursing Education, 44*(3), 131 - 134.

Reason for exclusion: Used scenario based simulation sessions with no HPSM's

Corbridge, S. J., McLaughlin, R., Tiffen, J., Wade, L., Templin, R., & Corbridge, T. C. (2008). Using simulation to enhance knowledge and confidence *The Nurse Practitioner: The American Journal of Primary Health Care, 33*(6), 12 -13.

Reason for exclusion: Participants were not undergraduate nursing students, but senior Nurse Practitioner students

Dobbs, C., Sweitzer, V., & Jeffries, P. (2006). Testing simulation design features using an insulin management simulation in nursing education. *INACSL Online Journal, 2*(1).

Reason for exclusion: Used scenario based simulation sessions with no HPSM's

Henneman, E. A., & Cunningham, H. (2005). Using clinical simulation to teach patient safety in an acute/critical care nursing course. *Nurse educator, 30*(4), 172-177.

Reason for exclusion: Not related to review objectives; it was about process and methods used to implement HPSM in an acute/critical care nursing course

Horan, K. M. (2009). Using the human patient simulator to foster critical thinking in critical situations. *Nursing Education Perspectives, 30*(1), 28 -30

Reason for exclusion: Not related to review objectives, a descriptive example of incorporating a HPSM scenario in a nursing program

Jeffries, P. R., Woolf, S., & Linde, B. (2003). Technology-based vs. traditional instruction: a comparison of two methods for teaching the skill of performing a 12-lead ECG. *Nurse Education Perspectives, 24*(2), 70 -74.

Reason for exclusion: Did not use HPSM but used CD ROM simulation

Kardong-Edgren, S., Anderson, M., & Michaels, J. (2007). Does simulation fidelity improve student test scores? *INACSL Online Journal, 3*(1), 8.

Reason for exclusion: Included pre-nursing students

Larew, C., Lessans, S., Debra, S., Foster, D., & Covington, B. G. (2006). Innovations in clinical simulation: application of Benner's theory in an interactive patient care simulation. *Nursing Education Perspectives 27*(1), 16 – 21.

Reason for exclusion: A review of simulation and gives examples of its use in medical-surgical scenario, not related to review objectives

Lasater, K. (2007). Clinical judgment development: Using simulation to create an assessment rubric. *Journal of Nursing Education, 46*(11), 496-503.

Reason for exclusion: Did not use HPSM and therefore not related to review objectives)

Lowdermilk, D. L., & Fishel, A. H. (1991). Computer simulations as a measure of nursing students' decision-making skills. *The Journal of Nursing Education, 30*(1), 34 - 39.

Reason for exclusion: Year of publication before 1999 & did not use HPSM, therefore not related to review objectives

Appendix VI: Quality assessment of included studies

Author	Was the assignment to treatment groups truly random	Were participants blinded to treatment allocation?	Was allocation to treatment groups concealed from the allocator?	Were the outcomes of people who withdrew described and included in the analysis?	Were those assessing outcomes blind to the treatment allocation	Were the control and treatment groups comparable at entry?	Were groups treated identically other than for the named interventions?	Were outcomes measured in the same way for all groups?	Were outcome measures in a reliable way	Was appropriate statistical analysis used?
Alinier, et al.	1	2	2	2	2	1	1	1	1	1
Brannan, et al.	1	2	2	2	2	1	1	1	1	1
Hoffmann, et al.	1	2	2	2	2	1	1	1	1	1
Howard	1	2	2	1	2	1	1	1	1	1
Jeffries & Rizzolo	1	2	2	2	2	1	1	1	1	2
Radhakrishnan, et al.	1	2	2	1	2	1	1	1	1	1
Ravert	1	2	2	1	2	1	1	1	1	1
Schumacher	1	2	2	3	3	1	1	1	1	1

Key 1 = Yes, 2 = No, 3 = Unclear

Appendix VII: Characteristics of included studies

Author Year Country	Method Participant Setting	Intervention	Outcome measures	Results	Notes
Alinier, Hunt, Gordon 2004 UK	**Method**: Pre/post-test design with randomisation to experimental group **Participants:** Second year diploma of nursing students **(N =101)** **Setting:** University of Hertfordshire simulation lab	**Group 1 (n=29)** 3 hr simulation session using SimMan **Group 2 (n=38)** Usual nursing course	• **Competence** • **Confidence in working in technological environment** • **Stressfulness of working in a technological environment**	**Competence (mean)** **Pretest** *Group 1*: 50.19 *Group 2* : 49.59 *p* value :NS **Posttest** *Group 1:* 63.52 *Group 2*: 56.35 *p* value : < 0.05 **Confidence** *Group 1*: 3.48 *Group 2*: 3.50 *p* value :NS **Stressfulness** *Group 1*: 2.79 *Group 2*: 2.93 *p* value: NS	No data on how randomization was achieved n = 34 withdrew after Baseline OSCE
Brannan, White, Bezanson 2008 USA	**Method**: Prospective, quasi-experimental, preand post-test comparison design **Participants:** Baccalaureate nursing students **(N = 107)** **Setting:** WellStar College of Health and Human Service, Kennesaw State University	**Group 1 (n = 54)** Case study with HPSM pre-programmed to replicate distinct physiological changes; no lecture **Group 2 (n = 53)** 2 hr traditional lecture	• **Knowledge gain (AMIQ)** • **Confidence Level (CL)**	**AMIQ (mean ± SD)** **Pretest** *Group 1*: 12.62 ± 2.34 *Group 2* : 11.31 ± 3.01 *p* value : 0.014 **Posttest** *Group 1:* 15.58 ± 2.13 *Group 2*: 14.17 ± 1.86 *p* value : 0.002 **CL (mean ± SD)** **Baseline** *Group 1*: 98.72 ± 16.74 *Group 2*: 100. 88 ± 20.36 *p* value :NS	Comparisons of demographics and educational statistics of Groups 1 and 2 were statistically nonsignificant

Author Year Country	Method Participant Setting	Intervention	Outcome measures	Results	Notes
				Posttest *Group 1:* 106.29 ± 19.71 *Group 2*: 113.51 ± 17.87 *p* value : NS	
Hoffmann, O'Donnell, Kim 2007 USA	**Method**: Pre- and posttest repeated-measure design. **Participants:** Senior baccalaureate nursing students **(N = 29)** **Setting:** Simulation Lab Department of Acute and Tertiary Care, University of Pittsburgh School of Nursing, Pittsburgh	Students were assigned to groups and all the groups completed 7 weeks of traditional clinical experience (45 hours total) and 7 weeks of HPSM (45 hours total), using SimMan	**Knowledge attainment assessed (BKAT) 3 months post simulation**	**BKAT (mean ± SD)** *All groups* **Pretest** 52.52 ± 8.40 *p* value : < 0.05 T Test: -7.77 **Posttest** 62.76 ± 7.18 *p* value : < 0.005 T Test: -7.77	
Howard 2007 USA	**Method**: Multi-site, quantitative quasi-experimental, pre-test and post-test design **Participants:** Undergraduate nursing students **(N = 49)** **Setting:** Robert Morris University School of Nursing & Sharon Regional Hospital School of Nursing simulation centres	**Group 1 (n =25)** HPSM **Group 2 (n = 24)** Case study	• **Knowledge gain (HESI)** • **Critical thinking** • **Students perspectives of HPSM**	**HESI (mean ± SD)** **Pretest** *Group 1*: 713.12 ± 153.56 *Group 2* : 786.17 ± 184.81 *p* value : 0.037 **Posttest** *Group 1:* 738.00 ± 131.01 *Group 2*: 670.08 ± 181.83 *p* value : 0.037 **Critical Thinking (mean ± SD)** **Pretest** *Group 1*: 700.72 ± 156.64 *Group 2* : 770.04 ± 185.70 *p* value : 0.051 **Posttest** *Group 1*: 737.56 ± 131.57 *Group 2* : 668.25 ± 162.66 p value : 0.051 **Student Perspectives of HPSMs (mean)**	Offered a cost-benefit analysis of integrating simulation into undergraduate nursing curriculum

Author Year Country	**Method Participant Setting**	**Intervention**	**Outcome measures**	**Results**	**Notes**
				Group 1: 3.75 *Group 2* : 3.25 *p* value = 0.10	
Jeffries, Rizzolo 2006 USA	**Method**: Randomized experimental ,multi-site (8), multi-method, multi-phase design **Participants:** Nursing students enrolled in their first medical-surgical nursing course **(N = 403)** **Setting:** multiple sites	Three types of simulation used in the study namely: **Group 1** paper/pencil case study simulation **Group 2** static manikin **Group 3** HPSM SimMan.	SDS, EPSS, used to assess: • **Knowledge gain** • **Self-perceived judgment** • **Student satisfaction**	**Knowledge gain** *Group 1: Pre and post test* *p value:* p < 0 .0001 **Self-perceived judgment** *No significant differences between the 3 groups* **Student satisfaction** *Group 3: Significantly higher level of satisfaction*	Important data missing Inadequate statistical analysis of results
Radhakrishnan, Roche, Cunningham 2007 USA	**Method**: Quasi-experimental post-test design **Participants:** Senior BSN students **(N = 13)** **Setting:** University of Massachusetts, School of Nursing	**Group 1: (n = 6)** Simulation experience with SimMan complex two-patient assignment and routine clinical requirements **Group 2: (n = 6)** Clinical requirements with no simulated experience **Group 1 & 2** : Routine two-patient clinical using SimMan scenarios at end of semester	• **Safety** • **Basic assessment skills** • **Focused assessment skills** • **Interventions** • **Delegation** • **Communication**	**Safety (score)** *Group 1:* 45 *Group 2:* 34 *p value:* 0.001 **Basic assessment skills (score)** *Group 1:* 43 *Group 2:* 33 *p* value: 0.009 **Focused assessment skills (score)** *Group 1:* 28 *Group 2:* 32 *p* value: NS **Interventions (score)** *Group 1:* 50 *Group 2:* 47 *p* value: NS **Delegation (score)** *Group 1:* 3 *Group 2:* 3 *p* value: NS **communication (score)**	One participant withdrew before the study began Participants were 10 females and 2 males

Author Year Country	Method Participant Setting	Intervention	Outcome measures	Results	Notes
				Group 1: 20 *Group 2:*20 *p value:* NS **Mean individual score** *Group 1:* 34.83 *Group 2:* 32.17 *p value:* NS	
Ravert 2008 USA	**Method**: Randomised, pre-test-post-test experimental design **Participants:** Undergraduate BSN students in their first medical-surgical nursing course **(N= 40)** **Setting:** Nursing Learning Center and clinical Simulation Lab, Brigham Young University, College of Nursing	**Group 1: (n =13)** **Group 1: (n =13)** Non-HPSM group that participated in regular education process and five enrichment sessions **Group 2: (n = 12)** HPSM group and regular education plus five enrichment sessions **Group 3: (n = 15)** Regular education process and no enrichment sessions	• **Critical thinking disposition** • **Critical thinking skill**	**California critical thinking disposition (SD)** **Pretest** *Group 1*: 15.63 *Group 2:* 24.23 *Group 3:* 29.81 **Posttest** *Group 1*: 20.96 *Group 2:* 34.07 *Group 3:* 44.71 **California critical thinking skill test (SD)** **Pretest** *Group 1*: 8.57 *Group 2:* 8.94 *Group 3:* 3.87 **Posttest** *Group 1*: 17.86 *Group 2:* 16.34 *Group 3:* 5.72	3 participants dropped out due to busyness and inability to met schedule required by study

Author Year Country	**Method Participant Setting**	**Intervention**	**Outcome measures**	**Results**	**Notes**
Author: Schumacher 2004 USA	**Method**: Descriptive, quasi-experimental, pretest-postset design **Participants:** Beginning baccalaureate undergraduate nursing students **(N = 88)** **Setting:** Baccalaureate nursing school in South Eastern US	**Three learning activities and three groups for each activity** 1. Classroom 2. Simulation 3. Combination of classroom & simulation **Group 1 (N = 48)** **n_1 = 16** **n_2 = 16** **n_3= 16** **Group 2 (N = 37)** high-fidelity computer simulation instruction **n_1 = 11** **n_2 = 16** **n_3= 10** **Group 3 (N = 36)** combination of traditional didactic classroom and simulation instruction **n_1 = 11** **n_2 = 15** **n_3= 10**	A 60-item HESI exam pretest and a 20-item HESI exam which measured: • **Critical thinking** • **Learning outcomes**	**Critical thinking** **Posttest** *Group 1:* *p value: NS* *Group 2 & 3* p value : $p \leq 0.002$ **Learning outcomes** **Posttest** *Group 1:* *p value: NS* *Group 2 & 3* p value : $p \leq 0.001$ **Critical thinking and learning outcomes** *Group 3 significantly higher than subject's in Group 2*	Randomization was by block rank ordering technique