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# The contribution of high-fidelity simulation to nursing students' confidence and competence: a systematic review

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**Background:** High-fidelity simulation (HFS) has been proposed as a novel, supplemental teaching-learning strategy to enhance students' confidence and competence in nursing practice.
**Aim:** To describe available evidence about the effects of HFS on students' confidence and competence within nursing educational programmes.
**Methods:** A review of studies published between 2000 and 2011 was undertaken using the following databases: CINAHL, Proquest, MEDLINE, Science Direct, OVID and Chinese Academic Journal. The concepts of confidence and competence as they related to HFS in nursing education were used for screening the literature. Quantitative studies were assessed for methodological quality.
**Findings:** Eighteen English and six Chinese studies addressed confidence and competence as outcomes of simulation and were retrieved in this review. The results of meta-analysis indicated a mixed contribution of HFS to confidence and competency with a lack of high-quality random control trials and large sample sizes.
**Conclusions:** Although qualitative studies presented positive results, there was still insufficient evidence for supporting the notion that students' confidence and competency are enhanced through HFS. More quantitative studies are needed to demonstrate effectiveness. There was a deficit of formal measurement tools available to evaluate HFS. Most research pays no attention to validation of measurements. The increased confidence and competence after simulation may not be realized until the student experiences a real situation like the one in the simulation. More research is needed to examine the transferability of the simulation experience into real situations.

*Keywords*: Competence, Confidence, Nursing Student, Simulation, Systematic Review

## Introduction

Nursing is a practice profession and active learning by caring for patients has been the preferred method of achieving competency in nursing practice (Sportsman et al. 2009). Faced with increasingly complex clinical situations, nurses must respond with accurate clinical judgment. It is crucial to bridge the gap that exists between what students learn in the classroom and how they apply what they learn in their clinical practice. The major focus of clinical education is facilitating the development of knowledge application, accurate clinical judgment and skill development.

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### The problem

Educators are challenged to find adequate clinical experiences for their students (Hennenman & Cunningham 2005). Limited clinical placement and shortened lengths of stay for patients affect the opportunities for clinical experiences with real patient care situations. The complexity of healthcare systems makes it difficult to provide nursing students with sufficient clinical experiences to ensure their competency. Although learning by doing is a long established means for facilitating knowledge acquisition, it is not always practical or cost-effective to engage in skill training with real patients because of the increased acuity of patients and patient safety issues. Such constraints affect a nursing student's ability to develop the necessary clinical competence to care for patients. Fortunately, patient simulators provide a very realistic substitute situation (Gaba 2004).

### Simulation as a possible solution

Simulation is designed to encourage active participation in the learning process allowing students to construct knowledge, explore assumptions, and develop psychomotor skills in a safe environment (Sinclaire & Ferguson 2009). There are three types of simulation with different abilities to mimic reality. Low-fidelity simulation uses manikins that are less similar to reality, such as intravenous (IV) training arms, intramuscular (IM) injection hips. Intermediate-fidelity simulation uses manikins that offer breath sounds, heart sounds and bowel sounds, and allow for initiation of IV therapy but lack the complexity and realism of patient scenarios. High-fidelity simulation (HFS) is an approach to experiential learning using life-size manikins with actual physiological and pharmacological responses, and sophisticated interactive capability in realistic scenarios. Students can make, detect and correct patient care errors without negative consequences (Nagle et al. 2009). HFS has been proposed as a novel, supplemental teaching-learning strategy to enhance the transfer of student confidence and competence from the classroom to the clinical nursing environment (Bambini et al. 2009).

The use of simulation as a teaching strategy is gaining wider acceptance in nursing education in both the school and clinical settings. Researchers have investigated the potential advantages of using HFS in the training of nursing skills and evaluated the changes in students' confidence and clinical competence after simulation. Although simulation-based training is becoming more common, outcomes research on the use and effectiveness of simulation is inconsistent and varies in methodological rigor and substantive focus. Therefore, it is necessary to review and synthesize existing evidence about the effects of HFS.

## Aim

The aim of this systematic review is to describe available evidence about the effects of HFS on students' confidence and competence within nursing educational programmes.

## Method

### Criteria for considering studies for this review

*Type of participants*

The study populations were nursing students, new graduates or nurses who were participating in simulation-based training in educational programmes.

*Types of studies*

Primary studies addressing evaluation of HFS on confidence and competency in nursing education were eligible for inclusion. The studies included experimental or quasi-experimental studies as well as descriptive or qualitative studies. Studies were excluded if they used case study, or role-play simulation, simulated interviews, standardized patients or low/intermediate-fidelity simulation as interventions. As there was no active search of the grey literature (i.e. conference proceedings or unpublished theses or dissertations), there potentially were other relevant studies that were not included in this review.

*Type of intervention*

In this review, the experimental group (EG) received scenario-based simulation and demonstrated skill competency using realistic scenarios with a high-fidelity manikin, such as human patient simulator (HPS, SimMan, Medical Education Technologies, Inc., Sarasota, FL, USA; and Laerdal Sales Office, New York, NY, USA), MicroSim (Laerdal Sales Office) or Emergency Care Simulators (ECS) (Laerdal Sales Office). The simulation included case study with background information, simulated states and events, expected student behaviours and questions for students during each of the states and events. The learning processes include scenario clarification, group discussion, practice with simulator, reflection and evaluation. The control group (CG) experienced traditional teaching without a simulator, such as lectures combined with demonstrations and/or student practice.

### Search strategy

A review of studies published between 2000 and 2011 was undertaken using the following databases: CINAHL, Proquest, MEDLINE, Science Direct, OVID and Chinese Academic Journal. The search terms included *simulation, nursing, confidence, competence* and *high-fidelity*. A search with the phrase *simulation* and

**Table 1 Description of qualitative studies**

| *Study* | *Participants* | *Instruments* | *Duration of HFS* | *Findings* |
|---|---|---|---|---|
| Kaddoura (2010) | 10 new graduate nurses | Semi-structured interview | 8 days | The participants were confident enough to take care of a critically ill patient. |
| Moule et al. (2008) | 69 students | Individual interview | Five sessions | Simulation can contribute to developing clinical skills and confidence to practice. |
| Reilly & Spratt (2007) | 20 year 2 students | Focus group interviews | 40 min | Simulation increased students' confidence and better prepared them for the clinical practice. |

HFS = high-fidelity simulation.

*nursing* produced results that were too broad, so advanced searching with the term of *confidence or competence* was performed. The search was done until an overlap in the articles was observed. Finally, a manual searching of *high-fidelity* was performed.

**Assessment of methodological quality**

Two independent reviewers assessed the eligibility of each study and the methodological quality. Assessment of quality was limited to experimental studies. The quality of controlled trials was evaluated with the Jadad scale focusing on the methods for random allocation, double blinding, and withdrawals and dropouts. The total scores ranged from 0 to 5 points, where trials with 0–2 points were considered to be of poor quality, and those with 3–5 points represented high-quality trials (Hu & Li 2007).

**Types of outcome measures**

Confidence and competence were measured by self-report instruments, focus group interviews or individual interview.

**Data extraction and synthesis**

Data were extracted only from papers that met the quality standards specified above. The results of randomized controlled trials (RCTs) or non-RCTs were pooled in statistical meta-analysis using Review manager software from the Cochrane Collaboration (Review manager V4.3 (The Australasian Cochrane Centre, The Cochrane Collaboration, Victoria, Australia) is the software used for preparing and maintaining systematic reviews, performing meta-analyses and presenting the results graphically). All results were to be double entered. In order to combine conceptually similar outcomes measured on different instruments, the standardized mean differences (SMD) for continuous outcome data and their 95% confidence intervals (CIs) were calculated rather than weighted mean differences. Heterogeneity between combined studies was tested using the standard Chi-square test. Significant heterogeneity suggests that the studies differ more from each other than would be expected by chance. The random effect model was run when a significant heterogeneity was shown. If the 95% CI for the SMD is greater than zero, this indicates a significant effect favouring the intervention, whereas CIs overlapping or less than zero indicate no effect of the intervention, or an effect favouring the control. Additionally, the findings from quasi-experimental or descriptive or qualitative studies were presented in a narrative form.

## Findings

Initially, 153 English articles and 81 Chinese articles were related to the effect or effectiveness of simulations in nursing educational programmes. Thirty-three English and 28 Chinese papers were reviewed to determine the effect of HFS. Only 18 English and six Chinese studies addressed confidence and competence as outcomes of HFS and were retrieved in this review (see Tables 1 and 2).

**The effects of simulation on confidence and competence**

*Qualitative studies*

The data from a semi-structured interview (Kaddoura 2010) demonstrated that clinical simulation increased participants' confidence in dealing with critical situations. Participants believed they were confident enough to take care of a critically ill patient who required intubation, cardio version, defibrillation, chest tube insertion or cardiopulmonary resuscitation. Reilly & Spratt (2007) carried out a small qualitative study to investigate nursing students' perceptions of clinical simulation, and reported an increase in self-confidence. They found that simulation is an innovative strategy that promotes active learning and has great potential for developing clinical competence and increasing confidence. Moule et al. (2008) reported that simulation was positively received by students. The simulations allowed interdisciplinary discussions among the students, which highlighted different aspects of their professional practice, and could enhance the acquisition and development of clinical skills.

**Table 2 Description of quantitative studies**

| *Study* | *Design* | *Participants* | *Instruments* | *Duration of HFS* | *Findings* |
|---|---|---|---|---|---|
| Abdo & Ravert (2006) | Descriptive study | 48 students | Satisfaction survey | 5 h | Students (52.9%) perceived an increased confidence and an improved clinical competence. |
| Alinier et al. (2006) | Randomized controlled trial Jadad score 3 | 99 year 2 students | Confidence survey | 6 h | Students' perceptions of confidence in pre-and post-operative care were similar between two groups. |
| Bambini et al. (2009) | Quasi-experimental study | 112 students | Self-efficacy questionnaire and three open-ended questions | 3 h | 20 students completed the survey and reported an increased confidence in post-partum and newborn nursing. Mean score of self-efficacy was increased from 28.66 ± 7.72 to 42.14 ± 7.45 ($P < 0.01$). |
| Bearnson & Wiker (2005) | Descriptive study | Year 1 students (no sample size) | A brief survey | 6 h | Simulation increased the confidence in medication administration skills. |
| Birkhoff & Donner (2010) | Descriptive study | 19 nurses | A short-answer survey | 2 days | Simulation increased team collaboration and communication. |
| Blum et al. (2010) | Non-randomized controlled trial Jadad score 2 | 53 junior students | Lasater Clinical Judgment Rubric | 13 weeks | The traditional group had a greater increase in confidence and competence than the simulation group. |
| Brannan et al. (2008) | Non-randomized controlled trial Jadad score 2 | 107 junior students | Cognitive skills and confidence evaluation | 2 h | Both groups were significantly different on mean score of cognitive skills, but not on mean score of confidence. |
| Burns et al. (2010) | Quasi-experimental study | 114 year 1 students | Simulation evaluation | 3 h | Students felt more confident in nursing skills after simulation (mean difference 0.58 ± 1.20, $P < 0.1$). |
| Dillard et al. (2009) | Descriptive study | 68 junior students | Simulation evaluation | 15 min | Students demonstrated strong ability to notice, interpret and respond appropriately in controlled simulation. |
| Feingold et al. (2004) | Descriptive study | 65 students | Simulation evaluation | Two semesters | Less than half of students considered simulation increased their confidence and clinical competence. |
| Gordon & Buckley (2009) | Quasi-experimental study | 50 graduate students | Confidence questionnaire | 3 h | Participants increased confidence in emergency care. |
| Jin & Xu (2010) | Descriptive study | 228 students | Simulation evaluation | No mention | 216 students reported simulation enhanced students' professional ability in emergency care. |
| Kuznar (2007) | Descriptive study | 37 students | Satisfaction survey | No mention | Simulation increased confidence in going to the real clinical setting and helped to manage clinical emergencies and determine priority aspects of nursing care. |
| Liao (2011) | Non-randomized controlled trial Jadad score 2 | 106 students | Simulation evaluation | No mention | Simulation improved students' abilities in clinical judgment, clinical thinking, communication and critical thinking. |
| Luo (2009) | Descriptive study | 308 students | Simulation evaluation | 9 h | Simulation is helpful to promote students' clinical decision making on critical care and team collaboration. |
| Ma et al. (2010) | Descriptive study | 200 students | Simulation evaluation | 4 h | Simulation improved the abilities of communication, team collaboration and clinical judgment and problem solving. |
| Smith & Roehrs (2009) | Descriptive study | 72 junior students | Self-confidence in learning scale | 2 weeks | 68 students felt confident in their ability to care for a patient with a respiratory condition (mean score 4.2 ± 0.5). |
| Wagner et al. (2009) | Descriptive study | 64 senior students | Confidence questionnaire | Full day | Students strongly agreed or agreed simulation increased confidence in nursing abilities. |
| Wotton et al. (2010) | Descriptive study | 300 year 3 students | Simulation evaluation | 45 min | Students (95%) agreed that simulation helped to develop rationale for actions. |
| Zhang et al. (2009) | Descriptive study | 213 year 4 students | Simulation evaluation | 6 h | Simulation promoted students' problem-solving ability in emergency care. |
| Zhao et al. (2009) | Non-randomized controlled trial Jadad score 2 | 146 students | Simulation evaluation | 12 h | The simulation group presented better nursing skills than the traditional group. Simulation improved team collaboration and fostered clinical reasoning. |

HFS = high-fidelity simulation.

*Quantitative studies*

The reviewed quantitative studies supported an increase in students' confidence in clinical skills (Abdo & Ravert 2006; Bearnson & Wiker 2005; Burns et al. 2010; Kuznar 2007, and in various skills necessary for post-partum and newborn nursing (Bambini et al. 2009), and in their ability to care for a patient with a respiratory condition (Smith & Roehrs 2009) after simulation. Gordon & Buckley (2009) used simulation in teaching acute patient care for nurses. Participants (94%) reported their confidence in recognizing an unstable patient, initiating interventions to correct airway obstruction and altered circulation, and keeping others informed during an emergency had all increased after simulation. Wagner et al. (2009) reported clinical simulation provided an opportunity for senior nursing students to build confidence in their discharge teaching skills with post-partum mothers and their families. HFS increased participants' team collaboration and communication in the training for paediatric advanced life support (Birkhoff & Donner 2010).

Simulation using the ECS or MicroSim was used as an innovative method for emergency care training among Chinese nursing students. The majority of students considered HFS as helpful in enhancing their clinical problem-solving ability (94.2%; Zhang et al. 2009), their clinical decision making in critical care (93.3%) and team collaboration (93.0%; Luo 2009), clinical reasoning (83.56%; Zhao et al. 2009) and professional ability (91.6%; Jin & Xu 2010). Many students reported that simulation effectively improved their abilities in communication (84%), team collaboration (91%), clinical judgment (88%) and problem solving (90.5%; Ma et al. 2010). Compared with the CG ($n_1 = 53$), more students in the EG ($n_2 = 53$) suggested simulation improved their abilities in clinical judgment (90.6% vs. 79.2%, $P < 0.05$), clinical thinking (94.3% vs. 81.1%, $P < 0.05$), communication (92.5% vs. 75.5%, $P < 0.05$) and critical thinking (90.6% vs. 73.6%, $P < 0.05$; Liao 2011).

Conversely, Feingold et al. (2004) found that less than half of the students believed that simulation increased their confidence (46.9%) or improved their clinical competence (46.9%) in advanced acute care. When transferring learning experience to real clinical settings, students may focus on individual bits of information and lack a unified view of the whole. Alinier et al. (2006) found that there was no significant difference in confidence between students who participated in HFS and students who did not participate. The results of Blum et al. (2010) indicated no statistically significant differences in mean scores of self-confidence and clinical competence in either group, and students in the traditional group evidenced a greater increase in confidence and clinical competence when compared to the simulation group. A comparison study (Brannan et al. 2008) using traditional classroom lecture and the HPS method was conducted to test the differences in cognitive skills and confidence gains between two groups of junior nursing students learning about acute myocardial infarction. The HPS group had higher levels of cognitive skills in nursing care of a patient with acute myocardial infraction compared with the traditional group, but no significant outcome differences in confidence was found between the two groups.

In this systematic review, heterogeneity between combined studies was demonstrated in the measurements of confidence ($\chi^2 = 5.82, P = 0.05$) and competence ($\chi^2 = 171.09, P < 0.000\,01$), so a random effect model was run and 95% CI for SDM was reported. The result of the meta-analysis supported a mixed effect. HFS either decreased the standardized mean score of confidence (by 0.45 point) and competence (by 0.95 point) or increased confidence (by 0.43 point) and competence (by 5.00 points; see Table 3).

## Discussion

Confidence and competence after the use of HFS in nursing education were discussed in the reviewed studies. The HFS could actively engage students individually in the learning process. Students demonstrated strong ability to notice, interpret and respond appropriately in controlled simulation. Simulation-based learning provides a risk-free environment where students can incorporate cognitive, psychomotor and affective skill acquisition. Students demonstrated increased confidence when delivering patient care after practising with a high-fidelity simulator. Simulation fosters students' autonomy, independence and develops sound analytical skills (Peteani 2004). The reviewed studies using quasi-experimental, descriptive or qualitative design reported an increased confidence and competence after simulation, but this review did not provide robust evidence on the evaluation of HFS for improved confidence and competence. The results from three experimental studies showed no statistically significant differences in mean scores of self-confidence (Alinier et al. 2006; Blum et al. 2010) or clinical competence (Blum et al. 2010; Brannan et al. 2008) between the EG and CG. The lack of significant findings related to confidence levels was not a surprising result since students' confidence levels were measured from only one context, either after traditional classroom learning or after the HPS method. Students' confidence after any teaching would naturally be higher if they perceived they met the learning objectives for the class.

The increase of confidence and competence was shown among undergraduate nursing students in most reviewed studies, new graduate nurses (Gordon & Buckley 2009; Kaddoura 2010) or nurses (Birkhoff & Donner 2010), but students' levels of clinical

**Table 3 The effect of high-fidelity simulations on confidence and competence**

| *Outcome* | *Study* | *Experimental group Mean ± SD (n)* | *Control group Mean ± SD (n)* | *Meta-analysis* | | |
|---|---|---|---|---|---|---|
| | | | | *SMD (95% CI random)* | *Overall effect* | *P-value* |
| Confidence | Alinier et al. (2006) | 3.40 ± 0.80 (49) | 3.50 ± 1.00 (50) | −0.11 (−0.50~0.28) | | |
| | Blum et al. (2010) | 12.48 ± 1.30 (37) | 13.03 ± 1.38 (16) | −0.41 (−1.00~0.18) | | |
| | Brannan et al. (2008) | 113.51 ± 17.87 (54) | 106.29 ± 19.71 (53) | 0.38 (0.00~0.76) | | |
| Total | | | | −0.01 (−0.45~0.43) | $Z = 0.03$ | 0.97 |
| Competence | Blum et al. (2010) | 13.68 ± 1.93 (37) | 14.13 ± 1.41 (16) | −0.25 (−0.84~0.34) | | |
| | Brannan et al. (2008) | 15.58 ± 2.13 (54) | 14.17 ± 1.86 (53) | 0.70 (0.31~1.09) | | |
| | Zhao et al. (2009) | 24.92 ± 1.12 (73) | 18.75 ± 1.05 (73) | 5.65 (4.92~6.39) | | |
| Total | | | | 2.02 (−0.95~5.00) | $Z = 1.33$ | 0.18 |

CI = confidence interval; SD = standard deviation; SMD = standardized mean differences.

experience or previous learning were not considered. More substantive data are needed to identify the change of confidence and competence after simulation at the different educational stages.

Additionally, a mixed contribution of HFS to confidence and competence was found by meta-analysis. The extant quality of the published research was generally weak. Only four comparative studies (one RCT and three non-RCTs) examining the diffidence on the mean scores of confidence and competence were retrieved in this meta-analysis. In these studies (Alinier et al. 2006; Blum et al. 2010; Brannan et al. 2008; Zhao et al. 2009), the duration of simulation ranged from 2 h to 13 weeks, and different instruments were used to compare the confidence and competence between simulation and traditional groups. These variations in intervention and evaluation methods may influence outcome measurement and the results of meta-analysis. In addition, non-RCTs and small sample size resulted in insufficient power to detect effects of the various interventions on the outcomes. Therefore, there was insufficient evidence for supporting the notion that students' confidence and competency are enhanced through HFS. On the other hand, the cost of simulation is related to the level of fidelity and the technology being employed. The costs of HFS are higher compared to the common manikins of lower fidelity. It is necessary to justify the value of use comparing high-fidelity and low-fidelity simulation (Kneebone 2005). The additional research on the level of fidelity simulation and its impact on student learning outcomes are necessary.

## Limitations

The results of this review highlighted some limitations in the evaluation of simulation as an education intervention. There was a deficit of formal measurement tools available to evaluate HFS. In order to evaluate outcomes, researchers selected different existing instruments or developed some evaluation forms to evaluate the confidence and competence. These measurement tools have been typically used for traditional clinical assessments and not specifically designed for HFS. Most research pays no attention to validation of measurements. The validity and inter-rater reliability of the marking were rarely described. Using a variety of methods in comparative studies may lead to the difficulties in controlling for this variance in evaluation methods, and become a potential bias in drawing inference or quantifying the results from the review. It is necessary to call for the development of evaluation tools designed specifically for a HFS.

Furthermore, confidence was usually measured using a self-report instrument. Personality disorders are often evident in self-report, but may not be assessed adequately simply by asking respondents if they have each diagnostic criterion (Polit & Beck 2006). Self-report may lead to biased reporting and can be inaccurate (poor recall or bias) by comparison with observation. Standardized objective measurements should be formulated to measure student outcomes. Research in this field requires attention in terms of rigor and quality. Even if reliable and valid instruments for the measurement of clinical competence are developed, there still remains the issue about what level of performance indicates competence. The question is whether competence can be assessed by addressing several individual competencies when considering the interaction between competencies. In this case, the measurement of competence possibly can be task directed or competency specific when it is being judged by observing or measuring performance.

In addition, nurse educators are challenged to implement teaching strategies that promote learners' confidence and clinical competency. Simulation offers a unique mode for experiential learning and evaluation, but the appropriate use of the spectrum

of simulation typology requires strategic planning. It should be a concern about whether learning is occurring under the right conditions. Smith & Roehrs (2009) reported that design characteristics of the HFS specifically, clear objectives and a challenging experience, significantly correlated with satisfaction and self-confidence. Dillon et al. (2004) identified the challenges and benefits of using simulation in competency validation. Simulation is not totally realistic, so there is a need to validate whether proficiencies demonstrated in the simulated environment are transferred to the real clinical situation. Simulated-based assessments have the potential to be useful in evaluating clinical competencies, but establishing these competencies will be challenging. Nurse educators should acquire the knowledge and skills needed to use this education strategy, develop realistic case scenarios, and design and validate standardized and reliable testing methods. Although increased confidence and competence after HFS were reported in reviewed studies, it was not always measured in a clinical setting. The student may perceive an increase in confidence because of being in a controlled, supervised setting where he or she can do no harm. Perhaps the increase of confidence and competence is not realized until the student experiences a real situation like the one in the simulation. More research needs to be conducted to examine the transferability of the simulation experience into real clinical situations.

## Conclusions

There was insufficient strong evidence to support the efficacy of facilitating students' confidence and competency through HFSs. This systematic review indicated a mixed contribution of HFSs to confidence and competency with a lack of high-quality random control trials and large sample sizes. Qualitative studies looking at HPS use demonstrate positive results. However, more quantitative studies are needed to demonstrate effectiveness. Very few studies have objectively evaluated the outcomes of simulation use; hence, it is necessary to call for the development of evaluation tools designed specifically for a HFS. Standardized objective evaluation tools need to be developed to measure confidence and competence. More high-quality RCTs with larger sample sizes should be conducted to determine the effect of HFS on students' confidence and competence. Further research needs to be conducted to examine the transferability of the simulation experience into real clinical situations.

## Author contributions

All authors were involved in study conception and design, data collection and analysis, drafting of manuscript, critical revisions for important intellectual content, statistical expertise, and administrative.

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