The role of simulation in developing clinical knowledge and increasing clinical confidence in first-year radiography students

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Abstract

Background: First-year radiography students at Monash University participate in simulation learning activities using role-play, x-ray phantom imaging, and pre- and post-clinical placement. Simulation-based learning is commonly used across Australia in radiography and medical imaging teaching programs. However, little research about its role in radiography education has been undertaken. This study aimed to measure knowledge gained by radiography students from simulation activities and how they perceived that simulation activities developed their knowledge and confidence in clinical skills and decision-making.

Methods: Pre-and post-tests were conducted to measure students' knowledge acquisition after the simulation learning activities. Students' perceptions of the simulation activities were evaluated by a 40-item paper-based survey using a 5-point Likert scale.

Results: Fifty-five students participated in the pre-and post-tests, and simulation learning activities increased knowledge as shown by a significant increase in the post-test scores compared with the pre-test scores ($p < 0.001$). All 51 students completed the survey. Results indicated that the simulation activities increased students' confidence in aligning the x-ray equipment, patient positioning and giving verbal instructions to patients. During the simulation activities, students learnt from errors they made, feedback given by tutors and through observing their peers.

Conclusion: Simulation-based learning can enhance students' radiographic knowledge and improve students' confidence in some elements of clinical skills and decision-making.

Keywords: simulation-based learning, diagnostic radiography, low-fidelity, knowledge acquisition, role-play, self-confidence, x-ray phantom.

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Introduction

Simulation-based learning is integrated into many healthcare curricula to prepare students for clinical practice (Grant & Marriage, 2012; Harder, 2010; Issenberg & Scalese, 2008). Simulation-based learning aims to "imitate real patients, anatomic regions or clinical tasks, or to mirror the real-life situations in which medical services are rendered" (Issenberg & Scalese, 2008, p. 33). Simulation learning activities enable healthcare educators to deliver learning outcomes to students through the features of fidelity and feedback.

The fidelity of the simulation describes the degree of realism of the recreated environment, situation or personal experience (Weller, Nestel, Marsall, Brooks, & Conn, 2012). Low-fidelity simulation offers limited interactivity and commonly includes simple anatomical replicas of various body parts, such as the knee and shoulder joints (Maran & Glavin, 2003; Wilson, Shepherd, Kelly, & Pitzner, 2005) or role playing as patients or health professionals in simple clinical scenarios (Crea, 2011; Seybert & Kane-Gill, 2011; Stegmann, Pilz, Siebeck, & Fisched, 2012). Intermediate-fidelity simulations offer realistic experiences and may involve manikins with heart and breath sounds (Seropian & Samuelson, 2004) or mock CT scanners and patient simulators (Sica, Barron, Blum, Frenna, & Raemer, 1999). High-fidelity simulations use simulators that appear and respond realistically (Baillie & Curzio, 2009) and include life-sized human manikins integrated with computer software to mimic human physiological responses (Kuznar, 2007), and may include interprofessional clinical teams role-playing complex situations (Giuliani et al., 2014), which enable students or health professionals to feel as if they were interacting with real patients in real-life situations (Traynor, Gallagher, Martin, & Smyth, 2010; Vyas, Wombwell, Russell, & Caligiuri, 2010).

An important feature of simulation-based learning is the immediate feedback offered to improve student performance in a safe environment (Bienstock et al., 2007), allowing students to participate in active learning as they create meaningful reflections and self-evaluations (Fowler, 2008).

Self-confidence

Simulation-based learning can build self-confidence (Alfes, 2011; Meechan, Jones, & Valler-Jones, 2011) and knowledge (Jarzemsky & McGrath, 2008; Traynor et al., 2010). Confidence in clinical skills can influence students' learning ability (Melincavage, 2011) and clinical performance (Cheung & Au, 2011). Low confidence in clinical skills can be a learning obstacle (Gore, Hunt, Parker, & Raines, 2011; Melincavage, 2011) creating anxiety, which can negatively impact on task performance (Smith et al., 2001) and jeopardise patient safety and comfort (Baillie & Curzio, 2009).

Knowledge gain

The effectiveness of simulation-based learning has been determined through student self-reported knowledge gain and through objective measurements of students' knowledge. Most of these studies have focused on high-fidelity simulation. This level of simulation has been shown to be effective in developing students' knowledge about patient responses to medication (Bearnson & Wiker, 2005), administration of anesthesia (Schwid et al., 2002) and cardiopulmonary resuscitation (Ackermann, 2009). In contrast, little is known about the effectiveness of low-fidelity simulation.

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Simulation-based learning in diagnostic radiography teaching

Simulation-based learning promotes learning as an active process in which students reflect on their prior knowledge and construct their own views of the world through the physical and social interactions experienced (Kolb & Kolb, 2005). Simulation-based learning can provide complex, realistic and risk-free learning environments; therefore, it is particularly useful for teaching radiography students, as training on real patients is not possible due to the harmful ionising radiation involved (Gaba, 2004). In simulation learning, radiography students can practise their clinical skills without compromising patients' safety (Wright, Rolland, & Kancherla, 1995). A study by Thoirs, Giles and Barber (2011) found that simulation-based learning was widely used in radiography degree programs across Australia. The simulation activities commonly used included student role play, the use of manikins and anatomical body parts and the use of imaging equipment (Thoirs et al., 2011). Despite the prevalence of simulation learning in radiography programs, there has been little research examining its role in knowledge and skills development. The aim of this study was to determine the effectiveness of simulation learning activities for engaging radiography students in building knowledge and confidence as well as preparing them for clinical practice.

Aims of the study

The primary aims of this research were to:

1. Assess the role of simulation activities (role-play and phantom imaging) in first-year radiography students' knowledge gains in anatomy, radiation protection, radiographic positioning and exposure factor settings.
2. Evaluate the student experience of the simulation activities of role-play and phantom imaging, and their perceptions of the impact of the simulation activities in building knowledge and confidence in clinical skills.

Methods

This study used a mixed-method design with before and after repeated measures. The simulation laboratory class (SLC) was the first simulation class undertaken by students in the degree program. The structure of the degree program includes a clinical placement of 3–6 weeks in each semester of years 1–3 and a 6-month placement in the final year (Figure 1). Students had completed one clinical placement of 3 weeks in the previous semester at the time of the study.

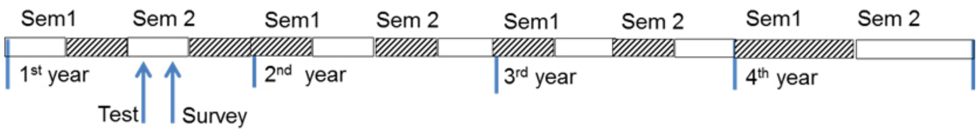

Figure 1. Structure of the 4-year radiography program showing the timing of the simulation class, the pre & post testing (Test) and the survey (Survey). The hatched bars show the timing and length of the clinical placements undertaken by students during the 4 years of the program.

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Pre- and post-tests that focused on radiography of the abdomen, pelvis and hip joint were administered in hard copy at the beginning and end of the simulation laboratory class (SLC) in week 3 of semester 2 in year 1 of the radiography program (Figure 1). The pre- and post- tests contained seven questions designed specifically for the radiographic topic. Question 1 asked students to label key features on a textbook diagram of the pelvis and assessed knowledge of anatomy. Questions 2–4 were multiple-choice questions designed to assess technical knowledge associated with patient positioning and radiation protection during an imaging procedure on the pelvis. Question 5 was a short answer question to assess knowledge regarding clinical indication for an antero-posterior pelvic projection. Questions 6 and 7 were also short answer questions designed to assess technical knowledge associated with radiographic positioning and exposure factors required when imaging the hip and pelvis. The elements assessed in each question are listed in Table 1. During the week prior to the pre- and post- tests, students had a face-to-face lecture on the pelvis and hip joint, which covered the radiographic elements of the test. Students were expected to study the relevant textbook and lecture notes prior to the SLC.

To evaluate students' experience and their perception of the impact of the simulation activities on their clinical practice, the Simulation Experience Survey (SES) was constructed. This was done by choosing relevant items from three previously published surveys that had investigated the implementation of simulation learning in healthcare studies and its effectiveness in preparing students for clinical practice (Baillie & Curzio, 2009; McCaughey & Traynor, 2010; McGregor & Giuliano, 2012). The SES contained 40 items that identified students' perceptions of the simulation learning activities in building radiographic knowledge and self-confidence. The survey questions used a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree) and was administered in hard copy to the students in the week following the SLC.

Participants

Fifty-five students in first year of the Bachelor of Radiography and Medical Imaging program at Monash University were invited to participate in this study. The students were pre-allocated randomly into approximately three equal groups (Group one: n=18, Group two: n=19, Group three: n=18) to conduct their laboratory sessions on separate days within the same week. Within each group, the students were further divided into three subgroups, approximately six students in each, to rotate through the three laboratory activities. Students worked in groups of six for the SLC, which consisted of two separate simulation activities (role-play and x-ray phantom imaging) designed to teach the practical and technical aspects of general radiography of the abdomen, pelvis and hip. Each simulation activity was supervised by an experienced qualified radiographer.

Role-play

The role-play occurred in a simulation environment imitating a radiology department with a waiting room and an imaging room. In the role-play activity, students acted as the "radiographer" or the "patient" while the rest of the group observed. The "radiographer"

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was given a request form containing replicated patient details and clinical notes. The "radiographer" was required to greet the "patient" in the waiting room and escort him or her to the imaging room, giving clear verbal instructions to the "patient" while positioning him or her, palpating for superficial body landmarks, adjusting the central ray placement and selecting the correct image receptor size, additional immobilisation devices and exposure factors. Students used a Philips Optimus 65 x-ray generator system, but no actual x-ray images were taken. Students then discharged the "patient".

X-ray phantom imaging

The x-ray phantom used in this study was a life-sized full-body anthromorphologic phantom, Kyoto Kagaku PBU-60 ("Mr. Kyoto", Figures 2 and 3). Mr. Kyoto has moveable joints, artificial bony structures and internal organs that produce realistic plain x-ray images. Students positioned Mr Kyoto for abdomen and pelvis projections, and selected and adjusted exposure factors before taking x-ray images with the Shimadzu UD150L-RII x-ray generator system. Students evaluated and discussed the images, including any post-processing requirements, with the supervising radiographer.

Data analysis

Data were entered into SPSS (version 20.0, Chicago, USA), and the package was used to obtain descriptive statistics for student demographics and the confidence survey, and then to statistically analyse the data collected from the pre-and post-tests and the survey.

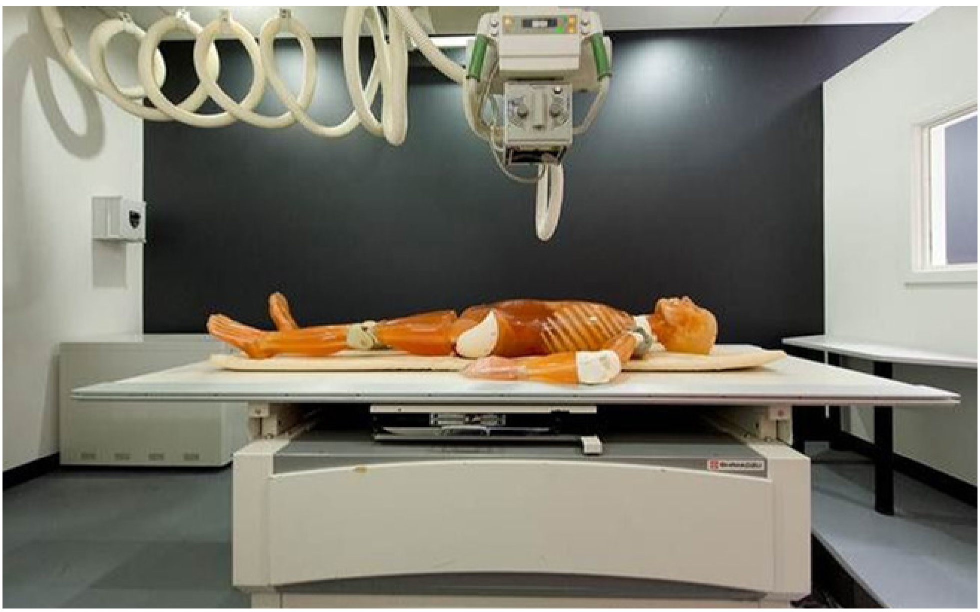

Figure 2. Mr Kyoto in the x-ray laboratory.

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A Cronbach's alpha test was used to test for reliability of items on the SES. Wilcoxon's sign-ranks test was used to analyse the pre- and post-test results. A *p* value <0.05 was considered statistically significant.

Ethical considerations

Ethics approval was granted from the Monash University Human Research Ethics Committee (MUHREC) prior to the commencement of this research project.

Results

Demographics

The mean age (range) of the first-year students was 19 (17–24) years. There were 16 male students (29.1%) and 39 female students (70.9%), with 51 domestic students (92.7%) and four international students (7.3%).

Figure 3. Radiography students using the x-ray phantom for simulation learning activities.

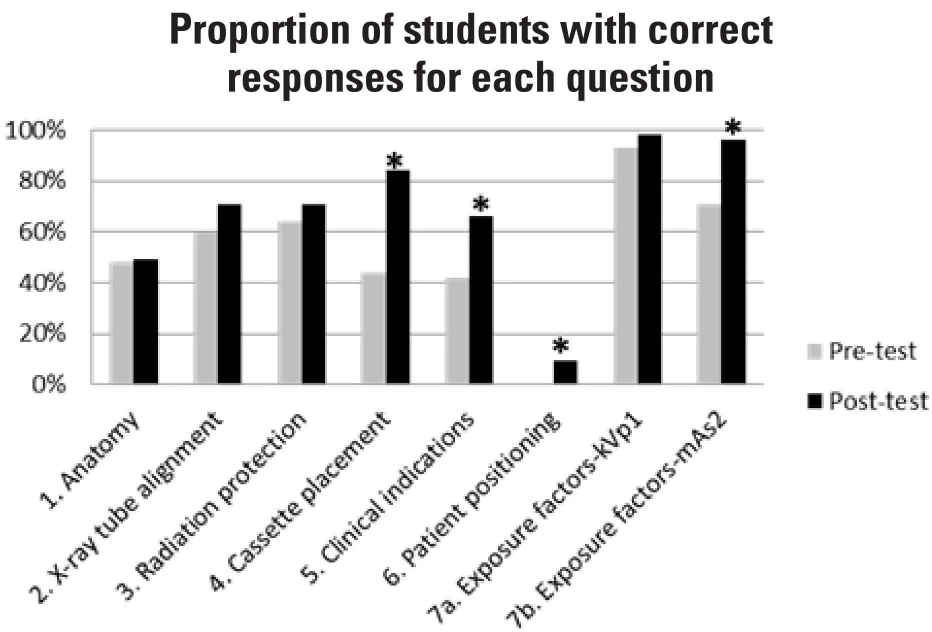

Figure 4. Frequency of correct answers for each question on the pre- and post-test.
*Significant difference in median scores ($p < 0.05$)

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Table 1
Pre- and Post-test Scores and the Percentage of Students with Full Marks for Each Question (Total n=55)

		Pre-test Mean ± SEM	Post-test Mean ± SEM	*p* value
Total score		13.53 ± 0.36	16.01 ± 0.31	< 0.001
Question	Radiographic element tested	Pre-test % correct	Post-test % correct	*p* value
1	Anatomy	48%	49%	0.398
2	X-ray tube alignment	60%	71%	0.134
3	Radiation protection	64%	71%	0.206
4	Cassette placement	44%	84%	< 0.001
5	Clinical indications	42%	66%	0.005
6	Patient positioning	0%	9%	< 0.001
7a	Exposure factors-kVp[1]	93%	98%	0.083
7b	Exposure factors-mAs[2]	71%	96%	< 0.001

1 kVp refers to peak kilovoltage
2 mAs refers to milliampere-seconds

The role of simulation activities in knowledge gains

Students' knowledge gains were measured by using pre- and post-tests. All students (n=55) completed the pre- and post-tests. The mean score on the post-test (16.01 ± 0.31, mean ± SEM) was significantly increased compared to the pre-test (13.52 ± 0.36, $p < 0.001$, Table 1). Questions 4, 5, 6 and 7b showed a statistical improvement in correct responses (Table 1 and Figure 4).

Simulation experience survey

The response rate of the survey was 93% (n=51). Cronbach's alpha for the 40-item SES was 0.846, demonstrating a good reliability.

Students' experience of the simulation learning activities

The majority of the students agreed that simulation activities encouraged them to practise their clinical skills since they were supervised by a tutor (96.1%, Item 3) and patients would not be harmed (92.2%, Item 2, Table 2). All students agreed that they learnt from the errors they made during the SLC. Two-thirds of students agreed that the simulated environment of the radiology skills laboratory reflected a realistic clinical setting (Item 5, Table 2), and a similar number reported that the SLC activities did not make them more anxious about doing their next clinical placement (68.6%, Item 6). All students (Item 7, Table 2) valued the feedback given by tutors, and most were satisfied with the amount of feedback given (78.4%) and agreed that they always critically reflected on this feedback (84.3%). The majority of students learnt from observing their peers undergoing role-play (98.0%, Item 21) and imaging the phantom (94.1%, Item 29).

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Table 2
Student Experience of the Simulation Learning Activities (Role-play and Imaging Mr Kyoto)

Item No.		Agree/ strongly agree % (n)	Undecided % (n)	Disagree/ strongly disagree % (n)
4	I feel comfortable learning from simulation learning activities as I will not harm any patients.	86.3% (44)	7.8% (4)	5.9% (3)
5	Simulation learning activities encourage me to practise my clinical skills as I know I will not harm any patients.	92.2% (47)	5.9% (3)	2.0% (1)
6	Simulation learning activities encourage me to practice my clinical skills as I am supervised by a tutor.	96.1% (49)	3.9% (2)	0.0%
7	I learn from the errors I make in simulation learning activities.	100.0% (51)	0.0%	0.0%
8	I believe the simulated environment of the radiology skills laboratory reflects a realistic clinical setting.	66.7% (34)	21.6% (11)	11.8% (6)
9	The simulation learning activities made me more anxious about doing clinical placement.	15.7% (8)	15.7% (8)	68.6% (35)
1	I value the feedback given to me by tutors.	100.0% (51)	0.0%	0.0%
2	I am satisfied with the amount of feedback given.	78.4% (40)	13.7% (7)	7.8% (4)
3	I critically reflect on the feedback given by my tutors.	84.3% (43)	9.8% (5)	5.9% (3)
21	I learn from observing my peers undergoing role-play.	98.0% (50)	2.0% (1)	0.0%
29	I learn from observing my peers imaging the phantom.	94.1% (48)	3.9% (2)	2.0% (1)

Students' experience of the role-play activity

Most students agreed that role-play improved their confidence in patient positioning (88.2%, Item 10, Table 3), providing verbal instructions to patients (56.9%, Item 11) and aligning the x-ray tube (96.1%, Item 12). The role-play activity increased students' understanding of choosing appropriate radiographic projections (70.6%, Item 13) and their ability to identify and palpate for superficial body landmarks (90.2%, Item 14), position patients (96.1%, Item 15), provide verbal instructions to patients (68.6%, Item 16), adjust the x-ray tube (98%, Item 17) and select appropriate exposure factors (66.6%, Item 18).

All students relied on their tutors when selecting the radiographic projections (Item 19) and deciding whether they had correctly positioned the x-ray equipment (Item 20) and the "patient" (Item 21). Two-thirds of students agreed that the role-play activities helped

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Table 3
Students' Experience of the Role-play Activity

Item No.		5 % (n)	4 % (n)	3 % (n)	2 % (n)	1 % (n)
On a scale of 1 to 5, to what extent did role-play activities: (1 = not at all, 5 = a great deal)						
10	improve your confidence in patient positioning?	37.3% (19)	49.0% (25)	13.7% (7)	0.0%	0.0%
11	improve your confidence in giving patients verbal instructions about positioning?	21.6% (11)	37.3% (19)	33.3% (17)	7.8% (4)	0.0%
12	improve your confidence in aligning the x-ray tube?	54.9% (28)	41.2% (21)	2.0% (1)	2.0% (2)	0.0%
On a scale of 1 to 5, to what extent do role-play activities increase your understanding of:						
15	choosing appropriate radiographic projections?	21.6% (11)	49.0% (25)	27.5% (14)	2.0% (1)	0.0%
16	identifying and palpating for superficial body landmarks?	49.0% (25)	41.2% (21)	7.8% (4)	2.0% (1)	0.0%
17	patient positioning?	51.0% (26)	45.1% (23)	3.9% (2)	0.0%	0.0%
18	providing patients verbal instructions about positioning?	29.4% (15)	39.2% (20)	23.5% (12)	7.8% (4)	0.0%
19	adjusting x-ray tube?	64.7% (33)	33.3% (17)	2.0% (1)	0.0%	0.0%
20	selecting appropriate exposure factors?	33.3% (17)	33.3% (17)	25.5% (13)	7.8% (4)	0.0%
On a scale of 1 to 5, to what extent do you rely on the tutor to:						
22	decide on selection of what radiographic projections to take?	7.8% (4)	54.9% (28)	25.5% (13)	11.8% (6)	0.0%
23	decide whether you have correctly positioned the x-ray equipment?	17.7% (9)	45.1% (23)	23.5% (12)	13.7% (7)	0.0%
24	guide you on whether or not the "pretend" patient is correctly positioned?	17.6% (9)	52.9% (27)	17.6% (9)	11.8% (6)	0.0%

		Agree/ strongly agree	Undecided	Disagree/ strongly disagree
13	Role-play helps me feel less awkward/ embarrassed about palpating superficial body landmarks on patients?	66.6% (34)	25.5% (13)	7.8% (4)
14	Role-play activities increase my understanding of ways to implement radiation protection?	76.5% (39)	17.6% (9)	5.9% (3)

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Table 4
Students' Experience of Imaging with the X-ray Phantom Mr. Kyoto (% Responses)

		5 % (n)	4 % (n)	3 % (n)	2 % (n)	1 % (n)
To what extent did imaging Mr. Kyoto increase your knowledge of: (1 = not at all, 5 = a great deal)						
35	selecting appropriate exposure factors?	11.8% (6)	39.2% (20)	35.3% (18)	13.7% (7)	0.0%
36	patient positioning?	21.6% (11)	51.0% (26)	21.6% (11)	3.9% (2)	2.0% (1)
37	identifying and palpating for superficial body landmarks?	9.8% (5)	41.2% (21)	31.4% (16)	15.7% (8)	2.0% (1)
38	adjusting the x-ray tube?	41.2% (21)	41.2% (21)	15.7% (8)	0.0%	2.0% (1)
39	image quality assessment?	21.6% (11)	54.9% (28)	15.7% (8)	7.8% (4)	0.0%
40	image recognition?	27.5% (14)	54.9% (28)	11.8% (6)	5.9% (3)	0.0%
In order to increase your radiographic knowledge, how realistic do you think an x-ray phantom needs to be for the following: (1 = realism does not matter at all, 5 = as realistic as possible)						
25	Patient positioning?	45.1% (23)	37.3% (19)	15.7% (8)	2.0% (1)	0.0%
26	Identifying and palpating for superficial body landmarks?	64.7% (33)	13.7% (7)	19.6% (10)	2.0% (1)	0.0%
27	Adjusting x-ray tube?	33.3% (17)	33.3% (17)	19.6% (10)	11.8% (6)	2.0% (1)
28	Image quality assessment?	54.9% (28)	25.5% (13)	15.7% (8)	3.9% (2)	0.0%

		Agree/ strongly agree (%)	Undecided (%)	Disagree/ strongly disagree (%)
30	Mr. Kyoto is able to reflect the features of a real x-ray patient.	66.7% (34)	11.8% (6)	21.6% (11)
31	It is difficult to engage with Mr. Kyoto as it is just an inanimate object.	56.9% (29)	25.5% (13)	17.6% (9)
32	I prefer imaging Mr. Kyoto than real patients to practise my radiographic skills.	25.4% (13)	27.5% (14)	47.1% (24)
33	Imaging Mr. Kyoto requires clinical decision-making skills.	50.9% (26)	25.5% (13)	23.5% (12)
34	My clinical skills would improve with repeated practice on imaging Mr. Kyoto.	82.3% (42)	13.7% (7)	3.9% (2)

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them to feel less awkward about palpating superficial body landmarks on patients (Item 22, Table 3). Students were positive about role-play increasing their understanding of ways to implement radiation protection (78.4% agreed, Item 23, Table 3).

Students' experience of the x-ray phantom, Mr. Kyoto

Imaging Mr. Kyoto increased students' perceived knowledge of patient positioning (72.0%, Item 25), adjusting the x-ray tube (82.4%, Item 27), assessing image quality (74.5%, Item 28) and image recognition (80.4%, Item 29). Fewer students agreed that Mr. Kyoto increased knowledge about selecting appropriate exposure factors (51%, Item 24, Table 4) or identifying and palpating superficial body landmarks (50.0%, Item 26).

However, most students agreed that the life-like appearance of Mr. Kyoto was important in increasing their knowledge of patient positioning (82.4%, Item 30, Table 4), identifying and palpating for superficial body landmarks (78.4%, Item 31), adjusting the x-ray tube (66.6%, Item 32) and assessing image quality (80.4%, Item 33).

Students thought that Mr. Kyoto reflected features of a real patient (68.6%, Item 34 Table 5) and that managing him required clinical decision-making (50.9%, Item 37, Table 5). Some students reported difficulty engaging with Mr. Kyoto (56.9%), and few preferred imaging Mr Kyoto to imaging real patients (25.5%, Item 36). However, many students agreed that repeated practice on imaging Mr. Kyoto would improve their clinical skills (82.3%, Item 38).

Discussion

The simulation learning activities used in this study (role-play and x-ray phantom imaging) are low-fidelity simulations. Prior to this study, it was unclear how much radiographic knowledge students gain from simulation learning activities. This study has demonstrated that low-fidelity simulation can significantly improve students' knowledge about clinical indications, patient positioning, cassette placement and selection of exposure factors for radiographic projections. Increased clinical knowledge has been demonstrated previously in studies involving pharmacy students in team simulation of patient care using clinical scenarios (Vyas et al., 2010), in simulation learning activities on cardiopulmonary resuscitation skills for medical students (Owen, Mugford, Follows, & Plummer, 2006), cannulation or venepuncture (Maran & Glavin, 2003) and insertion of urinary catheters (Weller et al., 2012). Although Mr. Kyoto is an inanimate x-ray phantom lacking physiological characteristics, this study has shown that it is still able to improve students' perception of learning radiographic projections. Hence, high-fidelity complex models are not necessarily required to teach basic clinical skills to first-year radiography students (Maran & Glavin, 2003). However, this does not mean that realism is not important for radiography teaching. Students in this study indicated that the x-ray phantom needed to be realistic to some extent to increase knowledge of the various radiographic elements. Besides the phantom itself, the simulated environment also needed to be realistic. Without a certain degree of realism, students may focus exclusively on learning a skill, with little consideration

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of the clinical context in which the skill is undertaken. This has often been cited as one of the drawbacks of low-fidelity simulation (Kneebone, Black, Yadollahi, & Darzi, 2006; Reid-Searl, Happell, & Vieth, 2012). In this study, two-thirds of students agreed that the simulation laboratory had the appearance and impression of a clinical setting rather than a university laboratory. A higher percentage agreed that they learnt from the simulation learning activities. This indicates that learning from simulation is not solely dependent upon the degree of realism but is also related to other aspects of the simulation activities. These include feedback and guidance offered by the tutors and a safe environment in which students can learn from their mistakes and from one another. The majority of students found that the simulation learning activities decreased their anxiety about doing clinical placements. These are positive findings because the clinical environment faced by healthcare students can be stressful, and lead to anxiety (Gore et al., 2011; Harder, 2010) and an inability to cope (Innes, 1998).

Imaging Mr. Kyoto provides students the opportunity to expand their clinical reasoning skills. However, in this study only half the students recognised that imaging Mr. Kyoto required them to make clinical decisions. When imaging Mr. Kyoto in the simulation laboratory, students were required to position Mr. Kyoto, align the x-ray tube, select exposure factors and decide whether the image was of acceptable quality. These are important clinical decisions that radiographers must be able to make in the clinical setting. Another possible explanation is that some students found it difficult to engage with the x-ray phantom due to its low fidelity. Conversely, 82% of students agreed that their clinical skills would be improved if they had repeated practice with Mr Kyoto. Further studies are required to investigate the extent of clinical decision-making learnt from phantom imaging and whether repeated practice would improve students' learning in this domain. Students in our study indicated that they relied on their tutors to make their clinical decisions. This could be due to their relative inexperience, as first-year students who had limited clinical placement experience. The years of experience that the tutors have as a qualified radiographer may have given students the confidence to rely on their tutors for clinical guidance. Another possible reason may be students' inexperience with pelvic and hip joint radiography, as they only had an hour face-to-face lecture covering the context of the laboratory session prior to the simulation activities. Although students require guidance from tutors to achieve the learning objectives (DeBourgh & Prion, 2011) and to correct errors (Reilly & Spratt, 2007), an over-reliance may inhibit learning in the simulated learning setting. Students in our study valued the overall feedback given by their tutors and agreed that they critically reflect on this. A limitation of our study was not distinguishing between the two simulation activities in the pre- and post-tests and some survey questions, and not asking students to what extent they relied upon their tutors during the decision-making process.

Tutors played an important role in the simulation learning activities. Students indicated that supervision by a tutor encouraged them to practise their clinical skills and that these hands-on experiences allowed them to make errors and to learn from these. Students understood that errors served as "significant events" in their learning, as was also found by Coutts & Rogers (1999). Errors made in a real clinical setting

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can compromise patient safety. This highlights the importance of tutor feedback in simulation-based learning. The students in our study valued and reflected upon the feedback provided by tutors. This is consistent with the findings of other studies using low- to intermediate-fidelity simulation (Alinier, Hunt, Gordon, R., & Harwood, 2006; Baillie & Curzio, 2009).

Students in this study positively perceived the role-play activities in terms of improving their confidence in giving verbal instructions to patients, positioning patients and aligning the x-ray tube. Students were less positive about role-play increasing their understanding of choosing the appropriate radiographic projections and selecting the appropriate exposure factors. The role-play components that students were most positive about included patient positioning and identifying and palpating superficial body landmarks. These radiographic elements require patient interaction, and the study indicates that having students acting in the role of the "patient" can simulate some aspects of the clinical setting.

An interesting finding of this study is the impact of peers on the simulation learning activities. Almost all students rated learning from observing their peers highly, in both types of simulation activities. This supports the findings of a recent study by Stegmann et al. (2012), where undergraduate medical students learnt how to effectively communicate with patients by observing others.

Limitations

One limitation of this study is that Monash University had recently acquired Mr. Kyoto. The week that the pre-and post-tests were conducted was the first time the students and teaching staff had used this phantom. As a consequence, there was unfamiliarity with the use of Mr. Kyoto for both the students and teaching staff. This may have impacted on the extent of students' knowledge acquisition. According to Seropian and Samuelson (2004), in order to "reap the maximum benefits" (p. 169) of simulators, educators need to familiarise themselves with the simulation to enhance student learning. Another limitation is that data was obtained from one cohort of students in a particular SLC, and therefore the results may not be transferable to the same cohort in other simulation classes or to other cohorts of students.

Conclusion

This study provides insight into the role of simulation learning in radiography education. The low-fidelity simulation activities of role-play and x-ray phantom imaging are an effective approach to enhancing students' radiographic knowledge. Students learnt from simulation activities since they provided opportunities to make errors, receive feedback from tutors on their performance and observe their peers undergoing these activities. Students perceive role-play as a way to improve their confidence in positioning patients, giving verbal instructions and aligning x-ray equipment. Further studies are required to understand why students do not think these opportunities help them develop judgement and decision-making skills.

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References

Ackermann, A. (2009). Investigation of learning outcomes for the acquisition and retention of CPR knowledge and skills learned with the use of high-fidelity simulation. *Clinical Simulation in Nursing*, *5*(6), e213–e222.

Alfes, C. (2011). Evaluating the use of simulation with beginning nursing students. *Journal of Nursing Educatio*n, *50*(2), 89–93.

Alinier, G., Hunt, B., Gordon, R., & Harwood, C. (2006). Effectiveness of intermediate-fidelity simulation training technology in undergraduate nursing education. *Journal of Advanced Nursing*, *54*(3), 359–369.

Baillie, L., & Curzio, J. (2009). Students' and facilitators' perceptions of simulation in practice learning. *Nurse Education in Practice*, *9*(5), 297–306.

Bearnson, C., & Wiker, K. (2005). Human patient simulators: A new face in baccalaureate nursing education at Brigham Young University. *Journal of Nursing Education*, *44*(9), 421–425.

Bienstock, J., Katz, N., Cox, S., Hueppchen, N., Erickson, S., & Puscheck, E. (2007). To the point: Medical education reviews—providing feedback. *American Journal of Obstetrics and Gynecology*, *196*(6), 508–513.

Cheung, R., & Au, T. (2011). Nursing students' anxiety and clinical performance. *Journal of Nursing Education*, *50*(5), 286–289.

Coutts, L., & Rogers, J. (1999). Predictors of student self-assessment accuracy during a clinical performance exam: Comparisons between over-estimators and under-estimators of SP-evaluated performance. *Journal of the Association of American Medical Colleges*, *74*(10), 128–130.

Crea, K. A. (2011). Patient simulation: Practice skill development through the use of human patient simulation. *American Journal of Pharmaceutical Education*, *75*(9), article 188. doi: 10.5688/aipe759188

DeBourgh, G., & Prion, S. (2011). Using simulation to teach prelicensure nursing students to minimize patient risk and harm. *Clinical Simulation in Nursing*, *7*(2), e47–e45.

Fowler, J. (2008). Experiential learning and its facilitation. *Nurse Education Today*, *28*(4), 427–433.

Gaba, D. (2004). The future vision of simulation in health care. *Quality and Safety in Health Care*, *13*(1), i2–i10.

Gore, T., Hunt, C., Parker, F., & Raines, K. (2011). The effects of simulated clinical experiences on anxiety: Nursing students' perspectives. *Clinical Simulation in Nursing*, *7*(5), e175–e180.

Grant, D., & Marriage, S. (2012). Training using medical simulation. *Archives of Disease in Childhood*, *97*(3), 255–259.

Harder, B. (2010). Use of simulation in teaching and learning in health sciences: A systematic review. J*ournal of Nursing Education*, *49*(1), 23–28.

ISSN 1442-1100

Innes, J. (1998). A qualitative insight into the experiences of postgraduate radiography students: Causes of stress and methods of coping. *Radiography*, *4*(2), 89–100.

Issenberg, S., & Scalese, R. (2008). Simulation in health care education. *Perspectives in Biology and Medicine*, *51*(1), 31–46.

Jarzemsky, P., & McGrath, J. (2008). Look before you leap: Lessons learned when introducing clinical simulation. *Nurse Educator*, *33*(2), 90−95.

Kneebone, R., Black, S., Yadollahi, F., & Darzi, A. (2006). The human face of simulation: Patient-focused simulation training. *Academic Medicine*, *81*(10), 919−924.

Kolb, A., & Kolb, D. (2005). Learning styles and learning spaces: Enhancing experiential learning in higher education. *Academy of Management Learning & Education*, *4*(2), 192−212.

Kuznar, K. (2007). Associate degree nursing students' perceptions of learning using a high-fidelity human patient simulator. *Teaching and Learning Nursing*, *2*(2), 46−52.

Maran, N., & Glavin, R. (2003). Low- to high-fidelity simulation: A continuum of medical education? *Medical Education*, *37*(1), 22−28.

McCaughey, C. S., & Traynor, M. K. (2010). The role of simulation in nurse education. *Nurse Education Today*, *30*, 827−832.

McGregor, M., & Guiliano, D. (2012). Manikin-based clinical simulation in chiropatic education. *The Journal of Chiropractic Education*, *26*(1), 14−23.

Meechan, R., Jones, H., & Valler-Jones, T. (2011). Students' perspectives on their skills acquisition and confidence. *British Journal of Nursing*, *20*(7), 445−450.

Melincavage, S. (2011). Student nurses' experiences of anxiety in the clinical setting. *Nurse Education Today*, *31*(8), 785−789.

Owen, H., Mugford, B., Follows, V., & Plummer, J. (2006). Comparison of three simulation-based training methods for management of medical emergencies. *Resuscitation*, *71*(2), 204−211.

Reid-Searl, K., Happell, B., & Vieth, L. (2012). High fidelity patient silicone simulation: A qualitative evaluation of nursing students' experiences. *Collegian*, *19*(2), 77−83.

Reilly, A., & Spratt, C. (2007). The perceptions of undergraduate student nurses of high-fidelity simulation-based learning: A case report from the University of Tasmania. *Nurse Education Today*, *27*(6), 542−550.

Schwid, H., Rooke, G., Carline, J., Steadman, R., Murray, W., & Olympio, M. (2002). Evaluation of anaesthesia residents using mannequin-based simulation: A multi institutional study. *Anesthesiology*, *97*(6), 1434−1444.

Seropian, M., & Samuelson, J. (2004). Simulation: Not just a manikin. *Journal of Nursing Education*, *43*(4), 164−169.

Seybert, A., & Kane-Gill, S. (2011). Elective course in acute care using online learning and patient simulation. *American Journal of Pharmaceutical Education*, *75*(3), article 54. doi: 10.5688/ajpe75354

ISSN 1442-1100

Sica, G., Barron, D., Blum, R., Frenna, T., & Raemer, D. (1999). Computerized realistic simulation: A teaching module for crisis management in radiology. *American Journal of Radiology*, *172*, 301–304.

Smith, A., Ortiguera, S., Laskowski, E., Hartman, A., Mulenbach, D., Gaines, K., . . . Fisher, W. (2001). A preliminary analysis of psychophysiological variables and nursing performance in situations of increasing criticality. *Mayo Clinic Proceedings*, *76*(3), 275–284.

Stegmann, K., Pilz, F., Siebeck, M., & Fisched, F. (2012). Vicarious learning during simulations: Is it more effective than hands-on training. *Medical Education*, *46*(10), 1001–1008.

Thoirs, K., Giles, E., & Barber, W. (2011). The use and perceptions of simulation in medical radiation science education. *The Radiographer*, *58*(3), 5–11.

Traynor, M., Gallagher, A., Martin, L., & Smyth, S. (2010). From novice to expert: Using simulators to enhance practical skill. *British Journal of Nursing*, *19*(22), 1422–1426.

Vyas, D., Wombwell, E., Russell, E., & Caligiuri, F. (2010). High-fidelity patient simulation series to supplement introductory pharmacy practice experiences. *American Journal of Pharmaceutical Education*, *74*(9), article 169.

Weller, J., Nestel, D., Marsall, S., Brooks, P., & Conn, J. (2012). Simulation in clinical teaching and learning. *Medical Journal of Australia*, *196*(9), 1–5.

Wilson, M., Shepherd, I., Kelly, C., & Pitzner, J. (2005). Assessment of a low-fidelity human patient simulator for the acquisition of nursing skills. *Nurse Education Today*, *25*(1), 56–67

Wright, D., Rolland, J., & Kancherla, A. (1995). Using virtual reality to teach radiographic positioning. *Radiologic Technology*, *66*(4), 233–238.

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