Enhancing student nurses' medication calculation knowledge

Background:
Accurate calculation of dosages and safe administration of medications in clinical practice is an essential skill for the registered nurse. Appropriate educational preparation of student nurses is the key to ensuring they become safe practitioners in the workforce. A review of the literature on different approaches for teaching and assessing medication calculation with student nurses revealed three main factors that influenced student nurses’ ability to calculate medications accurately and identify mistakes. These factors include mathematical ability, particularly around multiplying with decimals, understanding medication formulas, and conceptualising medication dose.

Objectives: This study evaluated teaching interventions that focused on improving the students’ understanding of mathematical calculations, medication formulas and conceptualising medication doses.

Design: Evaluation study with teaching interventions and Time 1 and Time 2 medication tests.

Participants: 156, 2nd year Bachelor of Nursing students from an Australian University

Method: The teaching interventions over 8 weeks included teaching decimals and basic mathematical skills, using the correct mathematical formula for the medication and linking the medication to the patient case study. Time 1 and Time 2 medication tests out of ten, student demographics and reasons for attending tutorials were collected to evaluate the effectiveness of the teaching interventions.

Results: For Time 1 medication test pre interventions, the mean was 7.3 with a mode of 8 out of ten. Maths and incorrect medication formula were the most common mistake. For Time 2 medication test post interventions, the mean was 9.3 with a mode of 10. The most common reason for incorrect answer Time 2 was incorrect medication formula. The students identified that the smaller tutorial sizes and remediation of errors was the main reason for continued attendance.

Conclusions: The teaching intervention improved the accuracy of students’ medication calculation, specifically, understanding the correct formula to use and identifying errors of calculation.

Introduction
Administration of medications is a major component of the registered nurse’s role within all clinical settings. It is considered a high risk task which requires a consistently safe and accurate approach by the registered nurse in any work place (Levett-Jones & Bourgeois, 2011). Appropriate administration of medications contributes to overall patient safety, as incorrect medication administration and understanding of medication influence on the patient can lead to poor patient outcomes that extend beyond the immediate situation (Elliot & Joyce, 2005; Harvey et al., 2009; O'Shea, 1999). One of the initial concerns of the newly graduated nurse is the transition from supervised medication assessment at university to independent medication administration in the context of patient care, and the consequences of mistakes on patient outcomes (Goh & Watt, 2003). To reduce medication errors in new graduate nurses
and ensure safe clinical practice it is imperative that universities design effective teaching strategies, based on critical thinking when administering medications independently.

**Background**
The education of student nurses consists of balancing theoretical knowledge and real world experiences. Appropriate nursing education guides students from theory to practice and supports their development of knowledge and understanding which will enable them to make clinical decisions as a graduate (Benner, Sutphen, Leonard, & Day, 2010). Ideally, students are introduced to medication administration incrementally, concurrent with their understanding of pathophysiology and pharmacology. An approach to teaching which scaffolds and integrates the medication knowledge with different treatment modalities and differing levels of patient acuity assists the students’ progression. The principles of safe medication administration remain the same throughout a registered nurse’s career and can be applied as the knowledge and complexity of the medications are increased (Shihab, 2009). Therefore if students understand the principles developed from practising with realistic tasks during their education, they are likely to develop an attitude of reflection and critical thinking which, in turn, will improve their medication safety (Wright, 2008).

A review of current literature suggests there are three key factors which influence the student’s ability to perform accurate medication calculations (Elliot & Joyce, 2005; Harvey, et al., 2009; Pierce, Steinle, Stacey, & Widjaja, 2008; Wright, 2008). These factors are mathematical ability, understanding the medication formula and being able to link the patient to the medication. Focusing on these specific factors as an incremental approach will enable students to build an understanding of medication administration as they move from novice to beginner registered nurse (Benner, et al., 2010).

Nurses require a reasonable level of mathematical ability to perform and understand calculations related to medication administration (Harvey, et al., 2009). Current research identifies mathematical skills as a key component of safe and accurate administration of medications, with the ability to perform basic mathematical calculations, understand decimals and identify errors in calculation as pivotal to safe practice (Andrew, Salamonson, & Halcomb, 2009; Grandell-Niemi, Hupli, Puukka, & Leino-Kilpi, 2006; Harvey, et al., 2009; Jukes & Gilchrist, 2006). Basic mathematical ability is a combination of both the students’ ability and their personal confidence in performing calculations, which, in turn, influences their ability to accurately administer the medication to the patient (Andrew, et al., 2009).

Andrew et al.’s (2009) Australian research used a specific instrument developed to measure confidence in mathematical skills to explore students’ confidence in performing mathematics skills related to medication calculation. The study of 123 second year students reported a high positive correlation between confidence and higher performance in medication tests. Students identified least confidence in multiplication, particularly with decimals and fractions (Andrew, et al., 2009). Andrew et al. (2009) concluded that poor medication test results often reinforce the students’ lack of confidence about their ability to perform medication calculations accurately in the clinical setting. They recommended educational programs that aim to increase the students’ confidence in performing medication calculations; specifically working with the student to identify errors and providing structured feedback for the student to increase their knowledge.

For accurate medication administration, the student must understand the placement of the decimal, as incorrect placement can have dire repercussions on the final dose of medication given to the patient (Pierce, et al., 2008). Pierce, et al. (2008) focused on mathematical
ability, finding deficits in student learning relating to understanding decimal numbers and their application within medication calculation. This Australian research by Pierce, et al. (2008) explored the whole cohort of Bachelor Nurses from first to third year [N = 355] and completed an intervention on 96 second year students. Forty students were given one hour remedial decimal point teaching and the other 56 students no extra teaching. The intervention was successful in improving the students conceptual knowledge of decimals numbers (Pierce, et al., 2008). Previous research has noted that students often lack the knowledge and skills to multiply with decimals, even if a calculator is used (Harvey, et al., 2009; Pierce, et al., 2008). However, Pierce et al. (2008) argue that students finding these skills difficult can benefit from remediation with the use of directed feedback about errors and basic illustration of place value of decimals, which can increase their understanding of multiplying with decimals.

The use of the correct formula requires students to understand what they are attempting to calculate. Rice and Bell (2005) completed an intervention study with 30 nursing students at University of Texas, providing support for solving medication calculation problems using a dimensional analysis approach. The teaching intervention over two semesters provided students with a systematic approach to using the correct formula and placing the numbers in the formula correctly. Rice and Bell’s study reported that the students were more confident in medication calculation and were making fewer calculation errors (Rice & Bell, 2005).

Several research studies explored the use of a clinical case study approach to provide clinical authenticity to the medication calculation (Glaister, 2007; Greenfield, 2007). The use of realistic case studies provides students with a broader sense of what is required with medication administration in the clinical context (Greenfield, 2007). In this approach, students learn to link the patient with the medications and the patient assessment and follow up required, a strategy for understanding safe nursing practice (Peterson & Bechtel, 2000).

In an American research study, students were instructed on the use of computerised technology to increase their understanding of the medication calculation and link the medication to the patient safety concerns, such as changes in blood pressure (Greenfield, 2007). Personal digital assistants [PDA] or computerised learning programs purpose built for medication administration provided students with timely information and feedback on medication doses and patient information (Greenfield, 2007). The 87 nursing students across the three levels of the degree became more accurate and efficient at medication calculations. Other strategies used to teach medication calculations are the use of consistent feedback and identification of errors within their calculation, which increases the students’ ability to identify their own errors before administration of the medication (Elliot & Joyce, 2005; Wright, 2008).

One of the difficulties with teaching medication administration is the differing levels of students with undergraduate nursing programs and the challenge for academic staff is to address the disparate student learning needs (Hutchinson, Mitchell, & St John, 2011). Most Australian universities have multiple entry points for Bachelor of Nursing students and this needs to be considered in the teaching and assessing of students to ensure consistency in student understanding of safe medication administration (Hutchinson, Mitchell, & St John, 2011). These entry points include, commencing domestic students with no previous nursing experience and complete the full three year program, domestic students who are endorsed enrolled nurses [EEN diploma level nurse], and international students with varying nursing qualifications and graduate entry students [student with other graduate degrees], all of whom enter the degree at different year levels and at different ages. The EENs and international
students have medication administration practice within the clinical sector, but sometimes fail to make the links between the theory supporting medication administration and safe practice (Hutchinson, et al., 2011). In first year, students undertake courses in second semester which introduce safe medication administration concepts and complete an associated clinical practicum. There is an expectation that all students entering second year will have a similar understanding of basic medication calculations, however this does not seem to always be the case and some students appear to struggle with understanding the concepts of calculations and medications administration (Reid-Searl, Moxham, Walker, & Happell, 2010).

The findings from the literature identified some of the most significant factors in ‘getting it right’ for nurse educators seeking to prepare safe, effective graduates for medication administration. The aim of this study was therefore to implement and evaluate teaching interventions that would increase the knowledge and skills for safe medication administration in undergraduate nursing students.

Method
An evaluation study of second year undergraduate nursing student in an Australian University was undertaken to investigate whether teaching interventions aimed at improving the students’ maths ability, understanding of the formula and conceptualising the medication were effective in improving medication calculation accuracy. The Time 1 and Time 2 medication test provided data on the students’ medication ability. Student demographics such as level of experience, gender, and enrolment status were collected. Prior to the teaching interventions a ten question medication test was administered, Test 1. At the end of semester after the teaching interventions were completed the ten question medication test was administered again, Test 2. Incomplete questionnaires were removed from data analysis as recommended by Polit (2010). There were 22 questionnaires removed from analysis as a result of this data cleansing process.

Sample and setting
A convenience sample was drawn from second year undergraduate nursing students enrolled in an Australian metropolitan university [N = 178] who were asked to volunteer for the study. The second year students enrolled in the clinical subject are from several entry points. These entry points include continuing students from first year, enrolled nurses [diploma level], graduate entry [students with any previous bachelor degree] and international students [with varying health qualifications]. The medication tests were completed during non-mandatory tutorials, which ordinarily would have included this type of medication calculation practice and assessment.

Data collection
Time 1 medication test
The students participated in the ten question medication test during first face to face tutorial [n = 156, response rate 87%]. The students were given 30 minutes to complete the exam, calculation formulas were provided and calculators were allowed. The medication test was a standard medication test based on the course content and year level and contained the following range of questions; three oral medication [questions 1, 2, 9] two intramuscular injections [questions 7, 10], three intravenous rates [questions 3, 4, 5] one weight based [question 6] and one conversion question [question 8].

Demographics of the student were collected with the first medication test. This included gender, level of nursing experience as three categorical variables [EEN diploma level
international, other nurse related experience, nil], years since leaving school as three categorical variables [<4 years, 5-10 years, >10 years] and enrolment status as four categorical variables [domestic, international, indigenous Australian, graduate entry].

**Time 2 medication test**
The students participated in the medication test during the face to face tutorials at the end of semester, tutorial 9 [n = 124, response rate 69%]. The test contained ten medication calculations same types as Time 1 test and students were given 30 minutes in which to complete the exam, formulas were provided and calculators could be used. Students were also asked to complete a short questionnaire asking the number of tutorials attended as three categorical variables [less than 2, 2-5, over 5], reasons for non-attendance as three categorical variables [work, social, not interested] and to choose from a list of ten the benefits they gained from tutorials.

**Ethics**
The University ethics manager deemed the study as teaching evaluation rather than research and directed the researchers to follow ethical guidelines. The study was considered an evaluation of teaching with minimal risk to students and no element considered as student assessment and did not require full ethical clearance. All students were asked if they would like to participate in the study and provided with an information sheet which informed them of the nature of the study their right to participate or withdraw without penalty. The students were also advised that the medication calculation test would be de-identified and none of the results would be used as assessment items for the course. No students were disadvantaged through non-participation, as all students enrolled in the clinical subject had equal access to lecture and tutorial material relating to medication administration, a range of online resources, including online practice medication exam and reading resources including medication calculation text book. Current practice involved three medication calculation tutorials teaching formulas for different types of medications [oral, intramuscular and intravenous].

**Intervention**
One hour weekly tutorials provided the students with information, practical guidance and interactive teaching.

- Tutorial one Time 1 medication test completed. Students were stepped through decimals and basic mathematical skills.
- Tutorials two to five were practical sessions using clinical case studies and the formulas to work through oral and parental administration of medications. The medication formulas included oral drug dose, parenteral medication dose, intravenous dose, weight based formula.
- The students then attended a two week clinical placement in an acute hospital setting where they were supervised in the administration of medications.
- Tutorials six to eight were practical sessions on linking the medication, to the patient [case study] discussing actual medication calculation, patient safety regarding medication and how to identify errors of medication administration.
- Tutorial nine the Time 2 medication test was completed.

**Findings**
The participants were 143 females (92%), and 13 males (8%). Their level of experience as a nurse was reported as enrolled nurse EEN (n = 48, 31%), other (which denoted assistant in
nursing, dentist nurse, vet nurse (n = 5, 3%) and no experience in nursing (n = 103, 66%).

Students reported time since leaving school as less than four years (n = 52, 33%), five to ten years (n = 44, 28%) and over ten years (n = 55, 35%) [Missing = 5]. Their enrolment status shown as four categories included domestic student (n = 119, 76%), international students (n = 33, 21%), Indigenous Australian [Aboriginal or Torres Strait Islander descent] (n = 2, 2%) and graduate entry (n = 1, 1%).

A paired-sample t-test was conducted to evaluate the impact of the intervention on the student’s medication scores. There was a statistically significant increase in the medication scores from Time 1 (M = 7.05, SD = 2.6) to Time 2 [M = 9.45, SD = 0.9, t (104) = -10.8, p<.0001]. The eta squared statistic (.70) indicated a large effect size. See Figure 1 for details of spread of scores across Time 1 and Time 2.

Following the Time 1 medication test, pre intervention, for each question incorrectly answered the reason was noted, namely maths, formula, both maths and formula or not answered. The oral medications questions were answered incorrectly by 8 students (5%) and maths was the reason for the incorrect answer. Intravenous fluid questions were answered incorrectly by 75 students (48%). The reason for incorrect answer was wrong formula (25%) and incorrect maths (8%) or both formula and maths (5%). The weight based formula was incorrectly answered by 84 students (53%) most using the wrong formula (20%) or not providing an answer (24%). See Figure 2 for details of student errors.

Time 2 medication test, post intervention the intravenous fluid questions were answered incorrectly by 19 students (15%) the wrong formula used. The weight based formula was incorrectly answered by 33 students (27%), who used the wrong medication formula. See Figure 3 for student errors test 2.

Students reported attending over five of the tutorials (n = 98, 79%), attending two to five (n = 21, 17%) or less than two (n = 5, 4%) although a significant number of students (n = 32, 20%) did not complete the Time 2 test. Reasons for not attending tutorials completed by 39 students were work (n = 29, 74%), social (n = 8, 21%) and not interested (n = 2, 5%). Eighty-five students did not complete this question.

The students were asked to identify what benefits they considered the tutorials provided for them. Table 2 presents the frequency and percentage of the student’s response.

Discussion

The results of the study showed that the students’ medication calculation improved significantly between the Time 1 and Time 2. This indicates that strategies aimed at increasing students’ mathematical knowledge and understanding of the correct medication formula to use for each situation were effective in improving medication calculation for this group of student nurses. The analysis revealed that it was the student’s use of the incorrect formula in the Time 2 which caused them to answer incorrectly. This highlights the need for students to be consistently encouraged to use the formula for medication calculation as this will embed medication knowledge, as the difficulty and complexity of medication calculation increases over time. The students are then better equipped to understand the application and use of the correct formula.

The medication errors that the students made in both Time 1 and Time 2 were related to the calculation of the intravenous fluids and weight based formula, and these have been identified
as problem areas in previous research (Harne-Britner et al., 2006). The students’ mathematical ability improved during the semester, highlighting the benefit of smaller group teaching and specific strategies to increase their maths knowledge. This study revealed students’ perceptions of the main benefits of the tutorials as being related to their understanding the maths. This is consistent with previous research teaching students how to understand the decimal (Pierce, et al., 2008).

The diversity of students within clinical courses from school leavers to mature age entrants with or without prior nursing experience highlights the need for a range of teaching strategies which support gradual introduction of concepts and practice throughout the semester. These techniques should progress from teaching the basic mathematics to higher levels of clinical theory integration relating to medication administration and pharmacology (Burton, Dowling, Dorman, & Brodie, 2005). One of the aims of the teaching strategy used in this study was to begin at basic level, consolidating existing maths knowledge and familiarisation with several formulas. The visualisation of the medication dose and side effects through the use of case studies is a strategy that aims to teach students to link the medication calculation to administration of the medication and ultimately improve medication safety (Wright, 2008). Whilst the students did not identify this as being a significant benefit gained from the tutorials, the concept of visualising the medication dose may have increased their ability to identify errors when calculating the medication.

The teaching strategy of smaller interactive classes, which provide more opportunities for students to ask questions about medication calculations, was clearly identified by students as a benefit. Continued attendance of students to a non-mandatory class [63% attendance for semester] highlights the benefits of consistent student feedback. Anecdotal evidence from students suggested the students saw the benefits of linking the theory to practice. The medication tutorials also provided a non-confronting environment for students to receive remediation of medication calculation. This finding concurs with that of Elliot and Joyce (2005), who completed a teaching strategy aimed at remediation of medication calculation for students, which achieved an improvement of medication results. The current study used a similar strategy with an approach to building the students’ knowledge and confidence.

The attendance of two weeks of clinical placement provides students with opportunities to practice their medication skills and develop an understanding of the effects of medications on real patient disease states. Previous research has identified the positive benefits of clinical placement to scaffold the students’ knowledge of disease states and treatment (Brammer, 2008; Woolley & Jarvis, 2006). Reinforcement of safe medication practice was highlighted in the tutorials following the practical learning element of clinical placement, as the students were encouraged to make links between medication calculations, the administration of medications and clients’ conditions.

The 2nd year students engaged in the case studies in a beginning level although they lacked the clinical knowledge to realise the importance of the links between clinical and theory however the beginning links will form the basis for future medication safety. Evidence suggests that building students’ knowledge from novice to beginning practitioner level requires a scaffold approach where concepts are introduced and build on as the student develops the knowledge required for practice as a registered nurse (Benner, et al., 2010; Ebright, Urden, Patterson, & Chalko, 2004).
This study had a number of limitations. The quasi-experimental approach to collect information about the students’ medication ability may not have determined if the specific teaching strategies improved the students’ knowledge or if the overall semester of teaching improved the students’ medication knowledge. All students were provided with similar teaching and examination strategies, thus minimising the risk of unreliable medication test scores. The results and conclusions cannot be generalised to all levels of students as the incremental learning of the bachelor of nursing degree must be taken into account. Continuity of teaching strategies and scaffolding of skills and knowledge should be considered when implementing medication calculation teaching. A repeat evaluation of these teaching interventions relating to medication calculations may provide further validation of the value of this teaching strategy.

**Conclusion**
Safe medication administration, underpinned by evidence based practice and critical thinking, is an essential component of nursing practice. The teaching interventions utilised in this study offer effective strategies to improve the student nurses’ ability to calculate medications accurately and identify mistakes. The interventions targeted the three main factors that current literature considers to influence safe practice and the results clearly demonstrate student improvement with accuracy of medication calculation, understanding the correct use of formula and identifying self-errors within calculations. These interventions were incorporated into the core teaching of a second year clinical course and provided a range of supported learning opportunities for students to identify problem areas and engage in incremental development of safe medication practice.
Reference list


