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Review

Educational strategies aimed at improving student nurse's medication calculation skills: A review of the research literature

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A B S T R A C T

Medication administration is an important and essential nursing function with the potential for dangerous consequences if errors occur. Not only must nurses understand the use and outcomes of administering medications they must be able to calculate correct dosages. Medication administration and dosage calculation education occurs across the undergraduate program for student nurses. Research highlights inconsistencies in the approaches used by academics to enhance the student nurse's medication calculation abilities. The aim of this integrative review was to examine the literature available on effective education strategies for undergraduate student nurses on medication dosage calculations. A literature search of five health care databases: Sciencedirect, Cinahl, Pubmed, Proquest, Medline to identify journal articles between 1990 and 2012 was conducted. Research articles on medication calculation educational strategies were considered for inclusion in this review. The search yielded 266 papers of which 20 meet the inclusion criteria. A total of 5206 student nurse were included in the final review. The review revealed educational strategies fell into four types of strategies; traditional pedagogy, technology, psychomotor skills and blended learning. The results suggested student nurses showed some benefit from the different strategies; however more improvements could be made. More rigorous research into this area is needed.

Introduction

This paper presents an integrative review of the literature on education strategies for undergraduate student nurses. Effective mathematical skills are vital for medication calculations (Rainboth and DeMasi, 2006; Wright, 2007). However, many studies report student nurses have deficiencies in medication calculation abilities (Brown, 2002; Elliot and Joyce, 2005; Grandell-Niemi et al., 2006; Jukes and Gilchrist, 2006; O'Shea, 1999; Wright, 2005). Students are unprepared particularly in skills including fractions (Brown, 2002; Harvey et al., 2009; Wright, 2007), percentages (Wright, 2007), place values, interpreting data (Wright, 2007), Standard International units and formulae (Harvey et al., 2009). In order for student nurses to develop accurate safe administration of medications, strategies aimed at improving dosage calculations need to be implemented (Wright, 2007). The ability to perform medication calculations accurately and administer medication precisely is reinforced through many of the Australian Nursing and Midwifery Council National Competency Standards (2006) for the registered nurse (RN). The Australian Council for Safety and Quality in Health care has recommended safe administration of medications as a National Health priority area and strategies to combat issues are required (Reid-Searl et al., 2008). Research consistently highlights the need for improvements in the safe administration of medications to the patient yet there is little consistency in the approaches used by academics to enhance the student nurses understanding of medication dosage calculations (Andrew et al., 2009; Brown, 2002; Elliot and Joyce, 2005; Grandell-Niemi et al., 2006; Greenfield, 2007; Harvey et al., 2009; Kapborg and Rosander, 2001; O'Shea, 1999; Page and McKinney, 2007; Papastrat and Wallace, 2003; Rainboth and DeMasi, 2006; Wright, 2007, 2008). The aim of this review is perform an integrated review of the literature to examine the effectiveness of education strategies for undergraduate nursing students on medication dosage calculations. The aim will be achieved by way of a methodological analysis and presentation of past empirical and theoretical literature related to interventions to improve medication calculations for student nurses.

An integrative review of the literature is a nonexperimental design in which information derived from primary research is systematically considered (Gangong, 1987). Past research is summarised and overall conclusions are drawn from many different

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studies that reflect the past and current state of knowledge pertaining to a particular subject (Whitmore and Knafl, 2005). The review is conducted to make a more substantial contribution to nursing literature and nursing knowledge (Beyea and Nichll, 1998). This review is conducted to make a meaningful contribution related to strategies to improve medication calculations skills for student nurses.

Literature review

For the purpose of this review we have defined medication error as "a preventable event that may cause or lead to inappropriate medication use" (Department of Health (DoH), 2004, para. 1). The ability to calculate and understand the administration of medications underpins the safe practice for RNs (Elliot and Joyce, 2005; Greenfield, 2007; Harne-Britner et al., 2006; Pentin and Smith, 2006; Sung et al., 2008). The RN must not only understand all aspects of medication administration they must, more specifically ensure correct medication calculations and dosage for the safety of patients (Andrew et al., 2009; Nursing and Midwifery Board of Australia, 2006; Rainboth and DeMasi, 2006; Wright, 2005). Mathematical skills are imperative for nurses in calculating medication dosages, liquid solutions, strengths, as well as intake and output computations (Kapborg and Rosander, 2001)). Previous studies investigating the numeracy skills of undergraduate nurses have identified serious deficiencies with 8.1–10.6% able to obtain 90% pass mark (Blais and Bath, 1992; Jukes and Gilchrist, 2006) and 55% able to obtain 100% (Gillham and Chu, 1995). Poor drug calculation skills can result in incorrect medication administration to the patient (Harne-Britner et al., 2006; Kapborg and Rosander, 2001; Wright, 2005). Some studies have suggested between 7.5% and 27% of all adverse events are due to drug errors (Berga Culleré et al., 2009; Fahimi et al., 2008; Fanikos et al., 2007; Gurwitz et al., 2005; Manias, 2007; Røykenes and Larsen, 2010; Runciman et al., 2003). In Australia reported medication errors due to wrong medication dosages range from 1% (Coombes et al., 2001; Runciman et al., 2003) to 20% of errors (Dawson et al., 1993; Eastwood et al., 2009). Improper dose or quantity errors occurred for 17% of administration errors made by student nurses in the USA (Wolf et al., 2006). No studies were detected that reported the incidence of medication calculation errors by student nurses in Australia. Inaccurate drug calculations can lead to drug errors and potential harm to patients (Department of Health, 2000; O'Shea, 1999; Wolf et al., 2006). Any medication error is unacceptable.

Methods

Inclusion and exclusion criteria

In order to complete a critical integrative review, articles were considered for inclusion if they met the following criteria;

- Related to student nurse or nursing student
- Related to medication or drug calculation or dosage or numeracy
- Published between 1990 and 2012
- Hypothesis tested
- Included educational strategies and
- Written in English

Exclusion criteria were as follows:

- Not abstract and
- Not repeated

Search for relevant studies

An extensive and systematic literature search using the documented criteria was undertaken. The studies in this analysis were retrieved through an electronic search of five health care databases (Cummulative Index to Nursing and Allied Health Literature, Medline, Pubmed, Proquest and Sciencedirect). Search words used were: 'nurse', 'student', 'medication', 'drug', 'calculation', 'dosage', 'education' and 'numeracy'. Article abstracts were reviewed to establish relevance and were suitable full text articles were retrieved for closer examination of the inclusion and exclusion criteria. These studies were examined under the following headings: interventions, aim, research design, instruments, results or findings, discussion, limitations, implications for the future and conclusions.

Findings

Initially 17 004 articles were retrieved from the search of these databases, of these 266 were relevant to this review. There were 246 studies excluded on the basis of the inclusion criteria (see Fig. 1). Twenty met the inclusion criteria which focused on medication calculation interventions for student nurses and were included in this review (see Table 1) (Adams and Duffield, 1991; Costello, 2011; Coyne et al., 2013; Craig and Seller, 1995; Dilles et al., 2011; Glaister, 2007; Greenfield, 2007; Greenfield et al., 2006; Harne-Britner et al., 2006; Jackson and De Carlo, 2011; Kohtz and Gowda, 2010; Koohestani and Baghcheghi, 2010; McMullan et al., 2011; Pierce et al., 2008; Rainboth and DeMasi, 2006; Rice and Bell, 2005; Unver et al., 2013; Wright, 2007, 2008, 2012).

Findings and discussion

Sample sites and size of studies

Of the 20 studies, sixteen were conducted at single site (Adams and Duffield, 1991; Coyne et al., 2013; Craig and Seller, 1995; Glaister, 2007; Greenfield, 2007; Greenfield et al., 2006; Jackson and De Carlo, 2011; Kohtz and Gowda, 2010; Koohestani and Baghcheghi, 2010; Pierce et al., 2008; Rainboth and DeMasi,

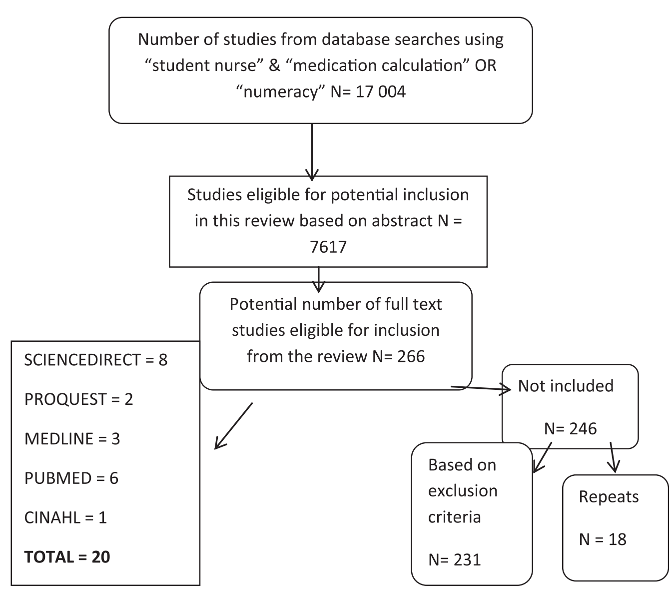

Fig. 1. Overall summation of articles retrieved for review.

Table 1
A summary of 20 studies found to meet the review inclusion criteria on medication calculation education strategies for student nurses.

Authors/country	Sample	Design	Intervention	Test type	Pass score	Calculator/aids/ equivalency tables/formula	Pass rates/results	Comments
Pierce et al., 2008, UK	2 groups, 1st-3rd year SN, Total $n = 355$, Remedial Decimal group $n = 40$, control group $n = 56$	Quasi-experimental post test 12 weeks later	INSTRUCTIONAL 1 h lecture on understanding decimals and remedial + CD-Rom (optional)	30 question Diagnostic Decimal Comparison Exam (Steinle 2004)	100%	Not reported	Number of students who attained pass scores First year $n = 127$, 51.2% Second year $n = 110$, 47.3% Third year $n = 118$, 70.3% Decimal group Mean pre test 4.5 post test 5.6 Control group Mean pre test 4.9 Post 4.8	• Non randomised, all students included • No power • No validity and reliability reported • Small sample • Single site
Adams and Duffield, 1991, Aust	1 group, 1st year SN, $n = 436$ pre test, 3rd year, $n = 106$ post test	Quasi-experimental pre test and 9 post tests (over 2 years)	INSTRUCTIONAL Lecture, tutorials and repeated worksheets	10 question drug calculation test	90%	Not reported	Marks improved over time, for first semester post test (papers 1–5), mean scores 7.55 to 9.10 but not sustained, second or third year post test (papers 6–9) mean scores 7.52 to 8.85 Students results improved during second and third year to coincide with off campus clinical placement	• Non randomised, all students included • No power • No validity or reliability reported • Small sample • Single site • Valid and reliable • Several instructors
Koohestani and Baghecheghi, 2010, Iran	2 groups, 2nd year SN, DA group $n = 21$, control group $n = 21$	RCT Pre test and 3 months post test	INSTRUCTIONAL Lectures and workshops DA *Control group* Formula method	10 question IV calculation test (2 marks per question)	100%	No calculator No aids	Pre test range 0–8 both groups Post test(1) range 14–20 both groups DA group pre test mean score 3.9 Post test mean score (1) 17.04 Post test mean score (2) 16.76 Control group pre test mean score 4.48 Post test mean score (1) 17.42 Post test mean score (2) 14.28 Both groups improved over time Post test still poor only 7.3% achieved 100%	• Simple randomisation • Consensus method • Same instructor for both interventions • No power • Valid and reliable Cronbach's alpha 0.81 • Small sample size • Single site
Kohtz and Gowda, 2010, USA	2 groups, senior SN, DA group $n = 36$, control group $n = 43$	Quasi-experimental Post test only timing not reported	INSTRUCTIONAL DA *Control group* RP and formula	24 questionnaire medication calculation exam	90%	Yes calculator	DA group 61.11% students achieved >90% 50% students achieved <100% Control group 65.12% students achieved >90% 39.29% students	• Non randomised groups similar, all students included • Groups selected by tutorial • Two instructors • No power reported

(*continued on next page*)

Table 1 (*continued*)

Authors/country	Sample	Design	Intervention	Test type	Pass score	Calculator/aids/ equivalency tables/formula	Pass rates/results	Comments
							achieved <100% No difference between the 2 types of instruction	• Content validity reported • No reliability reported • Small sample • Single site
Rice and Bell, 2005,USA	2 groups, senior SN, DA group $n = 65$, control group $n = 42$	Quasi-experimental post test only 1 week later	INSTRUCTIONAL DA 1.5 h instructional and support for students	15 question medication calculation exam Self perceived confidence	Not reported	Yes for pre but not post (calculators)	DA group (mean% correct) Pre test 79%, post test 92% Control group Pre test 93%, post test 90% DA Steady improvement over course, Control group stable No difference in dosage calculation problems for 2 groups	• Census method • Non randomised • No power • Descriptive analysis only • Small sample • Single site
Greenfield et al., 2006, USA	2 groups, 2nd year SN, DA group $n = 39$, control group $n = 26$	Quasi-experimental post test 5 weeks later	INSTRUCTIONAL DA First 4 weeks class instruction Practice problems *Control group* (previous semester) Formula method	25 question medication calculation exam	90%	Yes calculator	DA group mean 92.12 (range 75–100) 84.6% passed Control group mean 86.92 (range 46–100) 61.5% passed Use of *t-test* showed DA statistically significantly better than control	• Non randomised cohort selected by semester enrolled in • No power • No validity and reliability • Intervention group one year after the control group • Small sample • Single site
Craig and Seller, 1995, USA	2 groups, 2nd year SN, DA group, Diploma program, $n = 30$ control group, Associated degree program $n = 29$	Quasi-experimental pre and post test, 1 month before end of semester	INSTRUCTIONAL DA 2 h lecture Workbook *Control group* RP or dose/dose on hand method	20 medication calculation exam	Not reported	Yes calculator Yes conversion table	DA group Pre test Mean 5.167 (range 0–20) Post test Mean 14.30 (range 3–20) Control group Pre test Mean 11.138 Post test Mean 15.069	• Non randomised, groups selected by program • No power reported • Content validity • Reliability odd even split half test 0.714 • Two sites • Small sample size • Authors report statistically significant difference between 2 groups, however control group had higher mean scores post test
Jackson and De Carlo, 2011, USA	1 group, 1st year SN, $n = 2674$	Quasi-experimental, post test only, first day class of the next term	INSTRUCTIONAL R–P Instruction/small class groups Remediation	20 questionnaire medication calculation exam 3 resits	90%	No calculator No conversion tables	Pass rates improved from 50-60% to 84.1–97.4%	• Post test only • Non randomised, all students selected • Single site

								• No power, however large sample • No reported validity and reliability • Descriptive statistics only
Rainboth and DeMasi, 2006, USA	2 groups, Sophomore diploma SN, RP $n = 54$, control group $n = 45$	Quasi-experimental pre test post test 4 weeks and 3 months later	INSTRUCTIONAL RP assignments and practice worksheets	14 question medication calculation exam pre test 10 question medication calculation test post test Student perception of medication calculations	Not reported	Yes calculator Yes equivalency tables for pre test but not post test	RP group (14 question) Pre test mean 11.35 Post test mean 13.09 RP group (10 question) Post test mean 9.3 Control group Post test mean 9.2 Intervention group scores statistically significant higher than control group	• Census method • One instructor • Convenience sample non randomisation cohort selected by semester enrolled in • Non power • Validity established • Reliability low (0.135–0.674) • Post test same as pre test • Reliability for student perception nstrument 0.768 • Same instructor for both groups • Small sample • Single site
Dilles et al., 2011, Belgium	2 groups, BN students $n = 404$, schools $n = 17$, DN students $n = 209$, schools $n = 12$	Quasi-experimental post test only 3–4 months prior to graduation	INSTRUCTIONAL Lecture textbook	Medication knowledge and 5 question medication calculation test Self rated readiness	Not reported	No calculator	Mean scores for diploma students knowledge = 52%, calculation 53% Means scores for bachelor students knowledge = 55%, calculation = 66% 7% attained >70% and 0% attained >85% Results of test did not correlate to readiness to graduate Only 15% rated ready to become RN	• Non randomised, all schools invited • No power however, large sample size • Validity established • No reported reliability • Many instructors
Harne-Britner et al., 2006, USA	2 groups, senior SN $n = 31$, RN $n = 22$, (years of experience 4–34 years)	Quasi-experimental, pre test, post test 4 weeks later	INSTRUCTIONAL All lecture + 4 different interventions 1. 30 min tutorial 2. Workbook, calculating drug dosage (de Castillo & Werner-McCullough 2002) 3. Self study 4. None	20 question IV medication calculation exam Medication calculation survey	90%	Yes calculator	SN 58.4% able to attain pass mark RN 45.2% able to attain pass mark Senior SN pre test mean 15.9, post test mean 17.4 $p = 0.003$ Practicing RN pre test mean 15.5, post test 18.6 $p < 0.001$ Statistical difference between pre and post but not between SN and RN or group	• Non randomised, convenience sample • No power reported • Valid and reliable KR20, 0.764 • Small sample • Single site

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Table 1 (*continued*)

Authors/country	Sample	Design	Intervention	Test type	Pass score	Calculator/aids/ equivalency tables/formula	Pass rates/results	Comments
Greenfield, 2007, USA	2 groups, 1st to 3rd years SN, PDA group $n = 37$, control group $n = 50$	Quasi-experimental post test, end of spring semester at end of classes	TECHNOLOGY Personal use of PDA *Control group* Textbooks and calculator	Case study developed by researcher	90%	Calculator for control group	Speed and accuracy higher for PDA group Students continue to make errors	• Census method • Non randomised • No power • No validity or reliability reported • Small sample • Single site
McMullan et al., 2011, UK	2 groups, 2nd year SN, edrug group $n = 92$, control group $n = 137$	RCT, pre test post test	TECHNOLOGY E package DVD (self contained independent learning software) *Control group* handout	20 question drug calculation ability exam 6 question 6 questionnaire Drug calculation self efficacy scale (DCSES) Satisfaction scale	Not reported	No calculator	E package group Sep intake Pre test mean 41.2% Post test mean 48.4% Feb intake Pre test mean 36% Post test mean 47.6% Control group Sep intake Pre test mean 40% Post test mean 34.7% Feb intake Pre test mean 40.2% Post test mean 38.3% No statistically significant difference in self efficacy Students in E package more satisfied	• Cluster randomisation by site, all students invited • No power needed to be performed as all students included • Validity established • Reliability Cronbach's alpha 0.93–5 • Small sample • 3–4 sites • Not stated when post test occurred
Glaister, 2007, Aust	3 groups, 2nd year SN, $n = 97$	RCT Post test only 6 weeks later	TECHNOLOGY 3 interventions 1. Computerised learning (drug dosage software) 2. Integrative learning (2 × 1 h tutorials) 3. Computerised integrative learning	Computer attitude scale (CAS) Mathematics attitude scale (MAS) Mathematics test anxiety scale (MTAS)	100%	Not reported	12% have computer anxiety 20% have mathematics anxiety 14% have mathematics testing anxiety Students with lower anxiety performed better on test	• Randomisation by surname • No power reported • Number of students per group not reported • Validity established • Reliability Cronbach's alpha = 0.95 • Small sample • Single site
Unver et al, 2013, Turkey	1 group, senior SN $n = 85$, 4 groups $n = 22$ per group	Quasi-experimental pre test post test	TECHNOLOGY 4 h training session, Simulation (5)case studies	Objectively constructed evaluation form (OCEF) range (0–92) 22 item feedback on medication	Not reported	Not reported	Mean scores pre test 24.02 (range 1–61) Mean scores post test 54.28 (range 20–80) Statistically significant difference for intervention	• Non randomised, all students included • No power • No equivalent control group • No validity or reliability reported • Small sample • Single site
Wright, 2007, UK	1 group, $n = 44$ completed both pre and post test (matched pairs)	Quasi-experimental pre test post test, 7 months later	BLENDED LEARNING 2 h lecture Online maths sessions Workbook Practical sessions Private study Use of formula method	30 question drug calculation test	100%	Not reported	Pre test mean 16.5 Average marks 55%–71.2% Only 2 students achieved pass mark, pass rate 4.5%	• Non randomised • Convenience sample • No power • Validity established • Reliability not reported • Small sample • Single site

Wright, 2008, UK	2 groups, 2nd year SN, Blended learning group $n = 80$, control group $n = 92$	Quasi-experimental post test 12 months later	BLENDED LEARNING Lecture Tutorials Online and Face to Face Drug calculation workbook Textbooks	10 question IV drug calculation skills test	100%	Not reported	Statistically significant increase for the intervention group, however 15% more of the control group attained the pass mark	• Non randomised • No power • No validity or reliability • Small sample • Single site • 2 cohorts (separate times)
Costello, 2011, USA	1 group, freshman SN, $n = 26$	Quasi-experimental pre test post test(1), 1 month later, post test(2), 6 months later	INSTRUCTIONAL and PSYCHOMOTOR SKILLS 3 methods including formula, ratio-proportion and DA 8 stations set up to practice psychomotor skills	20 questions medication calculation exam	Not reported	Not reported	Mean differences in scores 9.76 points	• Census method • Non randomised • No power • No equivalent control group • No validity reported • Reliability Cronbach's alpha 0.74 • Small sample • Single site
Coyne, Needham, Rands, 2012, Aust	1 group, 2nd year SN, $n = 156$ pre test, $n = 105$ post test (not matched pairs)	Quasi-experimental pre test, post test 9 weeks later	BLENDED LEARNING and PSYCHOMOTOR SKILLS Lectures Tutorials (9) 2 weeks off campus clinical placement Practical sessions on campus Formula method	10 question medication calculation exam	Not reported	Yes calculator Yes formula	Mean scores pre test 7.05 Mean scores post test 9.45 Statistical significant increase for the intervention	• Census method • Non randomisation • No power • No equivalent control group • No validity or reliability reported • Small sample • Single site • All data collected used in the analysis (not matched pairs) • Data skewed, questions raised about selection of inferential statistic test
Wright, 2012, UK	1 group, 2nd year SN $n = 60$	Quasi-experimental post test last day of study	BLENDED LEARNING and PSYCHOMOTOR SKILLS Online workbook Simulated drug session Maths tutorial (optional) Off campus Clinical placement Self learning (Australia, 2006)	Perceptions of learning environments questionnaire (PLEQ) (QUT, 1994)	Not reported	Not reported	Time and resources are required to demonstrate 'real world' nursing	• Non randomised • No power reported • Valid and reliable • Small sample • Single site

Key: SN = student nurse, DA = dimensional analysis, RP = ratio-proportion, RCT = randomised control trial, QUT = Queensland University of Technology, IV = intravenous, DVD = digital video disc, PDA = personal digital assistant, RN = registered nurse, DN = diploma of nursing, BN = bachelor of nursing, KR20 = Kuder-Richardson.

Traditional formula

$$\frac{\text{Strength required}}{\text{Strength in stock}} = \text{number of tablets}$$

$$\frac{\text{Strength required}}{\text{Strength in stock}} \times \frac{\text{volume}}{1} = \text{volume to be given}$$

Ratio-proportion method

$$\frac{\text{Dosage required}}{\text{Stock dosage}} = \frac{\text{Required tablet OR volume}}{\text{Stock tablet OR volume}}$$

Fig. 2. Traditional formula.

2006; Rice and Bell, 2005; Unver et al., 2013; Wright, 2007, 2008, 2012), one was undertaken at two sites (Harne-Britner et al., 2006), one study was undertaken at three to four sites (McMullen et al., 2011) and one was conducted at 29 nursing schools (Dilles et al., 2011). Nine studies were conducted in the Unites States of America (Adams and Duffield, 1991; Costello, 2011; Craig and Seller, 1995; Greenfield, 2007; Greenfield et al., 2006; Jackson and De Carlo, 2011; Kohtz and Gowda, 2010; Rainboth and DeMasi, 2006; Rice and Bell, 2005), four in Britain (McMullan et al., 2011; Wright, 2007, 2008, 2012), three in Australia (Adams and Duffield, 1991; Coyne et al., 2013; Glaister, 2007), and one each in Iran (Adams and Duffield, 1991; Coyne et al., 2013; Glaister, 2007; Koohestani and Baghcheghi, 2010), Turkey (Unver et al., 2013) and Belgium (Dilles et al., 2011). One study had 2674 students (Jackson and De Carlo, 2011), two studies had between 613 and 229 participants (Dilles et al., 2011; McMullan et al., 2011), seven studies had between 96 and 172 participants (Adams and Duffield, 1991; Coyne et al., 2013; Glaister, 2007; Pierce et al., 2008; Rainboth and DeMasi, 2006; Rice and Bell, 2005; Wright, 2008) and ten studies had between 26 and 87 participants (Costello, 2011; Craig and Seller, 1995; Greenfield, 2007; Greenfield et al., 2006; Harne-Britner et al., 2006; Kohtz and Gowda, 2010; Koohestani and Baghcheghi, 2010; Unver et al., 2013; Wright, 2007, 2012) .

Research design of studies

All studies used convenience sampling of student nurses; one study included a comparison between NS and RN (Harne-Britner et al., 2006). Three studies used randomised control design (RCT) (Glaister, 2007; Koohestani and Baghcheghi, 2010; McMullan et al., 2011) and seventeen used quasiexperimental design (Adams and Duffield, 1991; Costello, 2011; Coyne et al., 2013; Craig and Seller, 1995; Dilles et al., 2011; Greenfield, 2007; Greenfield et al., 2006; Harne-Britner et al., 2006; Jackson and De Carlo, 2011; Kohtz and Gowda, 2010; Pierce et al., 2008; Rainboth and DeMasi, 2006; Rice and Bell, 2005; Unver et al., 2013; Wright, 2007, 2008, 2012). Five studies used two group pre test post test design (Craig and Seller, 1995; Harne-Britner et al., 2006; Pierce et al., 2008; Rainboth and DeMasi, 2006; Rice and Bell, 2005), one study investigated 29 groups (nursing schools) post test (Dilles et al., 2011), one study used three groups post test only with randomisation by surname (Glaister, 2007), four studies used two group post test (Greenfield, 2007; Greenfield et al., 2006; Kohtz and Gowda, 2010; Wright, 2008), five studies used pre test post test without control group (Adams and Duffield, 1991; Costello, 2011; Coyne et al., 2013; Unver et al., 2013; Wright, 2007) and two used post test only without control group (Jackson and De Carlo, 2011; Wright, 2012). The major weakness of quasiexperimental design is that the cause and effect inferences are difficult to establish rigorously(Polit, 2010).

Use of calculators

Seven studies reported allowing students use of calculators (Coyne et al., 2013; Craig and Seller, 1995; Greenfield, 2007; Greenfield et al., 2006; Kohtz and Gowda, 2010; Rainboth and DeMasi, 2006; Rice and Bell, 2005). Four refused students use of calculators (Dilles et al., 2011; Jackson and De Carlo, 2011; Koohestani and Baghecheghi, 2010; McMullan et al., 2011) and nine did not discuss calculator usage (Adams and Duffield, 1991; Costello, 2011; Glaister, 2007; Harne-Britner et al., 2006; Pierce et al., 2008; Unver et al., 2013; Wright, 2007, 2008, 2012). Two studies did not state reasons why calculators were not acceptable (Jackson and De Carlo, 2011; Koohestani and Baghcheghi, 2010), one reported calculators were not required for the level of difficulty of the calculations (Dilles et al., 2011) and one study reported calculators were not acceptable as they should not act as a substitute for arithmetical knowledge(McMullan et al., 2011).

Interventions of studies

Four main types of teaching strategies were identified during this review. These were traditional pedagogy, technology, psychomotor skills and blended learning.

Traditional pedagogy

Traditional or conventional pedagogies using the teacher centred model have been used effectively for many years by nurse educators to impart information and knowledge to allow students the acquisition of skills and abilities (Brown et al., 2008). The teaching strategies and environments in relation to medication dosage calculation abilities include face to face presentations including lectures (Adams and Duffield, 1991; Costello, 2011; Coyne et al., 2013; Craig and Seller, 1995; Dilles et al., 2011; Greenfield et al., 2006; Harne-Britner et al., 2006; Koohestani and Baghcheghi, 2010; Pierce et al., 2008; Rice and Bell, 2005; Wright, 2007, 2008), tutorials (Coyne et al., 2013; Harne-Britner et al., 2006; Wright, 2008, 2012), clinical practice laboratory sessions (Coyne et al., 2013; Wright, 2007, 2008) and remedial support (Jackson and De Carlo, 2011; Pierce et al., 2008).

Some institutions offer students self directed learning activities using worksheets/workbooks (Adams and Duffield, 1991; Harne-Britner et al., 2006; McMullan et al., 2011; Rainboth and DeMasi, 2006; Wright, 2007, 2008), assignments (Rainboth and DeMasi, 2006), nursing medication textbooks or nursing reference texts (Dilles et al., 2011; Greenfield, 2007; Rainboth and DeMasi, 2006; Wright, 2008). This review revealed one large study of 29 nursing schools in Belgium that used lectures as the most common method of delivering medication calculation education and textbooks as the most common used resource material (Dilles et al., 2011).

Four curricula subthemes identifying different approaches to teaching medication calculations were identified. The first was numeracy or the teaching of maths. Two studies focused on teaching interventions on numeracy, Pierce et al. (2008) delivered remediation for students' conceptual understanding of decimal numbers. Adams and Duffield (1991) used repeated mathematical drills for calculation ability displaying improvements over time.

Problem solving methods require the process of identifying the situation that is described and indicating a goal that is desired (Mayer and Anderson, 1991). It involves a two-step process, firstly representation of the problem and secondly finding a solution (Mayer and Anderson, 1991). There were three main problem solving techniques or subthemes using by the studies, these were formula, ratio-proportion and dimensional analysis. Traditional formula method (see Fig. 2) was reported used by five studies (Costello, 2011; Coyne et al., 2013; Greenfield et al., 2006; Kohtz and Gowda, 2010; Koohestani and Baghcheghi, 2010). Three studies used ratio-proportion method (Jackson and De Carlo, 2011; Kohtz and Gowda, 2010; Rainboth and DeMasi, 2006). Ratio-proportion method allows the nurse to calculate dosages by using the quantity of medication prescribed and the dosage available (Jackson and De Carlo, 2011; Rainboth and DeMasi, 2006).

The most common problem solving technique was the use of Dimensional Analysis (DA) which was evaluated by five studies (Craig and Sellers, 1995; Greenfield et al., 2006; Kohtz and Gowda, 2010; Koohestani and Baghecheghi, 2010; Rice and Bell, 2005). Dimensional analysis, also called factor label method, conversion factor method, unit analysis and quantity calculus is a systematic problem solving method used to develop mathematical and conceptual skills and calculate medication dosage problems (Craig and Seller, 1995; Koohestani and Baghcheghi, 2010; Rice and Bell, 2005). The DA method consists of arranging conversions and dosages into equations using the same logical format for all calculations (Cookson, 2013). The intention of DA is to address conceptual errors by removing traditional formulas or multiple step calculations (Cookson, 2013; Koohestani and Baghcheghi, 2010).

Technology

Five studies reported the use of computer or technology aided learning as their main education strategy. Two studies used computerised learning software packages (Adams and Duffield, 1991; Glaister, 2007) and one study used personal digital assistants (PDA) (Greenfield, 2007). One study used epackages and digital versatile disc (DVD)'s (McMullan et al., 2011). The fifth article revealed strategies aimed at improving student's anxiety or attitudes towards computers (Glaister, 2007).

Psychomotor skills and practice

One educational institutions investigated the use of simulations (Unver et al., 2013), two studies reported the use of practice stations (Costello, 2011; Wright, 2007), and two studies incorporated off campus clinical settings with real patients using real medications for development of medication calculation abilities (Coyne et al., 2013; Wright, 2012).

Blended learning

Six studies utilised varied and multiple curriculum strategies combining traditional teacher centred pedagogy with computer assisted and clinical based student centred learning (Coyne et al., 2013; Dilles et al., 2011; Harne-Britner et al., 2006; Wright, 2007, 2008, 2012). These strategies included lectures and drug calculation textbooks (Coyne et al., 2013; Dilles et al., 2011; Harne-Britner et al., 2006; Wright, 2007, 2008, 2012), tutorials (Coyne et al., 2013; Harne-Britner et al., 2006; Wright, 2008, 2012), online maths resources (Wright, 2007, 2008, 2012), self study workbook (Harne-Britner et al., 2006; Wright, 2007, 2008, 2012), clinical practice sessions (Wright, 2007, 2012), simulation clinical sessions and off campus clinical placement (Coyne et al., 2013; Wright, 2012).

Instruments

From the 20 studies, seventeen utilised medication or intravenous administration calculation examinations for data analysis (Adams and Duffield, 1991; Craig and Seller, 1995; Coyne et al., 2013; Costello, 2011; Dilles et al., 2011; Greenfield, 2007; Greenfield et al., 2006; Koohestani and Baghecheghi, 2010; Kohtz and Gowda, 2010; Harne-Britner et al., 2006; McMullan et al., 2011; Jackson and De Carlo, 2011; Pierce et al., 2008; Rainboth and DeMasi, 2006; Rice and Bell, 2005; Wright, 2007, 2008). The medication calculation test ranged from ten exam questions (Coyne et al., 2013; Koohestani and Baghecheghi, 2010; Rainboth and DeMasi, 2006; Wright, 2008) to 30 questions exams (Pierce et al., 2008; Wright, 2007). Instruments included measuring anxiety and attitude towards mathematics or computers using Mathematics Attitude Scale, Computer Attitude Scale and Mathematics Test Anxiety Rating Scale (Glaister, 2007). Other authors measured perceived confidence or ability using Self Perceived Confidence Survey (Rice and Bellm, 2005), self rated readiness (Dilles et al., 2011), perceptions of medication calculation and medication calculation skills performance (Rainboth and DeMasi, 2006), perceptions of learning environments questionnaire (Wright, 2012) and drug calculation self efficacy scale (McMullan et al., 2011). Other measures included satisfaction (McMullan et al., 2011), Objective Feedback on Medication Intervention Survey (Unver et al., 2013), Objectively Constructed Evaluation Form (Unver et al., 2013), Personal Digital Assistant (PDA) case study (Greenfield, 2007), and Medication Calculation Survey (Harne-Britner et al., 2006).

Studies results

Differing teaching strategies and methods have been implemented with mixed results (Papastrat and Wallace, 2003; Weeks et al., 2013; Weeks et al., 2001; Weeks et al., 2000). Overall the results of the 20 studies were mixed. Positive effects were reported for twelve studies (Adams and Duffield, 1991; Costello, 2011; Coyne et al., 2013; Greenfield, 2007; Greenfield et al., 2006; Harne-Britner et al., 2006; Jackson and De Carlo, 2011; Pierce et al., 2008; Rainboth and DeMasi, 2006; Unver et al., 2013; Wright, 2007, 2008). Positive results were detected for traditional pedagogy with the focus on mathematics or numeracy. The intervention group attaining higher mean scores on the 30 item Diagnostic Decimal Comparison exam (Pierce et al., 2008) and the mean scores for students who received mathematical drills improved over the three years of the undergraduate degree (Adams and Duffield, 1991). It is important to note, Adams and Duffield's (1991) study showed students improved drug calculation test results coinciding with off campus placement. Two of the six studies that used DA as the instructional approach to medication calculation showed positive effects. Greenfield et al. (2006) reported students who received DA instructions had higher mean scores than the control group that used formula method. Costello (2011) had significant improvements in mean differences in scores from pre test to post test for using all three methods of instruction including formula, ratio-proportion and DA and 8 practice stations. Three studies using blended learning incorporating psychomotor skills either off campus placement or practice stations have reported favourable results (Coyne et al., 2013; Wright, 2007, 2008). Six studies did not show differences between the intervention and control group with both educational strategies showing improvements over time (Craig and Seller, 1995; Dilles et al., 2011; Kohtz and Gowda, 2010; Koohestani and Baghcheghi, 2010; McMullan et al., 2011; Rice and Bell, 2005). These include no differences between groups in drug calculation test for five studies using traditional pedagogy (Craig and Seller, 1995; Dilles et al., 2011; Kohtz and Gowda, 2010; Koohestani and Baghcheghi, 2010; Rice and Bell, 2005). No differences were detected for one computer assisted learning study (McMullan et al., 2011). Two studies investigated computer and mathematical anxiety and resources identified by students required to demonstrate 'real world' nursing (Glaister, 2007; Wright, 2012).

Best practice research and clinical trials require sound measurement methods (Cook and Beckman, 2006). Of the 12 studies that reported differences detected, eight did not report validity or reliability (Adams and Duffield, 1991; Coyne et al., 2013; Greenfield, 2007; Greenfield et al., 2006; Jackson and De Carlo, 2011; Pierce et al., 2008; Unver et al., 2013; Wright, 2008), validity was established for three studies (Harne-Britner et al., 2006; Rainboth and DeMasi, 2006; Wright, 2007), two studies reported low (Cronbach's alpha 0.135–0.674) (Rainboth and DeMasi, 2006) to moderate reliability (Cronbach's alpha 0.74) (Costello, 2011). Other studies reported the use of odd-even split half test reliability (Craig and Sellers, 1995) or Kuder-Richardson (Harne-Britner et al., 2006) both of which were acceptable. Only two studies reported the use of a valid and reliable instrument (Harne-Britner et al., 2006; Wright, 2012). Of the six studies that did not report differences, two studies did not report validity and reliability (McMullan et al., 2011; Rice and Bell, 2005), two studies reported on validity but not reliability (Dilles et al., 2011; Kohtz and Gowda, 2010) and two studies reported both (Craig and Seller, 1995; Koohestani and Baghcheghi, 2010). One study which described their instrument's reliability and validity did not indicate figures or method of ascertaining validity (Wright, 2012). It is important that all studies use appropriate valid and reliable instruments (Polit, 2010). The reliability of an instrument reflects the quality of the instrument, definitions, wording and ease of use as well as the training and consistency with which it is used by health professionals. Validity on the other hand is based on the credibility or accuracy of the information generated using a health assessment instrument (George et al., 2003).

No study stated power analysis or provided sufficient justification for the size of their sample. Performing power analysis and sample size assessment is an important aspect of experimental design, because without these calculations, sample size may be inflated or inadequate (Polit and Beck, 2014). However, McMullan, et al. (2011) discussed the issue of using a power calculation was not necessary as all students were included. Seven studies used all students (Adams and Duffield, 1991; Coyne et al., 2013; Dilles et al., 2011; Jackson and De Carlo, 2011; Kohtz and Gowda, 2010; Pierce et al., 2008; Unver et al., 2013).

Another concern was the design of the studies, five studies used one group (Adams and Duffield, 1991; Costello, 2011; Jackson and De Carlo, 2011; Unver et al., 2013; Wright, 2007) and ten used post test only (Adams and Duffield, 1991; Dilles et al., 2011; Glaister, 2007; Greenfield, 2007; Greenfield et al., 2006; Jackson and De Carlo, 2011; Kohtz and Gowda, 2010; Pierce et al., 2008; Rice and Bell, 2005; Wright, 2008, 2012). Without baseline measures or an equivalent control group it is difficult to ascertain if the education strategy had any effect (Polit and Beck, 2014).

Pass marks

Seven of the twenty studies reported the number or percentage of students able to obtain the set pass mark (Dilles et al., 2011; Greenfield et al., 2006; Harne-Britner et al., 2006; Jackson and De Carlo, 2011; Kohtz and Gowda, 2010; Pierce et al., 2008; Wright, 2007). Three studies set pass marks at 100%, 4.5% of students (Wright, 2007), 51.2% of first year students (Pierce et al., 2008), 47.3–50% (Kohtz and Gowda, 2010; Pierce et al., 2008) and 70.3% of third years (Pierce et al., 2008) were able to achieve this. Four studies set pass marks at 85–90% (Dilles et al., 2011; Greenfield et al., 2006; Harne-Britner et al., 2006; Jackson and De Carlo, 2011). Post test, 84.1–97.4% of first years (Jackson and De Carlo, 2011), 61.5–84.6% of second years (Greenfield et al., 2006) and 0% (Dilles et al., 2011) to 58.5% (Harne-Britner et al., 2006) were able to obtain this.

Mean scores

Twelve studies used mean scores or percentages of mean scores to report findings (Adams and Duffield, 1991; Coyne et al., 2013; Craig and Seller, 1995; Dilles et al., 2011; Greenfield et al., 2006; Harne-Britner et al., 2006; Koohestani and Baghcheghi, 2010; McMullan et al., 2011; Pierce et al., 2008; Rainboth and DeMasi, 2006; Rice and Bell, 2005; Unver et al., 2013). All three studies that used one group showed mean scores improved over time (Adams and Duffield, 1991; Coyne et al., 2013; Unver et al., 2013). One study comparing two groups showed greater mean scores improvement for the intervention group than the control group (Greenfield et al., 2006). Of the eleven studies, eight did not detect differences in mean scores or percentage across time when comparing an intervention group and control group (Craig and Seller, 1995; Dilles et al., 2011; Harne-Britner et al., 2006; Koohestani and Baghcheghi, 2010; McMullan et al., 2011; Pierce et al., 2008; Rainboth and DeMasi, 2006; Rice and Bell, 2005).

Discussion

The purpose of this integrative review was to examine the research literature on the effects of education strategies on student nurses' dosage calculation abilities. The results from this review were mixed. A total of 20 studies were reviewed, all six studies using one group with no equivalent control group reported mean scores improving regardless of the education strategy (Adams and Duffield, 1991; Costello, 2011; Coyne et al., 2013; Jackson and De Carlo, 2011; Unver et al., 2013; Wright, 2007). Studies using two or more groups had mixed results. Statistically significant differences were detected for three studies (Greenfield et al., 2006; Rainboth and DeMasi, 2006; Wright, 2008). Positive findings were detected for four studies when studies compared non intervention control groups to intervention groups, however, these were not statistically significant (Greenfield, 2007; Kohtz and Gowda, 2010; McMullan et al., 2011; Pierce et al., 2008). No differences were detected for three studies between the control and intervention group with both groups showing improvements regardless of the intervention (Craig and Seller, 1995; Harne-Britner et al., 2006; Koohestani and Baghcheghi, 2010; Rice and Bell, 2005). No differences were detected for one large multi group study investigating traditional pedagogy (Dilles et al., 2011). One study investigated students perception of learning environments (Wright, 2012) and one study reported the number of students who were experiencing computer or mathematical anxiety (Glaister, 2007).

The sample size for most of these studies were relative small, 17 studies had less than 172 participants (Adams and Duffield, 1991; Costello, 2011; Coyne et al., 2013; Craig and Seller, 1995; Glaister, 2007; Greenfield, 2007; Greenfield et al., 2006; Harne-Britner et al., 2006; Kohtz and Gowda, 2010; Koohestani and Baghcheghi, 2010; Pierce et al., 2008; Rainboth and DeMasi, 2006; Rice and Bell, 2005; Unver et al., 2013; Wright, 2007, 2008, 2012). Three studies had between 2674 and 229 participants (Dilles et al., 2011; Jackson and De Carlo, 2011; McMullan et al., 2011). No study reported the use of power calculations to address the justification of the sample size. An important consideration in conducting and evaluating applied research is the sample size or number of participants in the study. Power analysis is conducted to determine the effect size or the sample size (Polit, 2010). This is used to minimise Type II error or the potential to incorrectly reject that there is a relationship between the dependent variable and the independent variable

(Polit and Beck, 2014). In clinical research trials, using inadequate sample sizes is precarious and the likelihood of Type II error increases (Polit and Beck, 2014).

The research design for three of the 20 reviewed articles was reported as two or three group randomised control trials. This design is considered the gold standard or the most advance type of quantitative research design (Fewtrell, 2011). These studies are more likely able to show causal relationships between intervention and outcomes (Fewtrell, 2011). In this review for all 20 studies the variable being manipulated or independent variable was the education strategy/ies. For eighteen of the reviewed articles the dependent variable was medication calculation knowledge as measured by a researcher developed drug calculation test/exam (Adams and Duffield, 1991; Costello, 2011; Coyne et al., 2013; Craig and Seller, 1995; Dilles et al., 2011; Greenfield, 2007; Greenfield et al., 2006; Harne-Britner et al., 2006; Jackson and De Carlo, 2011; Kohtz and Gowda, 2010; Koohestani and Baghcheghi, 2010; McMullan et al., 2011; Pierce et al., 2008; Rainboth and DeMasi, 2006; Rice and Bell, 2005; Unver et al., 2013; Wright, 2007, 2008). This raises concerns in regards to the validity and reliability of measuring medication calculation knowledge using a researcher developed drug calculation test, due to inconsistencies in developing the test.

Experimental designs are characterised by the use of the control group to which the intervention group is compared (Taylor et al., 2006). When studies compared two or more groups often the existence of a relationship between the control and intervention group is measured by comparing means or averages of the two groups for the required measured outcome (Polit, 2010). Six of the reviewed studies collected or reported data on the intervention groups only and all of these studies did report positive effects for the intervention group (Adams and Duffield, 1991; Costello, 2011; Coyne et al., 2013; Jackson and De Carlo, 2011; Unver et al., 2013; Wright, 2007). The use of no control group research design is termed non experimental or quasiexperimental and the major disadvantage in this design is it's weakness in its ability to determine casual relationships (Polit and Beck, 2014).

This review has identified some concerns regarding the strategies used to teach medication calculation to student nurses. Studies focussing on traditional or conventional teaching had mixed results. Strategies addressing student nurses numeracy skills revealed improvements from pre test to post test using either remedial support (Pierce et al., 2008) or repeated worksheet drills (Adams and Duffield, 1991). Pre test pass marks set between 75 and 100% for medication calculation exams, remain low, with 36% (McMullan et al., 2011) to 60% of students able to obtain this pass mark (Jackson and De Carlo, 2011). Solid foundation s in numeracy is essential to allow nurses to determine accurate medication dosage calculations (Arkell and Rutter, 2012). Arguably no errors for drug calculations and a pass mark of 100% should be the only acceptable score for medication calculation scores (Papastrat and Wallace, 2003). Many of the reviewed studies used scores lower than 100%. Only three of the 20 studies used pass marks of 100% (Koohestani and Baghecheghi, 2010; Wright, 2007, 2008), three studies have indicated pass marks of 90% (Greenfield et al., 2006; Harne-Britner et al., 2006; Kohtz and Gowda, 2010), ten studies did not report a required pass mark yet conducted medication calculation exams as methods of assessment (Adams and Duffield, 1991; Coyne et al., 2013; Costello, 2011; Craig and Sellers, 1995; Dilles et al., 2011; Greenfield, 2007; McMullan et al., 2011; Pierce et al., 2008; Rice and Bell, 2005; Rainboth and DeMasi, 2006).

Other studies investigating medication calculation abilities of students nurses indicate a pass mark of 90% (Bindler and Bayne, 1991; Bliss-Holtz, 1994; Cunningham and Roche, 2001; Harne-Britner et al., 2006; Jukes and Gilchrist, 2006), 75% for first years (Elliot and Joyce, 2005), 72% (Harvey et al., 2009) down to 70% as acceptable (Hilton, 1999). Many of these studies have reported favourable result however; this review continues to raise the issue of poor performance of nursing students on medication calculation exams with the number of students able to attain 100% pass marks remaining disturbing low despite the education strategies provided. Students who achieve 70% could effectively commit three errors in a 10-item exam and yet pass the exam; many of these errors are critical to calculation of medications and could potentially lead to devastating results in clinical practice. An alternative argument would be that the utilisation of medication calculation exams may not offer the best practice in assessment of medication administration skills (Wright, 2012).

Many studies have used medication calculation exams; this raises the issues of; reliability and validity, the experience of the person developing the exam questions, repeating same exams and inconsistencies of the use of calculators or other aids. The reliability of the use of a medication calculation exam as an instrument needs to reflect the quality of the instrument, definitions, wording and ease of use as well as training and consistency with which it is used by the health care professional. Validity on the other hand is based on the credibility or accuracy of the information generated using a health assessment instrument (George et al., 2003). It is therefore important that all studies use valid and reliable instruments. Few of the studies have reported using an expert in mathematics to assist in the development of the medication calculation exams.

This review revealed problem solving educational strategies did not have the intended effect. Problem solving involves the process of moving from one situation that is described, to the end situation or goal that is indicated (Mayer and Anderson, 1991). Problem representation therefore involves being able to develop to mentally represent the situation and then use this to form potential methods to solve the problem (Mayer and Anderson, 1991). In order to develop a representation of the problem, the information in the challenge needs to clearly represent the situation being depicted (Kaput, 1987). Drug calculations require the student to visualise the situation and develop critical thinking problem solving skills, however, if the situation is unfamiliar, not relevant to practice or if the student is inexperienced in clinical experience, the problem cannot be visualised or represented mentally and thus it will be difficult to solve (Weeks et al., 2013). Drug calculation errors having occurred when students are unable to conceptualise the problem (Bliss-Holtz, 1994; Hutton, 2003; Weeks et al., 2001; Wright, 2007). Drug calculation with the use of formulas have not demonstrated the desired outcomes with students struggling to put the numerical solution in clinical context or students abandoning this method to use a problem solving method to suit the clinical setting (Wright, 2008, 2009).

In both higher education and health care settings there is an increasingly widespread demand for the use of supportive technology (Petty, 2013). The 'blended' learning approach combines the traditional didactic lecture with online self directed learning resources (Petty, 2013). Effective use of technology including the use of podcast, PDA, epackages and DVD, software packages and simulations have been reported (Holland et al., 2013; McKinney and Page, 2009; McMullan et al., 2011; Noteborn et al., 2014; Sung et al., 2008; Unver et al., 2013; White et al., 2013). The use of technology may offer a cost effective, time saving method of delivering education (Skiba et al., 2008; Warren and Connors, 2007). Computer software packages can offer the student an opportunity, at times convenient to them, the ability to perform repetitive activities, practice in safe situations and undergo remediation which can reduce anxiety (Skiba et al., 2008; Warren and Connors, 2007). The use of online simulations and virtual learning spaces enables learners to develop procedural knowledge promoting active learning (Ke and Xie, 2009; Noteborn et al., 2014). Active learning with the use of online resources and interactive software involving learner participation and engagement has proven effective across educational settings (DeGagne, 2011; Noteborn et al., 2014). Studies show that active involvement brings about greater understanding and knowledge retention while simulating deeper cognitive processes and critical thinking skills (Conrad and Donaldson, 2004; Mareno et al., 2010).

In summary, this article critically reviews research literature in regards to strategies aimed at improving medication calculation skills. These studies increase our understanding of the issues surrounding medication calculation for student nurses. This article provides vital information for academic teaching strategies in an attempt to increase student nurses understanding and retention of medication calculations for the improved safety of patients.

Implications for practice

Multiple interventions including interactive lectures, clinical case studies, clinical experience, workbooks, online software, calculators, technology aimed at different learning styles needs further investigating to prove beneficial for improving medication calculation skills and mathematics skills for student nurses. Further examination is required in the method of assessing the medication calculation abilities of student's nurses. Further research needs to be conducted in larger cohorts.

Limitations

Limitations inherent in the design of some of these studies do not permit an assessment that interventions aimed at improving medication calculation skills are beneficial (or not) in all circumstances. Most studies which focused on student nurses used single or two sites, small sample sizes or questionable assessments. Randomisation when performed used simple, cluster or by last name or tutorial group. Many studies used self selection of students with limited data on students who did not choose to participate. Often those who choose not to participate may require more support. No study stated how they deduced the sample size. It is therefore difficult to generalise the findings from many of the 20 reviewed studies.

Conclusion

This paper represents a critical integrative review of the literature on interventions aimed at improving student nurse's medication calculation abilities. Of the 266 papers retrieved 20 met the inclusion criteria, two studies had more than 600 students, none reported how the sample size was deduced, and ten presented validity and/or reliability. Twelve of the studies reported positive results, of those six used traditional pedagogy, two used technology, one used psychomotor skills and three used blended learning to improve nursing calculation skills. Three studies used the gold standard of randomised control trial design. There is insufficient evidence to date to support the implementation of any particular strategy aimed at improving medication calculation skills for student nurses. The main outcome of this review is to establish that there are very few well designed and adequately powered studies specifically focused on this area of undergraduate nursing education. There needs to be more quality research on teaching strategies and assessment for undergraduate student nurses on their ability to accurately calculate medication dosages.

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