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Review

Incorporating medication administration safety in undergraduate nursing education: A literature review☆,☆☆

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ABSTRACT

Objective: The purpose of this review was to identify methods for incorporating medication administration safety in undergraduate nursing education.
Design: The Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines directed this review.
Data Sources: A search of four electronic databases (Cumulative Index to Nursing and Allied Health Literature, Education Resources Information Center, Google Scholar, and MedLine/PubMed MedLine/PubMed) as well as hand searches were conducted to identify original research published between 2005 and 2018.
Review Methods: Original empirical research describing a method for incorporating medication administration safety concepts in nursing education and examining its effectiveness on undergraduate nursing students' outcomes were selected for review. Articles describing medication safety education for graduate students, students other than those in nursing, and practicing nurses were excluded.
Results: Twelve original research articles were included for review. Three methods for incorporating medication administration safety in undergraduate nursing education were identified: simulation experiences, technology aids, and online learning modules. Most studies were conducted in North America. The use of different interventions as well as different outcome measures was noted as a limitation to the collective body of research in this area. Also, there was a lack of information regarding psychometric properties of instruments used among the studies reviewed.
Conclusion: Simulation experiences, use of technology aids, and online learning modules helped increase medication safety competence of nursing students. However, simulation equipment, select technology aids, and online learning may not be available for all nursing programs; therefore, educators should consider developing and testing classroom-based educational interventions. Moreover, future researchers should use or develop psychometrically sound instruments to measure nursing students' outcomes including competencies about medication administration safety.

1. Introduction

Medication errors are a concern for nurses and other healthcare providers globally. Such errors lead to adverse patient outcomes including long inpatient admissions, increased healthcare costs, and mortality (Cheragi et al., 2013). In fact, medical mistakes kill 250,000 patients in the United States (U.S.) annually (Makary and Daniel, 2016), and the cost of such errors exceeds $19 million per year (Shreve et al., 2010). As medication errors occur at any phase of the medication cycle, such as prescribing, dispensing, and administration (Latimer et al., 2017), any member of the healthcare team may contribute to a medication error. However, medication errors most commonly occur during the provision of nursing care (Cheragi et al., 2013).

Efforts toward educating future members of the healthcare workforce on safety have been made. The World Health Organization published the Patient Safety Curriculum Guide (Farley et al., 2015) to support the needs for patient safety education, including medication administration safety. In the U.S., the Quality and Safety Education for Nurses (QSEN) initiative was established with a goal of preparing future nurses with the knowledge, skills, and attitudes essential for providing patient care that is both safe and of a high quality. The QSEN initiative examined key components in nursing curricula and identified six competency areas, including patient-centered care, teamwork and collaboration, evidence-based practice, quality improvement, safety, and

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informatics (Cronenwett et al., 2007; Cronenwett et al., 2009). Medication administration is most certainly an area of nursing practice in which safety competencies must be employed.

Medication administration is one of the most critical nursing duties. Therefore, nurses play a vital role in preventing medication errors from reaching and harming patients (Latimer et al., 2017). With more individual drugs coming to market, and patients holding more prescription orders than ever before (Adhikari et al., 2014), schools of nursing (SON) have a duty to help ameliorate the occurrence of medication errors through the provision of thorough safety education.

2. Purpose

Despite efforts to guide and reform curricula across healthcare globally, it is unknown how medication safety is currently integrated in nursing curricula. In pre-licensure nursing programs instructors face challenges related to teaching a large amount of information, that can be difficult for students to retain (Thomas and Schuessler, 2016), in a short amount of time. Despite this challenge, instruction regarding practices promoting medication administration safety must be incorporated in to curriculum. Identification of such practices is missing from the current body of nursing education literature. Incorporating such practices will allow nursing students to adopt professional habits that support the avoidance of both medication errors and the negative sequelae of errors (e.g. prolonged admissions, increased medical costs, and death). Therefore, the purpose of the present review is to identify methods for incorporating medication safety concepts in undergraduate nursing education.

3. Methods

3.1. Search Procedure

The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines directed the review process (Moher et al., 2009). To identify articles for inclusion, the academic databases Cumulative Index to Nursing and Allied Health Literature (CINAHL), Education Resources Information Center (ERIC), MedLine/PubMed, Google Scholar, as well as hand searches of *Nurse Educator*, *Nursing Education Perspectives*, *Nurse Education Today*, the *Journal of Nursing Education*, and *Teaching and Learning in Nursing* were conducted. Search terms included *nurs** *educ**, *pharmacology*, *safety*, *undergraduate*, *medication*, and *medication error** were used.

3.2. Inclusion and Exclusion Criteria

Articles describing and evaluating safety incorporation across undergraduate curricula were of interest. Articles meeting the following criteria were included: available in the English language, published in peer-reviewed scholarly journals, and published between 2005 and 2018. This search window was employed for two distinct reasons. First, the authors planned to follow recommended literature review practices (Cronin et al., 2008) to select a least a 10-year search frame capture publications that were relevant and timely. The authors expanded the search window from a 2008 limiter to 2005 to coincide with the commencement of the QSEN (2018) initiative. Articles describing safety education for nurses in graduate programs or in the clinical setting were excluded.

3.3. Data Extraction and Analysis

Following selection of articles for inclusion in the review, data was extracted from each article an organized in to a matrix. Extracted data included the year of publication, journal, country of origin, sample, sample size, description of safety activity, lesson, or intervention, and results. Both authors confirmed accuracy of extracted data from each article. The authors performed a summative content analysis to identify themes among the extracted data (Hsieh and Shannon, 2005) to identify methods for incorporating medication safety concepts in undergraduate nursing education.

4. Results

4.1. CINAHL, ERIC, MedLine/PubMed and Hand Search

A total of 91 articles were found through search of noted databases and selected journals. Four articles were duplicates, leaving 87 articles to be reviewed by title and abstract for inclusion. Following a review of the title and abstract of each article, 72 were excluded. Of the remaining 15 sources, nine articles were excluded following full-text review.

4.2. Google Scholar

Using the same search terms and search limiters, over 21,000 articles were found through Google Scholar. Titles of the first 130 articles listed in order of relevancy were reviewed for inclusion. Articles listed past the first 130 were consistently not relevant to the present study. Eight articles were reviewed by abstract; two were excluded. None of the six remaining articles were excluded following full-text review.

Reasons for exclusion included but were not limited to sampling of registered nurses and other healthcare professionals and discussion papers regarding medication errors among students without report of curriculum interventions. A final sample of 12 original research articles was included for review. Fig. 1 displays the PRISMA diagram.

4.3. Article Characteristics

The 12 studies meeting inclusion criteria were fully reviewed. Most studies were conducted in North America. The publication dates of included studies ranged between 2007 and 2017. Samples of ten to 349 undergraduate students from both associate and baccalaureate nursing programs were studied across the included articles. Characteristics of each article are summarized in Table 1.

5. Summary of Evidence

Three themes relevant to incorporating safety concepts in to undergraduate nursing education were identified following a content analysis of the 12 included articles. Themes represented methods for incorporating medication safety concepts in nursing education: *simulation experiences*, *technology aids*, and *online learning modules*. Table 2 displays findings of each included study within the three themes.

5.1. Simulation Experiences

Researchers authoring five studies utilized simulation to help students gain knowledge, skills, and confidence related to safe medication administration. Simulation experiences were part of a course, replaced clinical hours, or supplemented a usual degree pathway.

Harris et al. (2014) conducted a quasi-experimental pilot study examining the effect of simulation on junior-level nursing students' medication calculation and administration abilities. Students in the intervention group (n = 79) attended a medication administration simulation review session whereas students in the control group (n = 79) attended a didactic medication administration review session one week prior to a medication administration exam. In the intervention group, students were assigned to groups of four and rotated through three simulation stations, using simulated medication and appropriate equipment. The researchers found the medication administration exam scores of the intervention group were significantly higher than the scores of the control group.

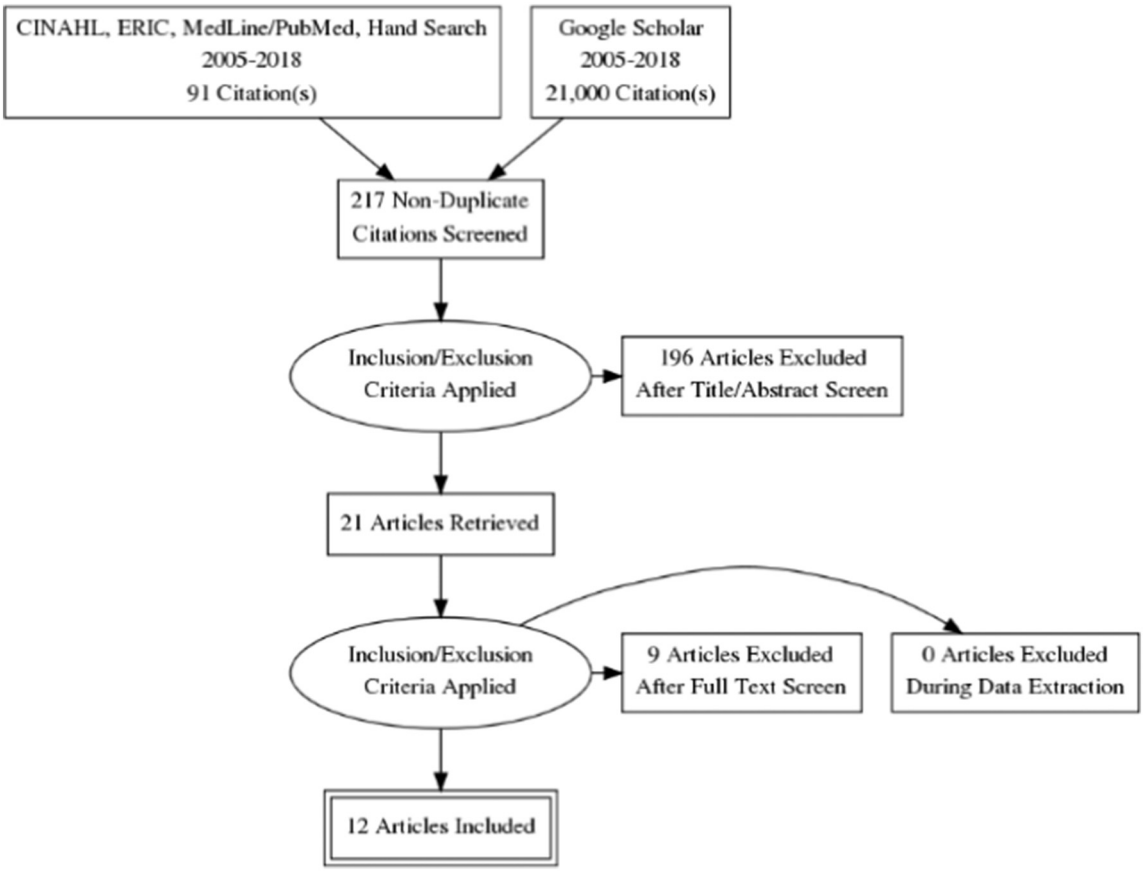

Fig. 1. This figure displays the PRISMA diagram.

Konieczny (2016) recruited 126 undergraduate nursing students to participate in a low fidelity (n = 65) or high fidelity (n = 61) simulation experience. The learning objectives of each simulation experience were focused on pharmacology and medication administration knowledge. Participants in both types of simulation were asked to administer oral, subcutaneous, and nebulized medications. The researcher developed a 10-item measure to evaluate performance of students in both groups. Following participation in the simulation experiences, the students completing the high facility simulation demonstrated greater knowledge gain than peers in the low fidelity simulation.

One group of researchers replaced early-term clinical hours with simulation experiences for 24 second-year undergraduate students (Sears et al., 2010). Thirty other students attended regularly scheduled off-campus clinical. The goal of the simulation experience was to help the participants overcome antecedents of medication errors, and increase safety in medication administration. This goal was achieved by including a medication administration component in the simulation. For both groups faculty collected data on any actual or potential medication errors, noting factors such as the location of the error, which of the five medication administration rights were violated, and factors contributing to the error or near miss. While 80% of the students in the control group made an error during the clinical rotation, only 29% of the intervention group students were involved in an error. Participation in simulation experiences in which medications were administered and gaps in student knowledge were addressed in a safe environment contributed to the significant difference between rates of error.

Another group of researchers added a simulation component to a pharmacology course to increase confidence and competence among undergraduate nursing students (Sanko and Mckay, 2017). The QSEN-

Table 1
Article characteristics.

First author, year	Country	Journal	Sample	Program type
Cibulka, 2011	USA	Journal of Nursing Education	78 students	BSN
Greenfield, 2007	USA	Journal of Nursing Education	87 junior and senior students	BSN
Ferguson, 2014	USA	Teaching and Learning in Nursing	51 first-year students	ADN
Harris, 2014	USA	Nursing Education Perspectives	158 junior students	BSN
Holland, 2013	UK	Nurse Education Today	322 students	3-year program
Konieczny, 2016	USA	Teaching and Learning in Nursing	126 students	ADN
Lee, 2013	Taiwan	Nurse Education Today	349 students	ADN and BSN
Mettiäinen, 2014	Finland	Nurse Education in Practice	244 students	BSN
Pauly-O'Neill, 2013	USA	Nursing Education Perspectives32	32 junior students	BSN
Schneidereith, 2015	USA	Nurse Education Perspectives	10 senior students	BSN
Sears, 2010	Canada	Journal of Nursing Education	54 second-year students	BSN
Sanko, 2017	USA	Nurse Educator	120 students	BSN

Note. BSN, bachelor of science in nursing; ADN, associate degree in nursing.

Table 2
Themes and related evidence.

Theme	First author, year	Intervention	Control	Results
Simulation experiences	Harris, 2014	Medication administration simulation review session	Didactic medication administration review session in a classroom setting	Students in the intervention group scored significantly higher on a medication administration exam than those in the control group.
	Konieczny, 2016	High fidelity simulation used to teach pharmacology and medication administration knowledge.	Low fidelity simulation used to teach pharmacology and medication administration knowledge.	Students learning from the high fidelity simulation experience demonstrated greater knowledge gain.
	Pauly-O'Neill, 2013	High fidelity simulation combined with lecture and clinical experiences used for intensive practice with IV medication administration in pediatric patients.	–	There was an increase in knowledge and self-reported confidence of important medication administration skills for pediatric patients.
	Sears, 2010	Clinical hours replaced with simulation experience in which students administered medication.	Clinical hours only	29% (7 of 24) students completing the simulation made medication errors in clinical, while 80% (24 of 30) students completing only clinical made medication errors.
	Sanko, 2017	Simulation scenarios focused on calculation and administration of oral, subcutaneous, and IV medications	No simulation scenarios	Students participating in simulation reported fewer medication-related adverse events in future clinical experiences. Students participating in simulation reported an increase in confidence with medication administration.
Technology aids	Cibulka et al., 2011	Students accessed information regarding medication using personal digital assistants (PDAs) in a pharmacology course.	–	78% students reported that use of PDA helped their learning.
	Ferguson, 2014	Automated medication dispensing unit used during simulation	–	Use of the automated medication dispensing unit reinforced students' knowledge base of the six rights of medication administration, as well as confidence in administering medications.
	Greenfield, 2007	Students accessed medication resources using PDAs while completing a case study with three medication calculations and three clinical decisions.	Students utilized a textbook as a reference during case study completion.	Students utilizing PDAs had greater accuracy and speed when completing the case study.
	Schneidereith, 2015	Google glass used to video record student processes of medication calculation and IV pump set-up.	–	30% of students could not correctly calculate infusion rate. The glass allowed the simulation faculty to identify specific source of calculation errors (e.g. pump programing, step in math).
Online learning modules	Holland, 2013	Standard teaching plus unlimited access to an online video of oral medication best practices	Standard teaching comprised of lecture session, skills session, and instructor availability	Pass rates on a clinical exam were similar in both groups, however, more students from the control group failed or had a low passing score. The intervention was more impactful for 'borderline' students.
	Lee, 2013	Standard teaching plus access to eight online modules regarding pediatric medication administration	Standard lecture courses	Students with access to the online videos had significantly higher scores on a medication administration and drug calculations evaluation.
	Mettiäinen, 2014	Medication administration online course	–	Student self-evaluations of competency improved significantly in four specific areas of medication safety: basic pharmacotherapy, IV medications, blood transfusion, and epidural administration.

Note. IV, intravenous; PDA, personal digital assistant.

identified knowledge, skills, and attitudes related to dosage calculation, high alert medication procedures, and checking values prior to medication administration directed the simulation. Students in the intervention group (n = 60) were to work in pairs during simulation experiences involving a variety of medications administered by oral, subcutaneous, and intravenous routes. Students in the control group completed the pharmacology course without simulation experiences. From completion of the course through graduation, improvements in competence were noted for students in both cohorts, however, confidence increased for the intervention group and decreased for the control group. The control group reported greater numbers of adverse events (e.g. incorrect medication administration, failure to properly identify patients, and equipment problems) during clinical. Students in the intervention group consistently administered medications over the correct time, performed expected hand hygiene, checked vital signs appropriately, administered the correct medications, and achieved safety outcomes.

Pauly-O'Neill and Prion (2013) added a high-fidelity simulation component to a pediatric nursing course. They examined the effect of a mixed educational approach (a class lecture, 50 clinical hours, and 40 simulation hours) on 32 students' knowledge and self-confidence with pediatric intravenous (IV) medication administration. Scenarios included complex IV medication preparation and weight-based dosing. Students completed researcher-developed pre- and post-tests to determine understanding and self-confidence regarding IV medication administration. An increase in students' self-confidence and knowledge of important medication administration skills for pediatric patients was noted.

5.2. Technology Aids

Four included studies reported the use of technology aids to increase medication administration safety among undergraduate nursing students. Researchers conducting these studies offered technology-based resources to further learning or obtain a closer look at the participants' medication administration processes.

Greenfield (2007) invited junior and senior-level undergraduate nursing students to join a study in which all students would complete a case study consisting of three medication calculations and three clinical decisions. One group of students would refer to a textbook for drug information and another group would access an electronic resource using a Personal Digital Assistant (PDA). Most students volunteering for this study did not own a PDA (n = 50), and were in the control group. Thirty-seven students did own a PDA, and participated in the intervention group. There were no statistically significant differences in student grade point average (GPA) between groups. Students were informed the case study was not a test of their knowledge, and they could access information from their textbook or PDA, depending on group. The accuracy of the case study solution and the time taken to complete the case study were measured. Students utilizing PDAs during case study completion had both greater accuracy and speed.

Cibulka and Crane-Wider (2011) examined the effectiveness of PDA use in a pharmacology course. Seventy-eight students were directed to search for important information (e.g., side effects) regarding medications using PDAs. Students reported the use of PDAs helped their learning and organization.

Google Glass is an eyewear product that allows users to access smartphone applications and messages, as well as record videos from a first-person perspective. Schneidereith (2015) invited ten senior-level undergraduate nursing students to wear Google Glass while working through a regularly scheduled high-fidelity simulation session. The scenario included a drug calculation and intravenous pump programing. All steps of scenario completion were captured on video using the Google Glass. While simulation instructors may usually only be able to note an error once a medication is administered, analysis of the Google Glass video allowed the researcher to identify the source of student medication errors. Three of the ten students were not able to safely administer the medication during the simulation scenario due to remedial miscalculations. The instructor determined students made mathematical mistakes leading to medication errors while calculating the medication dose and infusion rate. Knowing the specific step that was the root of the medication error aided the researcher in thoroughly debriefing with the students and providing suggestions to improve drug calculation accuracy and medication administration safety.

Ferguson et al. (2014) also enhanced simulation experiences with a technology aid. Researchers utilized an automated medication-dispensing unit to determine if such a tool would increase students' comfort with management of medications. The unit was equipped with a computer, 24 medication drawers, and a barcode scanner. After an orientation to the machine and medicating a simulation patient with medication from the machine, most students gained comfort in administering medications. Students also thought the machine helped reinforce the rights of mediation administration, and were therefore less likely to make errors.

5.3. Online Learning Modules

Three research teams developed and tested web-based learning modules to teach or reinforce medication safety practices.

Holland et al. (2013) made a video displaying an exemplar of best practices for oral medication administration available to students online. Across a sample of 322 undergraduate nursing students, 154 had access to the video and usual medication administration education, while 168 students served as the control group and received usual medication administration teaching. Usual teaching consisted of a three-hour lecture session, a three-hour skills session, and six-hours of instructor availability for extra help or skills exam preparation. Following learning, medication administration practices were tested using an Objective Structured Clinical Examination (OSCE); a summative assessment administered by instructors blinded to group assignment. Following analysis of exam scores, a Pearson chi-square test revealed statistically significant differences between the group assignment and exam outcome. Although pass rates for the exam were similar between groups, fewer students from the intervention group failed or had low scores. This intervention was noted to be a helpful tool for ‘borderline’ students, meaning those students who may perform slightly below an expected standard.

One research group developed an eight-module online program for learning pediatric medication safety (Lee and Lin, 2013). Module topics included medication administration equipment, commonly used pediatric medication administration techniques, age-related differences in medication administration, dosage calculation, parent education, errors and near-misses, pediatric medication resources, and a clinical setting orientation. The module was offered to students in the intervention group as tool to use beyond the regular course lectures. Students in the control group received a regular lecture course. The intervention group consisted of 269 students, while the control group included 88 students. Investigators developed a 50-item measurement scale to evaluate participants' knowledge related to pediatric medication administration and drug calculations. Following a pre- and two post-tests of the measurement scale, researchers determined the average post-test score was significantly higher for students in the intervention group.

Mettiäinen et al. (2014) developed an online course to teach nursing students about basics of pharmacotherapy, intravenous medications and infusions, epidural medication, and blood transfusions. The course was offered in addition to usual teaching for 244 nursing students. Investigators also developed a 27-item self-evaluation instrument to measure student competence across the course topics. The evaluation was implemented as a pre- and post-test. Following participation in the online course, students rated their own competence as significantly higher in the areas of basic pharmacotherapy, intravenous medications, blood transfusion, and epidural medication.

6. Discussion

SON incorporate learning objectives focused on safety across courses and degree levels. Safety-based curriculum is important to include in undergraduate courses to increase safety in medication administration practices. Ensuring pre-licensure students are able to implement safety in medication administration is imperative to minimizing errors at the bedside. Nurse educators' interventions to increase medication safety practices included in this review were focused on safety outcomes in simulation cases and the use of tech devices as learning aids.

Simulation was an effective way for educators authoring publications included in this review to improve medication administration safety for undergraduate nursing students. The use of simulation scenarios to convey these, and other, central tenets of safe practice is increasing as SON across the globe struggle to obtain clinical placements for all enrolled students (Burdick et al., 2016). An on-campus clinical or simulation lab experience offers students safe place to practice skills and make errors from which they may learn without harming a live patient. When SON build simulation labs and design lessons, the environment and scenario must be as much like the clinical area as possible. Faculty may consider adding additional antecedents of medication errors to simulation experiences, such as illegible orders (Carayon et al., 2017), use of abbreviations, environmental distractions (ringing phones or family members at the bedside) (Parry et al., 2015), so student nurses may practice management of these clinical components.

As not all SON have simulation labs, there is a need to develop and test classroom-based interventions. Activities that may be implemented in the classroom setting to help students think critically about error prevention or how to navigate a situation that may precipitate an error are needed. Such activities could be incorporated in to a pharmacology course, or across nursing specialties. Page and McKinney (2007) proposed a *Medication Safety Day* during which the awareness of medication safety issues among senior-level nursing students would be increased following presentations related to medication errors, high-risk medications, error-prone situations, and recommendations for safe practices. Instead of reserving such a day for the end of pre-licensure education, SON could incorporate this activity for students of all levels annually.

Technology aids utilized in studies included in this review were meant to be a learning tool, and not a safety net. It is a common misconception among healthcare providers and students that electronic ordering systems and medication dispensing units will prevent errors. While these systems may have safety mechanisms such as alerting nurses of potential medication interactions or too little time between administered doses, the adoption of such technology has revealed new sources of error specific to electronic medical records (Klehr et al., 2009).

Going forward, educators and researchers should plan to implement and study technology that is both current and accessible. This is a challenge, as new technologies come to market frequently, and swiftly leave previously cutting-edge devices obsolete. Unfortunately, the Google Glass program supporting use of the technology in education was discontinued. Educators may consider using a wearable body camera if they would like to follow the model of Schneidereith (2015). Although PDAs are no longer widely used, there are smartphone applications containing resources similar to those used by Greenfield (2007). Educators can suggest a reliable application to students to consult during clinical and simulation experiences.

Online learning modules developed for studies included in this review were used both as primary teaching methods (Mettiäinen et al., 2014) and methods to enhance traditional learning experiences (Holland et al., 2013; Lee and Lin, 2013). From studies in this review, it is not possible to conclude which type of online module is more effective as different outcome measures were used. Given the differing measures, and limited data on the utility of online modules to teach medication safety concepts, nurse educators should plan to offer such modules as complementary learning tools to traditional lecture, skills lab, and clinical experiences.

Activities aiming to diminish the shame of making a medication error should be incorporated across nursing curriculum. Cooper (2012) identified that, outside of clinical agency requirements on error reporting, there was little transparency surrounding medication errors in SON. Nursing students are traditionally goal-oriented and fear failure, which may lead to hiding of errors and near misses (Dunn, 2014). While faculty must convey the importance of reporting errors per clinical agency policy, they must also ensure students are aware of the reasons behind reporting. Beyond reporting for patient monitoring and legal reasons, students must know that all healthcare professionals stand to learn how to prevent future errors, when medication errors are reported and the causes behind such errors are reviewed. Leading students through a root cause analysis, as suggested by Dolansky et al. (2013) may be helpful in diminishing thoughts of punishment following an error. To further reduce stigma around errors, faculty may consider sharing stories of their own medication errors.

In the 12 studies reviewed, different interventions as well as different outcome measures were used. Among the three studies that tested the effect of simulation on medication safety, different outcomes were measured. For instance, Harris et al. (2014) measured nursing students' medication administration exam scores. Konieczny (2016) measured nursing students' knowledge related to medication administration using an author-developed 10-item knowledge assessment questionnaire. Pauly-O'Neill and Prion (2013) measured nursing students' knowledge and confidence of medication skills required for taking care of pediatric patients. Sears et al. (2010) measured nursing students' risks of medication errors using a survey instrument developed by one of the authors, which clinical instructors completed in order to report actual and potential medication errors made by students during simulations. Sanko and Mckay (2017) measured nursing students' self-reported medication administration confidence and competence as well as adverse events during simulations, using the medication administration competence and confidence scale (MACCS) and the simulated adverse event system (S-AERS). Due to the various interventions and outcome measures used in studies reviewed, it is difficult to reach a conclusion about which intervention has been most effective in improving nursing students' medication safety competencies. Researchers studying this topic in the future should consider conduct multi-site studies using the same measurement tools to determine the effectives of an intervention in relation to a specific outcome.

A lack of information provided regarding psychometric properties of measures used was noted among the studies included. Most instruments used in the included studies were developed by the author(s) of the research team, and only three (Konieczny, 2016; Sanko and Mckay, 2017; Sears et al., 2010) provided information about reliability or validity of the measures. For example, Konieczny (2016) developed a 10-item instrument to access nursing students' knowledge about medication administration and reported the instrument's reliability was assessed using a point biserial correlation. However, the author stated that only one of the 10 items had an acceptable value, indicating a lack of reliability of the measure. There was no discussion about the validity of the measure. Sears et al. (2010) reported examining face validity and inter-rater reliability of the instrument developed and used in their study, and the instrument established good reliability and validity. Sanko and Mckay (2017) demonstrated good reliability of the MACCS using item-total correlations; however, the instrument's validity was not discussed. Use of reliable and valid instruments to measure key study variables is important, as research findings cannot be considered sound if data are not psychometrically reliable (Furr and Bacharach, 2014). To generate meaningful data, researchers should use psychometrically sound measures when available. Further, efforts to develop reliable and valid instruments to measure nursing students' competencies about patient safety including medication safety should be made. Such tools

are limited in the literature (Lee et al., 2014).

Most studies included in this review were conducted in North America; eight in the U.S. and one in Canada. This may be related to the QSEN initiative, as U.S. SON have made efforts to integrate QSEN competencies in their programs (Cronenwett et al., 2007). Similarly, Lee et al. (2014) reported most studies regarding patient safety education were conducted in the U.S. and few in Europe. It is important to remember that, globally, approximately 5 of 100 hospitalized patients experience medication errors and medication errors are the most common errors involving nursing care (Latimer et al., 2017). Therefore, researchers based outside of North America are encouraged to study the present topic and share information on successful educational interventions.

6.1. Limitations

There are several limitations to this review. First, most studies included in this review were conducted in North America; thus findings may not be generalizable to nursing schools internationally. Also, this review included only studies published in English, and this approach may have excluded relevant evidence published in other languages. Finally, although the authors performed extensive database and hand searches, some relevant studies may have been unintentionally excluded from this review.

7. Conclusion

This review provides information regarding successful incorporation of medication safety concepts in undergraduate nursing education. In 12 original research studies reviewed, researchers demonstrated the effectiveness of simulation, technology-enhanced, and online learning experiences in fostering the medication administration safety skills of nursing students. As supports for such learning experiences are not available in all SON, educators should consider developing and testing classroom-based educational interventions. In the articles reviewed, different outcomes were measured for the similar interventions, which limits our ability to reach a consensus on the effectiveness of each intervention. In addition, this review revealed limited discussions of instruments' psychometric properties as well as a lack of use of reliable and valid instruments to measure outcome variables. A clear need exists to develop psychometrically sound tools in future research.

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