5-2018

Improving Medication Calculation Competence in Nursing Students through Schema-Based Dimensional Analysis Instruction

Laureen Turner
University of San Francisco, reenit@comcast.net

The University of San Francisco

IMPROVING MEDICATION CALCULATION COMPETENCE IN NURSING STUDENTS THROUGH SCHEMA-BASED DIMENSIONAL ANALYSIS INSTRUCTION

A Dissertation Presented
to
The Faculty of the School of Education
Learning and Instruction Department

In Partial Fulfillment
of the Requirements for the Degree
Doctor of Education

By
Laureen Turner
San Francisco
May 2018

THE UNIVESITY OF SAN FRANCISCO

Dissertation Abstract

Improving Medication Calculation Competence in Nursing Students Through
Schema-Based Dimensional Analysis Instruction

This study was aimed at improving the medication calculation competence of nursing students through a schema-based workshop in which dimensional analysis was used as the calculation method. The overreaching goal of this work was to improve the teaching of medication calculation in nursing education and prevent future medication errors.

This two-group descriptive posttest study included a historical comparison between fall 2016 and spring 2017 students. Spring students had the option to attend a newly designed workshop while fall students did not. Primary comparisons were of (a) percentage of students achieving 100% on the first attempt, (b) number of errors, and (c) type of errors on the Medication Calculation exam. The second independent variable was the use of dimensional analysis with the dependent variable being student accuracy on each item. The sample was drawn from prelicensure nursing students enrolled in the fifth of six semesters of nursing instruction in a bachelor of science nursing program in Northern California.

The research questions explored the effect of a schema-based dimensional analysis medication calculation workshop on the first-time pass rate, the type and number of errors, and student performance on the on the Medication Calculation exam. A final research question involved student perceptions of the workshop?

The results indicate that the spring students who attended the workshop had the best results. The means between groups demonstrated that the spring cohort who completed the workshop was the highest (9.85, *SD* = .42) when compared with the fall cohort (9.55, *SD* = .82) and with the spring students who did not attend the workshop (9.5, *SD* = .83). Additionally, only one (2%) spring student who completed the workshop missed more than one item on the exam compared with three (12%) spring students who did not attend the workshop and with ten (10%) fall students.

This dissertation, written under the direction of the candidate's dissertation committee and approved by the members of the committee, has been presented to and accepted by the Faculty of the School of Education in partial fulfillment of the requirements for the degree of Doctor of Education. The content and research methodologies presented in this work represent the work of the candidate alone.

Laureen Turner	May 17, 2018
Candidate	
Dissertation Committee	
Dr. Susan Prion	May 17, 2018
Chairperson	
Dr Robert Burns	May 17, 2018
Dr. Mathew Mitchell	May 17, 2018

DEDICATION

This work is dedicated to my husband Christian Turner. I thank you for your patience and support during this period of my life. Thank you for being there for me when I was stressed and lost faith in my abilities. Thank you for understanding on the 100th time I told you “no, I can’t.” Thank you again for the time and patience as I took months to recover and regroup from a tumultuous spring. You have been my partner, sounding board, research assistant, proofreader, coder, and most importantly, my rock. Thank you.

ACKNOWLEDGMENTS

There are so many people to acknowledge and thank.

First and foremost, I thank my supporter, confidant, proofreader, research assistant, and best friend. Christian, thank you so very much for your support over these past five years. I would not be where I am today without you. Thank you so very much for letting me follow my dreams no matter how crazy they are. Thank you for your proofreading services and for making sure I did not starve in the final weeks of writing this little essay.

Mom, you are always my champion and my support. You taught me to be a hard worker and to not give up. You taught me to be strong and overcome. Well, Mommie—I have, I am, and I did. Thank you.

Sherry, you are and always have been my hero. You are the one person I have always been able to call on in a time of need and know you are there. Thank you for never giving up on me, kicking me when I need it, laughing as necessary, and crying when needed. Thank you.

Naomi and Michele, the two of you have helped me more over these past few years than you will ever know. You both keep me grounded in what is actually important. Naomi, you remind me to smile and see life for what it is. We have seen, we have overcome, and we have so much more to do. Michele, you remind me of the importance of long-term friendship. Thank you for keeping me sane. To the two of you, I hope that now that this chapter of my life is closing that we will have much more time for adventures.

To all of my educators at the University of San Francisco, I made a conscious

decision to walk down a more difficult and lengthy path when I chose this degree. I did this as I wanted to be a better educator, and you did not disappoint. I have you all to thank. You have also turned me into a researcher. For that, I will be forever thankful.

Dr. Busk, from the first day we met and I wanted to transfer from another program, you have been a supporter and sounding board. You taught me more than I never knew there was about APA and statistics. I asked of you to ensure that in the end, I could understand the math behind the research and you delivered. Also, in your essentials course, you provided me with much needed tools to flip my class. Thank you. I have used much of what you have taught me to improve the education of nurses in our program and hope that, in the end, our contributions help grow good nurses.

Dr. Burns, here is something that you may not hear every day; I actually enjoyed research methods. You taught me a ton, and I am forever appreciative. Also, thank you for serving on my committee. Your comments and direction have been very useful. The largest thank you, however, goes for authoring your two essential guides. A thousand thanks as they provided the tools and structure I needed to get this little essay into a somewhat reasonable form.

Dr. Mitchell, you have taught me to be a better consumer of research through your think-alouds. Additionally, the tools I learned in your multimedia course have influenced my course design and have improved my teaching. I greatly appreciate the substantial time, effort, and energy you put into teaching and try to model that in my own teaching.

Dr. Rowden Quince, I am fortunate to have taken two courses from you. You have the unique ability to make a class interactive, engaging, and fun in a way that helps information stick. The material you taught in both motivation and instructional design has already had a profound effect on the way I teach in and out of the classroom. This semester you have taught me the importance of grace, compassion, and understanding at a time when I needed it the most. You Rockadoodle ! I am forever grateful to you.

Dr. Susan Prion, I do not think either of us knew what we were getting into when we decided to try this out. It is never a cakewalk to turn a peer relationship into a teacher/student role. You handled it with grace and compassion. This semester, as you know, was very difficult for reasons far outside of this process. Your consideration and care was always greatly appreciated.

TABLE OF CONTENTS

LIST OF TABLES

Table Page

LIST OF FIGURES

CHAPTER I

STATEMENT OF THE PROBLEM

The prevalence and incidence of medication errors is astounding. Medication errors are not only the most common, but they are also the riskiest, nursing error allowing for untoward patient outcomes (Cookson, 2013). The National Coordinating Council for Medication Error Reporting and Prevention (2017, p. 1) recently defined a medication error as “any preventable event that may cause or lead to inappropriate medication use or patient harm while the medication is in the control of the healthcare professional, patient, or consumer.” In the United States alone, at least 1.5 million people are injured by medication errors each year (Weeks, Clochesy, Hutton, & Moseley, 2013). The Institute for Medication Safety Practice (2015) estimated that medication error leads to one to two million hospitalizations and to 100,000 to 200,000 deaths in the United States annually. Multiple factors, from system-wide processes to the nurse’s ability to calculate accurately, influence the incidence of medication error. Given an environment of health-care reform, it is prudent for educators to identify methods for improving the incidence of medication error. The aim of this research, therefore, was to improve the medication calculation abilities of nursing students.

This study was also focused on medication calculations commonly found in the maternal–child health-care specialty where nurses care for women before, during, and after delivering their babies as well as for children from birth to the age of 18. In this specialty area, the margin for error is small, the stakes are high, the arithmetic is complex, and medication errors are common (Keers, Williams, Cooke, & Ashcroft, 2013). Furthermore, in maternal–child nursing, students are introduced to the concept of weight-based dosing. This approach requires calculation of the medication dosage in milligrams per kilogram of patient weight and then the precise amount of medication in milliliters to administer. This complicated multistep ratio/proportion problem-solving has been demonstrated to be the most difficult and error-prone medication calculation type (Bagnasco et al., 2016; Stolic, 2014).

Medication Calculation Research

The documented research on medication calculation in nursing education has been descriptive in nature, and its outcomes have highlighted both its importance as well as several concerns. First, in much of the literature, the inability of students to reach medication calculation mastery at 100% has been demonstrated (Bagnasco et al., 2016). Given the significance of calculation error, these findings are worrisome as inaccurate calculations may result in patient harm.

Next, researchers in several studies explored the types of questions that students found most challenging and discovered that the most difficult question type was ratio/proportion (Coyne, Needham, & Rands, 2013; Stolic, 2014). Ratio/proportion questions are common in nursing and often result in inaccurate calculations as a result of improper use of the formula or miscalculation. Furthermore, because of weight-based dosing, medication calculations in pediatrics involve ratio/proportion problem-solving most of the time.

Gender has also played a significant role in many studies with male students outperforming female students. These gender-based differences in mathematics lead to concern in a female-dominated profession (Bagnasco et al., 2016; Grandell-Niemi, Hupli, Puukka, & Leino-Kilpi, 2006; Jukes & Gilchrist, 2006; McMullan, Jones, & Lea, 2010).

Teaching Strategies Aimed at Improving Medication Calculation Performance

In many of the studies conducted on medication calculation performance in nursing education, multiple interventions were used, a control group was lacking, or both (Coyne et al., 2013; Ramjan et al., 2014; Stolic, 2014). Although many findings demonstrated improvement in student medication calculation, absent a control group and with multiple interventions involved, it is impossible to ascertain whether improvements were a result of the interventions, outside instruction, student practice with medication administration in the clinical setting, or some other extraneous factor (Coyne et al., 2013; Ramjan et al., 2014; Stolic, 2014).

Grugnetti, Bagnasco, Rosa, and Sasso (2014) reported on a promising study in which a single intervention was used, a medication calculation workshop. The researchers highlighted the use of a 30-hour workshop over the period of 2 weeks to improve medication calculation skills in nursing students. In this work, students demonstrated improvement in their ability to calculate accurately, which presumes that the workshop was helpful. Several different factors, however, could have accounted for this change, and without a comparison group, it is difficult to determine whether these gains were from the workshop or from an additional factor.

Promising Research on Dimensional Analysis in Nursing Education

Dimensional analysis (DA) is a systematic problem-solving method that has been used in the sciences to solve complicated, multistep calculation problems. The research findings in nursing education show promise for using DA as an effective approach for complicated medication calculation problems (Stolic, 2014). As a result of difficulties in study design, a persistent inability to reach the 100% mark of mastery, and limited current research, however, ongoing research is warranted. For example, in early work by Craig and Sellers (1995), the authors cited the efficacy of dimensional analysis instruction; nevertheless, the study groups were recruited from two different schools with different curricula and program types. Therefore, it is difficult to determine whether these groups were equivalent. Koohestani and Baghcheghi (2010) explored the use of DA and demonstrated improvement among the intervention group, yet they also reported that 85% of participants in the intervention group were unable to score 100%. This finding is alarming as every medication calculation error has the potential to become a medication administration error that can lead to patient harm. In more recent work, Cookson (2013) asserted that dimensional analysis is a simple method for calculation that may lead to a reduction in medication calculation errors and may improve patient safety.

In much of the literature on medication calculation in nursing education, scholars have reported the use of multiple step interventions (Coyne et al., 2013; Ramjan et al., 2014). These interventions included numeracy remediation, quizzes, case studies, and contextualized instruction. Additionally, the researchers in these studies did not report teaching on specific problem-solving methods such as dimensional analysis. Although the results of these studies demonstrated some improvement in students’ scores, students remained unable to master the exams at the 100% mark. As multiple interventions were included in each study over the course of a semester, it was unclear as to which interventions were most effective. Therefore, dimensional analysis was the solving method taught in the workshop highlighted in this study. A cohort of spring 2017 nursing students who completed the workshop was compared with their peers from the same cohort who did not attend the workshop. Additionally, these participants were compared with the prior semester cohort (fall 2016) as these students did not have access to this workshop.

Purpose of the Study

The purpose of this study was to extend prior research on medication calculation in nursing education and fill in previously mentioned gaps in the literature with a focus on improving nursing students' medication calculation accuracy.

To accomplish the stated purpose, a single intervention was used, a dimensional analysis workshop. In this study, treatment involved a three-hour-long workshop in the spring of 2017 that used dimensional analysis as the problem-solving process within the context of maternal–child nursing. Student performance on the Maternal Child Medication Calculation (Med Calc) exam was compared with the former (fall 2016) and the current (spring 2017) Senior One cohort of nursing students. This workshop was newly created, and thus, the fall 2016 students did not have access to this content. The areas of comparison were the first-time pass rate, the mean score on the exam, and a detailed analysis of student solving methods on individual items.

Significance of the Study

This study is important for several reasons. First, in looking at the overall significance of medication errors, these mistakes are both deadly and costly for patients and the health-care system. Although it is difficult to ascertain the full scope and cost of medication error, the Agency for Healthcare Research and Quality Patient Safety Network (2015) asserted that, on average, 5% of hospitalized patients have experienced an adverse reaction relating to medication. They further asserted that approximately 50%

of these adverse events were preventable. Medication errors can also cause undue stress on the nurse and reduce his or her confidence (Stolic, 2014) and sense of self-worth (Koharchick & Flavin, 2017). If nursing students are taught sound medication calculation practices in school, then there is a potential to avoid future errors as well as to improve the self-confidence of these students.

This work was aimed at connecting dimensional analysis and patient context in a workshop designed to develop the student's medication calculation schema further. Although each of these components has been studied individually, combining them is unique and demonstrates promise in the development of a schema for nursing students that will provide them with long-term medication calculation abilities that are transferable to various types of medication calculation. If this combination proves beneficial, it will identify a strategy for further improvement of teaching medication calculation in nursing education. Ongoing research into the calculation skills of nurses is necessary as it is presumed that medication errors will continue to be commonplace without a change in educational practices.

Theoretical Framework

One model that may be useful in understanding how to teach medication calculation most effectively to nursing students lies in schema theory. A schema provides the framework, outline, or plan for solving problems (Powell, 2011). As stated, this research is aimed at developing a medication calculation schema in nursing students that will improve accuracy. Therefore, by developing a medication calculation schema, it is possible to provide students with the needed structure to solve math problems accurately. This schema includes the identification of pertinent information, use of dimensional analysis, and the conceptualization of the answer within the context of maternal–child nursing.

Schema theory

As noted, schema theory provides a promising conceptual framework for understanding instructional practices that may improve medication calculation in nursing students. A schema is a knowledge structure that provides an organizational system for the storage of information (Driscoll, 2005). These storage containers, when used correctly, aid in retention of information and improve recall and accuracy.

For example, consider a typical garage filled with various household items such as sporting equipment, lawn tools, and holiday decorations. If the items are scattered throughout the garage, they are difficult to find and use. If the items are organized and connected with like items, however, they become easier to find and use, and accuracy increases. Additionally, when items are stored incorrectly, such as garden tools with sporting tools, the chance of using a tool incorrectly or selecting the wrong tool increases. The same is true with medication calculation as many students do not have their knowledgebase "stored" correctly and therefore struggle with what to do with the numbers, identifying the pertinent pieces of information in the question, inverting numbers in the equations, multiplying when they should divide, and having difficulty with the use of formulas (Hunter-Revell & McCurry, 2013). In schema theory, through the development of schema, information is processed faster and more accurately (Driscoll, 2005). Therefore, development of a medication calculation schema that structures these tasks, aids students in selecting the correct "tools," and accurately uses these may improve the student's performance in medication calculation.

Schema-based instruction (SBI) comprises instructional techniques designed to invoke prior schema and then add to these schemata to develop more complex schema, as well as to develop new schema. In nursing education, the use of SBI may aid in developing a medication calculation schema for students that is more accurate. This schema involves identifying necessary information, using dimensional analysis, and determining the fit of the answer in the context of the patient situation. These steps should promote the development of an accurate and effective method for medication calculation for the nursing student.

Background and Need

It is well known and readily documented that medication errors have serious consequences for patients. Adverse reactions, lengthened hospital stays, and death from medication errors account for 10% to 20% of errors among hospitalized patients (Sherriff, Burston, & Wallis, 2012). Although it is difficult to quantify the incidence of error in full, Fleming, Brady, and Malone (2014) have asserted that medication errors happen in approximately 20% of every medication administration.

In a systematic review of the prevalence and nature of medication administration errors, this problem was explored by researchers in a multinational study in which it was found that 25.6% of every potential opportunity for medication error results in error (Keers et al., 2013). Additionally, the rates for intravenous medication errors were significantly higher at 53.3%. Moreover, the reported error rate of medication administration in the pediatric setting was 34.8%, and the authors also claimed a 73.0% overall probability of making at least one error in the administration of intravenous (IV) medications with every single administration (Keers et al., 2013).

Furthermore, medication errors have a devastating impact on the nurse committing the mistake (Keers et al., 2013). Nurses committing medication errors often lack self-esteem, feel guilty, and are ashamed, which can undercut the nurse's clinical skills and professional judgment. Nevertheless, although nurses worry about their patients, they are also concerned with loss of respect from colleagues, poor performance evaluations, threats to licensure, and professional retribution, such as a lawsuit, imprisonment, and loss of a job, that coincide with serious medication administration errors. These factors can lead to significant incidences of posttraumatic stress syndrome (PTSD) and depression in the nurse (Keers et al., 2013). As a result, it is essential to find mechanisms to reduce medication error.

Calculation error incidence

Although the frequency of medication administration errors is high, administration of medications is multifactorial and includes several different processes and personnel. The nurse is the last link in the chain as he or she places the medication in the patient's hand. Estimates indicate that 11% to 14% of all medication errors are related to incorrect calculation (Fleming et al., 2014). Even though the amount of published research on nursing student medication error is limited, in an older study, the researchers suggested that medication error was the most frequently occurring error (56%) with the wrong dose as the most often recorded type of error in nursing students (Gregory, Guse, Davidson, Davis, & Russell, 2009). Consequently, the findings reported in the literature support assertions that calculation errors translate to the bedside and nurses need to improve their medication calculation skills to safeguard against medication error (Athanasakis, 2012).

Key factors relating to medication calculation errors

Bagnasco et al. (2016) explored factors that related to medication error in nursing students and found that the average student scores across the curriculum were 69%, 66%, and 62% for the first-, second-, and third-year students, respectively, demonstrating the need to reinforce mathematics instruction and assessment throughout the curriculum. Their primary findings indicated that students did not know how to multiply fractions or use decimals and often inverted the nominator and denominator when using formulas. Additionally, many students could not multiply and divide decimal numbers. The researchers found that 22% of students self-reported poor math skills.

Furthermore, gender played a significant role with the male students (n = 187) outperforming the female students (n = 539) on all six areas of the exam ($p < .05$). The differences between genders in mathematics lend to concern in this female-dominated profession. Lastly, the investigators asked students to report whether they had difficulties with the exam. Interestingly, 30% (214) of the students reported no difficulties with the exam, yet only 3% (n = 6) earned 100%, indicating either a lack of self-awareness of mathematic ability or a lack of understanding on the importance of 100% mastery in medication calculations (Bagnasco et al., 2016).

In total, these findings identified the primary areas of concern relating to medication calculation in nursing education. The following section highlights strategies to improve the medication calculation performance in nursing students.

Teaching strategies to improving medication calculation performance

Stolic (2014), in a literature review, identified key strategies previously reported to improve medication calculation skills in nursing students. Highlights from the review include the concern that in many of the included studies a single group and multiple interventions were used. Additionally, a single posttest was included. Stolic asserted that without a baseline, or an equivalent control group, it is difficult to ascertain whether instructional interventions had any effect.

A primary concern for researchers in this area has been that many schools set the student passing rate below 100%. Even with lower pass rates, however, passing rates were abysmal at 36%. Although in many studies, researchers reported gains in student performance, Stolic (2014) expressed concern about student inability to achieve the 100% mark on the medication calculation exam. No errors for drug calculation should be acceptable. Additionally, Stolic stated concern over teaching of formulas as formulas have not been demonstrated to be helpful and students struggle with their use. Therefore, Stolic suggested abandoning this method of calculation in the clinical setting.

Stolic (2014) also addressed the use of technology for teaching medication calculation with mixed results. The results of some studies demonstrated positive gains, whereas other did not. A key factor, however, was that students who were actively involved in their learning had greater retention and improved medication calculation scores. Stolic concluded that there is insufficient evidence in medication calculation and therefore encouraged further research with improved methodologies that include comparison groups.

Ramjan et al. (2014) reported on educational strategies designed to improve numeracy skills in nursing students by using a mixed-methods design. They employed a multiple step intervention consisting of online practice quizzes, simulated medication calculation scenarios, the medication calculation exam, targeted remediation workshops, retesting of the students who were unsuccessful on the first taking of the exam, a hands-on remediation workshop, and the final medication calculation examination.

Ramjan et al. (2014) did not report how many other interventions were completed by those who passed on the third attempt; nevertheless, they did report that the online quizzes were successful as a first-pass support strategy but not effective for the less independent students who needed face-to-face support. The researchers also indicated that 100% of students who attended the final hands-on workshop passed the exam. Nevertheless, these students had been exposed to several different strategies, so it is difficult to determine which strategies were successful.

Ramjan et al. (2014) also demonstrated the effectiveness of a multiple step program in improving nursing students' medication calculation scores. Through remediation, as well as through case-based scenarios and hands-on work, the researchers highlighted student success. As these interventions occurred in steps over the duration of a semester, however, it was difficult to determine which steps were most effective.

Next, Grugnetti et al. (2014) reported on the use of a dedicated medication calculation workshop among nursing students in a pretest–posttest study in which the use of a 30-hour workshop over the period of 2 weeks to improve medication calculation skills in nursing students was highlighted. For this investigation, researchers designed a realistic clinical setting with patient scenarios and built the medication calculations into the scenarios.

Data collection was completed by Grugnetti et al. (2014) through use of two tools: one for demographic information and the second as a math skills test. The math skills test was compiled through a panel of expert trainers and included 30 problems. Students took the exam before and after attending the workshop, were allowed 90 minutes for completion, and were not allowed to use calculators.

The initial results reported by Grugnetti et al. (2014) indicated no significant difference for age or nationality. The researchers reported the pretest results on the 30-item exam (mean [*M*] = 15.96, standard deviation [*SD*] = 4.84) compared with the posttest results (*M* = 25.20, *SD* = 3.63). Clearly, the students made significant gains in their ability to calculate accurately, which presumes that the workshop was helpful. Nevertheless, several different factors accounted for this change. Without a comparison group, it is difficult to determine whether these gains were from the workshop or from an additional factor. Future research into use of workshops should include a comparison group.

In most of these studies, scholars implemented multiple step interventions to improve student performance on medication calculation exams (Coyne et al., 2013; Ramjan et al., 2014). These interventions included numeracy remediation, quizzes, case studies, and contextualized instruction. Yet, teachings on specific problem-solving methods, such as dimensional analysis, were not stated. Although the findings from these studies demonstrated some improvement in students' scores, the students still did not achieve mastery at 100%. Additionally, as each of these studies included multiple interventions over the course of a semester, it was unclear as to which interventions were most effective. Therefore, in this study, performance was compared between student groups who completed a single intervention, a medication calculation workshop, with those who did not.

Research on dimensional analysis in nursing education

One promising strategy for medication calculation is dimensional analysis (DA). DA is a systematic problem-solving method typically used in science classes designed to solve complicated mathematics problems. The results of prior research in nursing education show promise for DA as a solution strategy for medication calculation problems; nevertheless, much of the research on DA in nursing education is not current and lacks in rigor.

In an early quasi-experimental study, Craig and Sellers (1995) explored the effects of dimensional analysis on the medication calculation abilities of nursing students. The two-hour educational intervention first explained the process of DA and then demonstrated its use starting with simple problems and working into problems of increased complexity. They introduced the concepts behind each problem type and ensured students had ample time to practice prior to moving on to more complicated problem types. Additionally, the researchers provided students with a workbook containing practice problems to reinforce content throughout the duration of the semester. The control group received traditional instruction (ratio/proportion instruction solutions and dose/dose on hand methods) and received the researcher-developed workbook to ensure results were not biased toward the extra practice items provided in the workbook.

Craig and Sellers (1995) also administered the pretest to both groups at the beginning of the semester before of any of the students had the opportunity to provide medications in the clinical setting. The posttest was administered in the last month of the semester after students had experienced medication administration in the clinical setting. The researchers allowed both groups to use a calculator and instructed them to show their work. Additionally, the researchers provided both groups with a conversion table and a list of common abbreviations for use during the exam.

The experimental group means on the 20-point exam (*M* = 5.167, *SD* = 4.504) for pretest and (M = 14.3, *SD* 4.721) for posttest reported by Craig and Sellers (1995) demonstrate lower mean scores when compared with the control (*M* = 11.138, *SD* = 3.861) on the pretest and (*M* = 15.069, *SD* = 2.777) on the posttest. As a result of the differences in pretest scores, however, the researchers found the gains from pretest to posttest to be improved in the experimental group (p = .00001).

Craig and Sellers (1995) also demonstrated that DA is helpful in teaching students how to solve medication calculation problems and can make up the differences between groups of varying abilities. A primary limitation with this study was that the control group and the experimental group were very different. The intervention group students attended a diploma nursing program, and the control students were enrolled in an associate degree program. These different program types have different prerequisite entry requirements as well as a different curriculum. Additionally, the two programs required a different level of mathematics preparation prior to program entry. Therefore, although the experimental group improved significantly more than the control group, it was not clear whether this is from the intervention, the type of nursing program the students attended, or simply from nursing education as a whole as the students had an entire semester of nursing education between pretest and posttest.

Rice and Bell (2005) further developed the research on DA in nursing school in a pilot study by exploring both number of errors and levels of student confidence in calculation ability with senior nursing students enrolled in their first clinical course (*N* =

107). At the beginning of the semester, students completed the normal course preclinical drug dose calculation quiz and a questionnaire asking whether they had used DA, their confidence in solving calculation problems, and demographic information. Students were then invited to participate in a DA workshop. After the course, the researchers provided students with a 20-item practice test with an answer key for additional practice. One week later, the students took a 15-item posttest without the aid of calculators.

In addition, Rice and Bell (2005) administered an end-of-the-semester survey to determine what effect using DA had on student confidence and ability to solve medication calculation problems. Dosage calculation questions from the preclinical quiz, instructional session posttest, and the three usual course examinations were compared for accuracy and type of calculation error (conceptual, computation, and conversion). These exams all included questions on oral, intramuscular, and intravenous medication calculation.

Rice and Bell (2005) reported from the beginning of the semester survey that 25% (27) of the students reported that medication calculation was confusing and stated an inability to memorize formulas as a key factor. The most common reason students gave for being unable to calculate correctly was an inability to set up the problem and a difficulty remembering the formula.

Interestingly, the intervention group (n = 30) scored less on the preclinical quiz (79%) when compared with the 77 students who chose not to attend the DA workshop (93%), yet they outperformed these students on post instruction exams (92% compared with 90%, respectively). Although the difference in scores between these groups was significant (p = .00001) at pretest (favoring the comparison group), the posttest scores were not significantly different. This finding indicates stronger gains in the intervention group.

Lastly, there were differences between error types with the intervention group making more calculation errors (75%) than the control group (42%) but less conceptual errors (20%) as compared with the control group (56%). This led Rice and Bell (2005) to conclude that DA may help students close the gap on conceptual understanding with the computational error gap potentially narrowed through calculator use. Though this study was limited to a convenience sample in a single university, useful information for development of medication calculation programs is provided that could be used at similar universities. Replicating this work and adding the use of calculators may improve medication calculation among nursing students.

Greenfield, Whelan, and Cohn (2006) added to the work on DA in a study designed to reduce medication errors in a quasi-experimental pilot study of nursing students. The researchers expected to find that students in the DA group (n = 39) would solve medication calculation problems with greater accuracy than those in the control group (= 26) taught the formula method. The convenience sample included group assignment based on student cohort with the two groups attending the program one year apart. Both groups had the same teacher, and the first four weeks of instruction were the same with the exception of the problem-solving method. The instructor administered the medication calculation exam in the fifth week of the semester. The instrument was a 25-item exam traditionally used in this course. Calculators were permitted, and students had 50 minutes to complete the exam.

Data analysis included t tests of student's grade-point average (GPA) and biophysical science grades to determine group equivalency and found no statistically significant differences. The posttest scores favored the experimental group (M = 92.20%, SD = 6.2%) when compared with the control group (M = 86.92%, SD = 14.5%). A t test revealed these scores were statistically significant (p = .05). Interestingly, the control group's GPA was higher than that of the experimental group, which indicates that the experimental group gains may have been larger than indicated as they may have been starting from a lower ability level.

Koohestani and Baghcheghi (2010) explored the use of DA in their quasi-experimental study aimed at comparing the effects of DA and formula on rapid and sustained learning of nursing students. This study involved sampling nursing students in their third semester and randomly assigning them to two groups (n = 42). For this study, both groups had the same instructor, took the same medication calculation exam, and were not allowed to use calculators. The exam was created by the researchers in conjunction with seven other academics and reference materials found in the literature. Students took the same exam before the intervention, immediately after, and three months later.

Koohestani and Baghcheghi (2010) reported that the sample was 71.4% female and that they were divided evenly between the groups. The researchers presented data that showed improvement for both groups compared with the pretest as the groups demonstrated no difference on pretest (t = .066, p > .05) or posttest one (t = –.630, p > .05) but a statistically significant difference on posttest two (t = –4.460, p < .05). Additionally, with a goal of 100% mastery, only 3 (15%) students in the intervention group earned 100%, whereas no one in the control group scored 100%. These findings led the researchers to claim that the rate of decline in scores for the control group exceeded that of the experimental group. Thus, the learning for the experimental group was more stable when compared with that for the control group. Based on these findings, the researchers suggested that students be taught DA. They expressed concerns over the overall lack of mastery at the 100% mark and suggested ongoing education, assessment, and reinforcement of information relating to medication calculation.

In a specific attempt to explore further the efficacy of DA for medication calculation, Kohtz and Gowda (2010) evaluated DA versus conventional methods such as use of formulas to prevent drug calculation errors among undergraduate nursing students. Students participated in the study for the single semester in which they received medication calculation instruction. The control group was taught conventional methods such as use of formula and ratio/proportion, whereas the intervention group was taught DA.

The instrument used by Kohtz and Gowda (2010) was a 24-item tool with a 90% passing mark. An analysis of variance (ANOVA) demonstrated no significant difference for age. Nevertheless, a significant finding for GPA indicated that the GPA for the control group was significantly higher than the GPA for the experimental group. The mean scores for the two groups demonstrated no significant difference between the DA group ($M = 20.92$, $SD = 4.252$) and the control ($M = 20.42$, $SD = 4.414$). Although this study was not designed to favor DA over the traditional instruction, its findings demonstrated that it was at least as good as the conventional instruction.

The results of the work on use of dimensional analysis to solve medication calculation problems are promising as Craig and Sellers (1995) demonstrated that improvement in medication calculation scores could be obtained through a two-hour DA teaching intervention. Rice and Bell (2005) further determined that a single workshop teaching DA increased student scores, especially for students who were struggling at the beginning of the semester with the DA group making more calculation errors and less conceptual errors. Moreover, the findings by Koohestani and Baghcheghi (2010) and by Kohtz and Gowda (2010) showed that DA was as effective a problem-solving method as alternative teaching strategies, yet Koohestani and Baghcheghi (2010) demonstrated the power of DA on maintenance as students in their study had a smaller decline in scores on the second posttest when compared with those in the control group. For these reasons, this study aimed at developing the nursing student's medication calculation schema through the use of DA as the problem-solving method.

Research Questions

This research study was designed to explore the impact of a schema-based dimensional analysis medication calculation workshop on student test scores. The research questions were created to build on prior research in this area and to fill in gaps in the literature. Four key questions were proposed:

1. What is the effect of a schema-based dimensional analysis medication calculation workshop on the first-time pass rate on the Maternal Child Medication Calculation (Med Calc) exam for senior prelicensure nursing students?
2. To what extent does participation in a schema-based dimensional analysis medication calculation workshop influence the type and number of errors on the Med Calc among prelicensure nursing students?

3. To what extent does use of dimensional analysis on the Med Calc influence student performance on the Med Calc?
4. What are student perceptions of the schema-based dimensional analysis medication calculation workshop?

Definition of Terms

Dimensional Analysis: Dimensional analysis is a method for solving arithmetic problems that require conversions. This method can be used whenever two quantities are directly proportional to one another and one must be converted into the other using a conversion factor (Craig & Sellers, 1995). Figure one depicts a simple example of the use of dimensional analysis where the given is a 250 mg tablet of medication and the order is 500mg of medication.

$$\frac{500\cancel{mg}}{1} \quad \frac{1 \text{ Tablet}}{250\ \cancel{mg}} \quad = \quad 2 \text{ Tablets}$$

Figure 1. Dimensional analysis sample.

Medication Calculation Policy: The policy for the medication calculation exam aims to ensure that students have the ability to calculate medications with 100% accuracy. Thus, there is no tolerance for errors. At the beginning of every clinical semester, each nursing student must take a medication calculation exam prior to administering medications in the clinical setting. Each exam is conceptual in nature and includes the type of calculations relevant to the student’s clinical level. Students are allowed three attempts at the exam. Students who do not achieve a 100% on one of the exams are failed from the course and face potential dismissal from the nursing program and the university.

Maternal Child Medication Calculation (Med Calc) Exam: The Med Calc exam is an exam used for the Senior One cohort of nursing students. This exam was initially developed by two faculty experts teaching both maternity and pediatric content. The exam was then reviewed by all clinical faculty teaching in either pediatrics or maternity who concluded that the exam is representative of the mathematics required in their individual clinical settings. Each exam is conceptual in nature with patient and or problem types appropriate for the intended instruction level. For the Med Calc, the students are seniors and working in both pediatrics and maternity. As a result, the questions are complicated and include weight-based dosing.

Medication Error: A medication error refers to any event that occurs during any stage of the medication administration process. The National Coordinating Council for Medication Error and Prevention (2017) has approved the following as its working definition of medication error:

> [A]ny preventable event that may cause or lead to inappropriate medication use or patient harm, while the medication is in the control of the health care professional, patient, or consumer. Such events may be related to professional practice, health care products, procedures, and systems including: prescribing; order communication; product labeling, packaging and nomenclature; compounding; dispensing; distribution; administration; education; monitoring; and use. (para. 1)

Number of Errors on the Med Calc: The number of errors was measured by counting each inaccurate item on the Med Calc exam.

Pass Rate: The pass rates for this study were calculated by dividing the number of students who achieved 100% accuracy on the exam by the total number of students attempting the exam.

Schema: A schema is a structure, framework, or blueprint for solving a problem (Powell, 2011). This study was aimed at developing the student's medication calculation schema through identification of important information, use of dimensional analysis, and identification of appropriateness for the given patient situation.

Student Perceptions of the Workshop: Student perceptions of the workshop were measured via a survey. First, student perceptions about the workshop content were measured through self-report using a Likert-style scale on eight separate items. Next, student perceptions about the length and level of the workshop were measured to assess whether students thought the workshop was too short, the right length, or too long. Lastly, students were asked to rate the visuals, acoustics, meeting space, and overall program as *excellent*, *very good*, *good*, *fair*, or *poor*.

Student Performance on the Med Calc: Student performance was measured by mean scores, number of items missed, and an individual assessment of items to include a problem-solving method.

Type of Errors on the Med Calc: Each exam with student error was reviewed, and the error was categorized as *calculation*, *conceptual*, *setup* or *decimal rounding*, Errors were coded as *calculation* when it appeared as though the error occurred in the calculator but the setup on the paper was correct. Items coded as *conceptual* involved the students inability to select the correct numbers to place into the equation. W*rong setup* errors were those where the correct numbers were chosen but they were not set up into the formula correctly. These errors typically involved inversion of the numerator and the denominator. *Rounding* errors included items where students were asked to round to one place and they rounded to the wrong place.

Schema-based Dimensional Analysis Workshop—"The Workshop": The workshop was designed to develop the student's medication calculation schema through identification of appropriate information, use of dimensional analysis, and determination of appropriateness within the context of maternal–child nursing.

Workshop Attendance: Attendance at this workshop was measured by student self-report of workshop attendance on a workshop attendance sheet that was distributed during a regularly scheduled course two days after the workshop.

CHAPTER II

REVIEW OF THE LITERATURE

This literature review is divided into three primary sections. The first section is an exploration of medication calculation challenges in nursing education followed by a discussion on previously attempted educational interventions aimed at improving nursing student medication calculation performance. Lastly is a discussion of schema theory and how the development of medication calculation schema may improve the medication calculation abilities in nursing students. The research into medication calculation in nursing education is limited and therefore, many of these studies are outdated.

Medication Calculation Challenges of Nursing Students

In several studies (Bagnasco et al., 2016; Grandell-Niemi, Hupli, Puukka, & Leino-Kilpi, 2005; Harvey et al., 2010; Jukes & Glichrist, 2005; McMullan, Jones, & Lea, 2010; Pierce, Steinle, Stacey, & Widjaja, 2008), scholars have explored the medication calculation skills in nursing education and have highlighted key issues including global concerns that may influence the incidence of medication administration error. Key questions that have been investigated are as follows: (a) What is the level of medication calculation competence in nursing students? (b) What is incidence of medication calculation error in nursing students? (c) What types of medication calculations are more difficult for nursing students? This section will further explore these questions.

Jukes and Gilchrist (2006) explored the numeracy skills of nursing students by investigating the medication calculation abilities of a single group of undergraduate nursing students at a single university in England. This descriptive study included a convenience sample of 45 nursing students. Of those, 37 consented to participate for an 82% participation rate. Students were given a 10-item calculation exam that was created in conjunction with the literature and reviewed for validity by expert staff at the university. Additionally, a pilot test was completed and the instrument was altered based on the results. The researchers reported the content of the exam to include questions relating to injections, tablets and mixtures, dilutions and strengths, and intravenous infusions. Furthermore, the questions were sorted by calculation type including division, multiplication, percentages, ratio/proportion, conversions, and multistep procedures. Also, for this study, the use of calculators was allowed.

Key findings reported by Jukes and Gilchrist (2006) included the inability of the students to score 100% on the exam. Given the context of medication administration and the significance of error, this was highly alarming. Jukes and Gilchrist reported a median score of 6/10 and a mean of 5.5 (*SD* = 2.3). The percentage of students that scored accurately on each question type was as follows: division and multiplication questions 74%, percentages 81%, multistep 54%, and ratio/proportion 7%. The inability of the students to calculate ratio/proportion questions was concerning as that calculation type is common in medication administration.

Jukes and Gilchrist (2006) found that nursing students struggle with math. Only 7% of students could accurately calculate the ratio/proportion problems commonly found in nursing. Their findings were consistent with those reported in the literature on nursing students’ difficulty obtaining calculation competency (Bagnasco et al., 2016; Grandell-Niemi et al., 2005; Harvey et al., 2010; Jukes & Glichrist, 2005; McMullan et al., 2010;

Pierce et al., 2008). Additionally, Jukes and Gilchrist found that many students failed to use formulas for solving the problems. The students cited that they had difficulty knowing what to do with the numbers that led the investigators to infer that the underlying problem with medication calculation was conceptual in nature. Additionally, students either failed to use formulas altogether or they used them incorrectly. Another finding was that students lack a conceptual understanding behind the meaning of the numbers that may then have led to their inability to conceptualize the meaning behind the math.

This research by Jukes and Gilchrist (2006) was a simple descriptive study in which they worked toward further defining the difficulty students have with calculation. The results further developed the understanding of this problem, yet they do not offer solutions. Future research, as highlighted by Jukes and Gilchrist, should be aimed at exploring the magnitude of the problem, an assessment by nurses identifying the specific numeracy needs in their clinical practice, improvement of calculation strategies, development of a framework to facilitate and assess numeracy ability in nursing students, and further improvement of educational strategies to close the theory–practice divide.

Bagnasco et al. (2016) studied undergraduate nursing students at a single university in Turin, Italy, in a descriptive study involving inviting all students (N = 726) registered in years 1, 2, and 3. They used both the assessment tool and the self-assessment questionnaire developed by Wright (2005). The assessment tool was designed to include two sections. Section 1 included key mathematical areas, such as (a) percentages, (b) multiplying fractions, (c) calculations with fractions, and (d) division and multiplications using factors of 10. The second section of the mathematic assessment included practice-based problems comprising medications from the clinical setting.

The second instrument used by Bagnasco et al. (2016) was aimed at gauging the student's self-assessment of mathematic ability. The tool asked students to rate their mathematical strength as *poor*, *sufficient*, or *good* in each of the aforementioned six areas. Additionally, to explore the student voice further, the researchers asked students to provide a written account of problematic items on the exam.

The average student scores reported by Bagnasco et al. (2016) across the curriculum were 69% (M = 22.12, SD = 5.86) for first-year students, 66% (M = 21.13, SD = 6.58) for second-year students, and 62% (M = 19.78, SD = 5.88) for third-year students. These scores were alarming, as each calculation error may indeed have resulted in a medication administration error. Additionally, the decline in the third-year scores was disquieting as these more advanced students should have had higher scores, further demonstrating the need to reinforce mathematics instruction and assessment throughout the curriculum.

An additional key finding in Bagnasco et al. (2016) was that only 3% of the students achieved mastery on the clinical performance questions that highlighted the need to teach mathematics in the context of clinical situations. Additionally, gender played a significant role with the male students (n = 187) outperforming the female students (n = 539) on all six areas of the exam (p < .05). The differences between gender in mathematics are documented in the literature and lend to concern in this female-dominated profession (Bagnasco et al., 2016; Grandell-Niemi et al., 2005; Jukes & Gilchrist, 2006; McMullan et al., 2010).

Lastly, Bagnasco et al. (2016) asked students to report whether they had difficulties with the exam. Interestingly, 30% (214) of the students reported no difficulties with the exam, yet only 3% (*n* = 6) earned 100%. This indicated either a lack of self-awareness of mathematic ability or a lack of understanding on the importance of 100% mastery in medication calculations. Twenty-two percent (*n* = 155) of the students reported difficulties on the exam citing the desire to have a calculator. Of those citing difficulties with the exam, 3% (*n* = 5) scored 100%. Predictably, when we compare mean scores between those who report difficulty with the exam and those who do not, students who do not report difficulty outperform those who do in each of the key mathematical areas.

Bagnasco et al. (2016) confirmed the findings reported by Grandell-Niemi et al. (2005), Harvey et al. (2010), Jukes and Glichrist (2005), McMullan et al. (2010), and Pierce et al. (2008) that nursing students struggle with medication calculation. The researchers felt that several factors influence the mathematic ability of students, including (a) use of calculators, (b) interpretation of information, (c) conversion of measures, and (d) conceptualization of calculations. They affirmed that undergraduate nursing students had difficulty calculating medication dosages as a result of lack of knowledge of basic math principles.

McMullan et al. (2010) further explored the numerical skills and medication calculation abilities of both nursing students and registered nurses (RNs) in a correlational study designed to investigate and correlate the relationship of age, status, experience, and medication calculation ability to numerical ability between nursing students and RNs. Through the use of a correlational approach, they employed a convenience sample of all fall (*n* = 137) and spring (*n* = 92) cohort nursing students attending the second year in a diploma nursing course as well as a convenience sample of 44 RNs. The nursing students were tested halfway through their second year, and the RNs were assessed two months into a medication prescribing training program. The one-hour test consisted of 35 questions without the aid of a calculator.

The test was divided into two key sections: numeric and medication calculation. The numerical ability section was based on the validated Australian literacy and numeracy test for certificate IV in nursing. The medication calculation test included 20 items covering the main types of calculations. McMullan et al. (2010) created this exam in conjunction with the literature on medication calculations. The instrument was then evaluated by nursing academics within the university to test for face validity. The university research ethics committee approved this study.

McMullan et al. (2010) used an independent-samples *t* test to explore between-group differences and found no statistically significant differences between the two nursing student cohorts (t = –9.44, df = 227, p = .66). Student cohort scores were then combined and reported as numerical ability (M = 54.8%, SD = 24.7) and total medication calculation ability (M = 36.2%, SD = 15.1). The researchers further divided the medication calculation ability into two scales: (a) solids, oral liquids, and injections and (b) medication percentages and infusion rates. The findings on these scales indicated that nursing students struggle more with percentages and infusion rates (M = 11.5%, SD 17.23) as compared with solids, oral liquids, and injections (M = 73.5%, SD = 20.70). These findings were statistically significant (t = 42.35, df = 228, p < .001).

These nursing student findings by McMullan et al. (2010) were compared to the RNs who scored higher than the students for arithmetic ability, yet alarmingly low (M =

63.1%, *SD* = 24.6). Additionally, RNs scored lower on calculation ability than they did on numerical ability (*M* = 40.8%, *SD* = 14.6) with similar findings to the students on the two scales of (a) solids, oral liquids, and injections (*M* = 82.7%, *SD* = 14.2) and (b) percentages and infusion rates (*M* = 12.5%, *SD* = 18.9). These findings were statistically significant for the RNs. In addition, the RNs performed significantly better on questions involving solids, oral liquids, and injections as opposed to on questions involving percentages and infusion rates ($t = 25.34$, $df = 43$, $p < .001$). McMullan et al. reported a statistically significant difference between RNs and students for the solids, oral liquids, and injections ($t = –2.99$, $df = 271$, $p = .003$), yet no statistically significant difference between students and RNs on the more difficult calculations of percentages and infusion rate calculations ($t = 25.34$, $df = 43$, $p < .062$).

In looking at the overall tolerance for error, these results by McMullan et al. (2010) are of concern. With an 80% passing mark, 55% of students and 45% of RNs failed the numerical ability test and 92% of students and 89% of nurses failed the medication calculation test. These findings indicated that nurses struggle with numeracy and complex calculations. Interestingly, there was a strong correlation between numerical and medication calculation abilities ($r = .6$, $n = 273$, $p < .001$). These findings also lead to the understanding that nurses need to focus first on basic numeracy competence and then need to develop a schema for solving math problems. This should start with simple math and then be advanced over time such that students establish a solid framework for approaching difficult medication calculations. Next, in consideration of the math involving percentages and infusion rates, the researchers suggested that these types of calculations are conceptual in nature; thus, educational interventions aimed at teaching these types of problems should be grounded in the conceptual patient care situation.

Nevertheless, as McMullan et al. (2010) conducted this study at a single university in England, the results might not be generalizable. Additionally, the RN sampling was self-selection and most RNs participating in the study worked in primary care and were enrolled in a prescribing program. Therefore, these nurses were not representative of the typical practicing RN and the results of their scores need to be considered in that context.

Grandell-Niemi et al. (2005) further explored the differences between RNs and nursing students in their work designed to investigate self-rated and actual mathematical skills of RNs and graduating nurses in Finland. The primary research questions were (a) what are nurses and nursing students' self-rated and actual mathematical skills, (b) are there differences between the two groups, and (c) how are the skills associated with background?

For this study by Grandell-Niemi et al. (2005), the sample was obtained from 5 hospitals and from 25 polytechnic schools providing prelicensure nursing education in Finland. The samples consisted of 364 nurses and 282 students from seven hospitals and five polytechnics in southern and northern Finland with response rates of 68% for nurses and 70% for students. The researchers developed the MCS test through a review of the literature. This instrument was divided into three sections: (a) demographics; (b) self-assessment of mathematic skill, pharmacologic skill, and interest; and (c) a computational and pharmacologic skills test. The computational section of this exam was further divided into basic math (BL) and high-level conversion (HLC). The exam had a total score of 29. The researchers presented findings that indicate that nurses (*M* = 22.7, *SD* = 4.7) outperformed nursing students (*M* = 17.8, *SD* = 6.1) on the total exam. In looking at the goal of mastery, 2.5% of the nurses (*n* = 9) and none of the nursing students scored 100%.

Grandell-Niemi et al. (2005) reported that mathematics are important for nurses with 50% of the nurses and 40% of the students reporting that they often calculate at work. Although the participants did not find math easy, they did state it was interesting, yet found their skills lacking. The calculations that both RNs and students struggled with are problems that are more difficult to conceptualize, such as the dilution of solids and the concentration of liquids. Additionally, in this study, RNs outperformed students. With their on-the-job experience, it is reasonable to think that conceptualization of medication administration would have been easier for practicing RNs. Combining these two key findings led to the argument that conceptualization of medication mathematics is important. Thus, the researchers asserted that further research on mathematical learning about how the mathematical knowledge of nurses and students is developed was needed.

Two primary limitations to this study by Grandell-Niemi et al. (2005) included the response rate and the instrument. The investigators claimed that the response rate was lower than expected and expressed concern that those with poor math ability may have not chosen to participate, thus, skewing the results as those who did respond may have been more motivated and therefore more knowledgeable about math. The researchers reported anecdotally that some nurses stated they knew their math skills were subpar so they choose not to participate. Second, the researchers did not report on the construct validity of the MCS instrument, and thus, it was possible that this was not a valid instrument.

The numeracy skills of nurses and nursing students have been found lacking in a variety of studies. Diving deeper into this phenomenon, two studies (Harvey et al., 2010; Pierce et al., 2008) are presented here in which the specific calculation types that students struggle with were explored. Harvey et al. (2010) examined the mathematic ability of preregistration nursing students and reported key areas of difficulty, including decimals, formulas, and fractions. This study involved a potential sample of 323 first-year nursing students taking a Web-delivered, entry-level numeracy exam. Three hundred and four students participated in the study for a 94% response rate. All students were administered the exam in the same environment under similar conditions.

The instrument presented by Harvey et al. (2010) was a 25-item exam created through collaboration with a multidisciplinary team, including a mathematician who specialized in teaching mathematics to adults and nurse lecturers who teach medication calculations. Items were developed to cover the relevant types of questions needed for medication administration in the clinical setting. Harvey et al. initially conducted a pilot test with 14 volunteers who provided feedback on the exam. The test was then altered and delivered to a full cohort of nursing students (n = 197). The initial pilot test found significant mathematical difficulties among the cohort, and thus, a decision was made to make this exam mandatory. Nevertheless, participation in the research study remained voluntary. Additionally, the researchers intentionally set the pass rate low (72%) to obtain sufficient numbers of students in the passing category to perform statistical analysis.

The results reported by Harvey et al. (2010) indicated that only 19% of students passed at the 72% mark. Citing a normal distribution of scores, (M = 14.45, SD = 3.695), the researchers claimed that students struggled the most with questions relating to decimals, formulas, and fractions. Additionally, this was compounded by questions that had a mixture of these features. The results revealed few differences within the group of students. The researchers first classified students by age into two categories, young (25 and younger) and mature (26 and older) and compared the pass/fail rates of the two groups. They reported their *t* test was not statistically significant. Next, they compared prior mathematic preparation and found key differences in groups with “A” level students outperforming the others. Although these preparatory levels were not equivalent to mathematic preparation in the United States, Harvey et al. (2010) claimed that preparation in math prior to entering nursing school had a significant impact on future medication calculation ability. The third reported demographic comparison was between the genders. The researchers documented 277 females (91%) and 27 males (9%). An independent *t* test demonstrated statistically significant differences favoring the male students ($p = .023$).

This study by Harvey et al. (2010) added to the findings previously reported by Bagnasco et al. (2016), Grandell-Niemi et al. (2005), Jukes and Gilchrist (2006), and McMullan et al. (2010), which all indicated that students struggle with numeracy content including decimals, formulas, and fractions. Harvey et al. (2010) expanded on prior claims of student difficulty in medication calculations with most students (81%) unable to pass at a 72% level. Interestingly, the researchers also claimed that their top-performing students also struggled with math.

When we further look into student difficulty with decimal numbers, we find that Pierce et al. (2008) explored whether a short diagnostic test and intervention would improve the understanding of decimal numbers for nursing students. These researchers employed a pretest–posttest design by administering the pretest to 100% of nursing students enrolled in all three levels of a nursing program (*N* = 355). They used the Decimal Comparison Test (Steinle, 2004). This instrument is a 30-item instrument based on research in which four primary areas are found to cause difficulty for many students: (a) zero as a digit, (b) the number zero, (c) decimals with repeated digits, and (d) pairs of decimals that were the same in the first two places. The results demonstrated that 56% (*n* = 200) of the students made no errors on the pretest. They found that the errors of the remaining students were confined to seven specific items that shared the following key features: (a) zero as a digit, (b) zero as a number, (c) decimals that are equal if rounded to two decimal places, and (d) decimals with repeated digits that are unequal if rounded.

Next, Pierce et al. (2008) offered a one-hour remedial teaching intervention to all students who did not achieve 100% mastery on the pretest. Initially, only 13 students reported they would attend the intervention, so the researchers altered the intervention and opted to include this content during a mandatory class session (*n* = 120). They then administered the posttest 12 weeks later to determine whether the students retained the information. Students also completed a brief survey about their experiences. Of those who completed the delayed posttest, 103 did not miss any questions on either exam and were thus excluded for the posttest analysis. This left a sample of 96 students who completed both exams with 40 who chose to attend the one-hour intervention and 56 who did not.

The results by Pierce et al. (2008) demonstrated a score increase in the intervention group from (*M* = 4.5, *SD* = 1.9) on the pretest to (*M* = 5.6, *SD* = 1.7) on the posttest, whereas scores from the comparison group remained mostly unchanged from pretest (*M* = 4.8, *SD* = 1.8) to posttest (*M* = 4.9, *SD* = 2.0). Additionally, the outcome of a repeated-measures analysis of variance (ANOVA) indicated that the effect of retesting was not significant (*F* = 3.064, *df* = 1, *p* = .083.), yet the intervention with retesting was significant (*F* = 6.308, *df* = 1, *p* = .014).

Pierce et al.'s (2008) findings expanded on those previously discussed in this section in that most nursing students do not have a deep understanding of decimal numbers. The error rates indicated that students have memory strategies that may be flawed and influence their ability to calculate complex calculations, and thus, they need to develop a solid foundation for solving medication calculation problems. Nevertheless, the investigators found that conceptual teaching of decimals was successful in improving nursing students' conceptual knowledge of decimal numbers and aided in improving their calculation scores. The authors claimed that those who have problems with decimals should have remedial instruction before learning the more advanced medication calculations. The results of this study demonstrated that educational interventions might improve student success on medication administration calculation.

Summary

The numeracy skills of nursing students are problematic. This section explored the key factors relating to medication calculation skills of nursing students and found that nursing students struggle with mathematics and have difficulty reaching 100% on medication calculation exams (Grandell-Niemi et al., 2005; Jukes & Glichrist, 2005; Stolic, 2014). Bagnasco et al. (2016) discovered that the average scores on medication calculation exams ranged from 62% to 69%, leaving much room for error, whereas McMullan et al. (2010) demonstrated that 92% of students and 89% of nurses failed the medication calculation test with a passing mark set at 80%, and only 19% of students passed at the 72% mark in the research conducted by Harvey et al. (2010). Nevertheless, the findings reported by Pierce et al. (2008) demonstrated the efficacy of a one-hour intervention to improve student scores on a decimal calculation test. In total, these findings demonstrated the need for further research as well as identified problematic mathematical areas. In the next section of this review, key strategies to improve the medication calculation performance in nursing students are highlighted.

Teaching Strategies to Improve Medication Calculation

Now that the need to address the calculation skills in nursing education has been explored, work aimed at creating educational interventions to improve the medication calculation performance of nursing students will be discussed.

Coyne, Needham, and Rands (2013) explored the use of multiple teaching interventions on improving medication calculation accuracy in a quasi-experimental study with pretest–posttest design with a convenience sample (*N* = 178) drawn from the second-year undergraduate nursing students at a single university in Australia. For this study, medication calculation exams were completed during a series of nonmandatory medication calculation tutorials. Test one was a ten-item exam in which students were given 30 minutes to complete. Formulas for calculation and calculators were provided. The test was standardized to match the difficulty level expected of students at that level in the curriculum. The researchers collected and reported on demographic information, including age, gender, level of nursing experience, and type of educational program. The second medication exam was completed during the ninth tutorial at the end of the semester. Additionally, students were asked to complete a questionnaire asking which parts of the tutorials were most helpful.

The intervention for this study by Coyne et al. (2013) involved a series of nine tutorials. Tutorial one included information on decimals and basic mathematics skills. The next four tutorials included guided practice with case studies and formulas where students worked through varying mathematical calculations. For these tutorials, students worked through problems on oral and intravenous medications. They were taught formulas for oral medication dose, parental medication dose, intravenous dose, and weight-based formulas. They then had two weeks of clinical practice. After the clinical practice, students had three additional tutorials with case studies designed to link the clinical setting to didactic instruction. These tutorials were also focused on patient safety as well as on identification of medication errors. The final session was the posttest.

The study participants included 143 females (92%) and 13 males (8%) with 103 reporting no prior nursing experience (66%). Coyne et al. (2013) identified n = 119, 76%, as domestic students; n = 33, 21%, as international students; and n = 2, 2%, as indigenous students. The researchers claimed these students were representational of the typical demographics in their region. The primary findings demonstrated an improvement in student scores on a ten-item exam from pretest (M = 7.05, SD = 2.6) to posttest (M = 9.45, SD = .9, $t(104) = –10.8$, $p < .0001$ with a large effect size ($\eta^2 = .7$).

Student scores improved from test one to test two, and Coyne et al. (2013) inferred the tutorials were effective. Nevertheless, it was difficult to ascertain whether improvements were a result of the other instruction provided to students over the course of the semester, the exposure to patients in the clinical setting, or the instructional tutorials.

Interestingly, after nine instructional sessions, students continued to struggle with key question types. For the posttest, 15% of the students missed the intravenous question and 27% missed the weight-based dosing questions. Coyne et al. (2013) claimed that the primary reason for failure on test two was incorrect use of formulas and, thus, asserted the need to solidify their selection and use into the teaching of medication calculation. Given that all of the students missing questions on posttest two used the wrong formula and the tutorials were based on teaching of formals, however, a different method for solving may be in order.

Coyne et al. (2013) presented the use of a series of instructional tutorials aimed at improving the mathematical ability of nursing students. The investigators claimed that the teaching techniques were responsible for the improved scores on test two. Nevertheless, after a full semester of teaching and experience in clinical, students should have improved without this intensive teaching. No comparison group was presented, however, and several students did not attend either or any of the tutorials. A comparison of scores by number of tutorials attended would have been useful in determining whether the intervention was indeed effective. Additionally, the researchers did not report the number of students who achieved mastery as 19 students (15%) missed the intravenous questions and 33 students (27%) missed the weight-based questions. It was clear that a large portion of students did not master this exam. In a climate where each error is a potential medication administration error, these results are alarming.

Ramjan et al. (2014) reported on educational strategies designed to improve numeracy skills in nursing students in a mixed-methods study in which they employed purposive sampling. The sampling pool consisted of 628 nursing students where 390 chose to participate for a 62% participation rate. The sample consisted of 327 females and 63 males. The researchers conducted a seven-step intervention to improve the numeracy outcomes of the students. The first intervention was a series of online practice quizzes designed to prepare the students for the exam. Next, three simulated medication calculation scenarios were incorporated into a regularly scheduled class. Step three was the first attempt on the medication calculation exam. For this exam, the investigators stressed that this exam was contextualized to make it more realistic for the students, yet they did not describe how they contextualized the exam nor did they provide sample questions. This exam was administered during week three of the semester. For step four, the investigators provided targeted remediation workshops for students who did not pass the first exam. These workshops involved a ratio of two to three lecturers to 20 students and included one hour of didactic remediation. The researchers did not report on the content or nature of the workshops. Next, step five was retesting of the students who were unsuccessful in step three. Step six involved a hands-on remediation workshop with a staffing ratio of one to two lecturers to ten students. The researchers did not report on the structure or content of this intervention. The final step was the final medication calculation examination.

The results reported by Ramjan et al. (2014) indicated no statistically significant difference between those who participated and those who did not when comparing age, gender, and percentage of international students. By using a backward stepwise conditional logistic regression analysis, the researchers reported the Pearson chi-squared scores as follows: Enrollment status (international) (p = .017), previous mathematic education (p = .013), online practice quiz attempts (p = .016), overall online quiz grades

($p < .001$), and perceived confidence were predictors of success on the medication calculation exam ($p < .001$).

After exam one, the students who failed ($n = 95$) were given a remedial support session. Of those that attended, 70% passed ($n = 63$), yet Ramjan et al. (2014) did not report the threshold score for passing. Thus, it is impossible to determine whether these rates infer 100% mastery or a lower threshold. The researchers reported that five students did not attend the remedial workshop and, of those, all failed. For the third attempt, 32 students needed to take the third exam. Of those students, 26 attended the final workshop and all passed the final test, whereas of the six students who did not attend the workshop, one did not pass. The researchers did not report how many other interventions were attended by those who passed on the third attempt. They did report that the online quizzes were successful as a first-pass support strategy but not effective for the less independent students who needed face-to-face support. Finally, the researchers reported that after the final hands-on workshop, 100% of students attending this workshop passed the exam. Nevertheless, these students had been exposed to several different strategies, so it is difficult to ascertain which strategies were successful.

Ramjan et al. (2014) demonstrated the effectiveness of a multiple step program in improving nursing students' medication calculation scores. Through remediation, as well as through case-based scenarios and hands-on work, the researchers demonstrated student success. As this intervention occurred in steps over the duration of a semester, however, it was difficult to determine which steps were most effective.

Wright (2007) reported on a study aimed at exploring strategies to improve the medication calculation skills of nursing students. A pretest–posttest design was employed with a convenience sample (*N* = 71). In this study, students took a medication calculation exam with 30 items on the first day of the course. Then, throughout the semester, the instructor provided various strategies aimed at improving students' performance in medication calculation. The investigator developed a series of five interventions. First, the researcher created an online math tutorial that covered areas known to be problematic such as place values, decimals, fractions, percentages, and multiplying fractions. These tutorials included online quizzes throughout so that students could self-assess their performance. Next, the investigator provided a two-hour lecture explaining formulas and their use. Third, the investigator provided all students with a medication calculation workbook. The investigator did not report on the content of this book but stated that answers were included in the book. Next, students attended a series of practical sessions in the skills lab aimed at linking medication calculation to clinical practice. These sessions included calculations involving drip rates with intravenous infusions and medication dosages involving both ampules and syringes. Lastly, the investigator provided students with a list of resources available to the students for private study.

The retest for these students was the same exam delivered seven months later. Only 44 (62.0%) of students returned the second test as others either left the program or were unavailable on the day of the examination. The results reported by Wright (2007) indicated improvement from the pretest (*M* = 16.5, 55.0%) to the posttest (*M* = 21.5, 71.2%). Indeed, student scores improved from the pretest ($p = .0005$, $t = 11.28$, $df = 43$).

Wright (2007) demonstrated that through multiple methods, student scores improved. Nevertheless, there was no indication as to which interventions aided the students. In addition, the scores remained alarmingly low with only two students achieving mastery at 100%. After a semester of education and clinical practice, it should be expected to have the scores go up, and thus, there is no way to determine whether the increase in scores is a result of clinical practice, the interventions, or a combination of these variables. The use of a comparison group may have aided in determining which interventions were most effective. Indeed, Wright's 2008 work involved such a comparison with these students serving as the experimental group.

Expanding on the 2007 study, Wright (2008) reported on a study exploring the teaching strategies designed to improve retention of medication calculation skills in nursing students in a quasi-experimental study involving two groups (*N* = 172). The groups were divided into a control (*n* = 92) group and an intervention (*n* = 80) group. The researcher did not report on how the two groups were assigned, yet indicated that both groups were drawn from two different cohorts and that the cohorts were mixed within the groups. The exam was a ten-item IV additives test that covers the main medication calculations found in the clinical setting, including dosage of ampules, conversions, drip rates, ratios, and percentages. The pass rate for this exam was set at 100%. This exam was delivered in the third year of the nursing program.

The intervention conducted by Wright (2008) involved a range of strategies designed to improve medication calculation previously described by Wright in 2007 that included a medication calculation skills session, an online tutorial, face-to-face tutorials, a medication calculation workbook, and a list of alternative medication calculation resources that were available in the library.

The results reported by Wright (2008) first indicated that the overall passing rate at 100% mastery was higher for the control group with 85.9% (*n* = 79) of the control group passing and only 75% (n = 60) of the intervention group passing. Thus, for overall mastery, it seemed as though the interventions were not successful. Nevertheless, the overall error rate favored the intervention group. The mean number of errors in the control group was 4.8 as compared with 3.9 for the intervention group.

To note, in the intervention group, ten students mislabeled their answers but calculated them correctly. In total, 14 errors in the intervention group were attributed to improper labeling, which, although important, does not indicate calculation ability. It would have been interesting if Wright (2008) had separated the true calculation errors.

In all, the control group was more able to achieve 100% mastery but the intervention group made less errors overall. The results reported by Wright (2008) showed promise in the strategies used, but further research is certainly needed to narrow down the specific strategies that may be useful in aiding medication calculation competence.

Grugnetti, Bagnasco, Rosa, and Sasso (2014) reported on the use of a dedicated medication calculation workshop among nursing students in a quasi-experimental study with pretest–posttest design. They highlighted the use of a 30-hour workshop over the period of 2 weeks to improve medication calculation skills in (N = 77) nursing students. For this investigation, the researchers designed a realistic clinical setting with patient scenarios and built the medication calculations into the scenarios. This workshop included problem-solving approaches used in solving medication calculation problems. Primary content in this workshop included a description of mathematics, use of a formulary, and how to read medication labels. Next, the investigators instructed students on how to identify medication orders on the chart, identify and use the needed equipment and aids to prepare medications, and how to administer medication through various routes such as oral or intravenous.

Data collection was completed by Grugnetti et al. (2014) through use of two tools: one for demographic collection and the second a math skills test. The math skills test was compiled through a panel of expert trainers and included 30 problems. Students took the exam before and after attending the workshop, were allowed 90 minutes for completion, and were not allowed to use calculators.

Initial results indicated no significant difference for age or nationality. Grugnetti et al. (2014) reported the pretest results on the 30-item exam as (M = 15.96, SD = 4.84) compared with the posttest results (M = 25.20, SD = 3.63). Clearly, the students made significant gains in their ability to calculate accurately, which presumes that the workshop was helpful. Nevertheless, several different factors accounted for this change. Without a comparison group, it is difficult to determine whether these gains were from the workshop or from an additional factor. Future research into use of workshops should include a comparison group.

Summary

Most of the studies reviewed implemented multiple step interventions to improve student performance on medication calculation exams (Coyne et al., 2013; Ramjan et al., 2014; Wright, 2007, 2008). These interventions included numeracy remediation, quizzes, case studies, and contextualized instruction. Additionally, the researchers did not state teachings on specific problem-solving methods such as dimensional analysis. Although the results of these studies demonstrated some improvement in students' scores, the students remained shy of achieving mastery at 100%. Moreover, as each of these studies included multiple interventions over the course of a semester, it was unclear as to which interventions were most effective. In one study, the authors reported on the use of a dedicated medication calculation workshop as being effective in improving nursing student medication calculation performance. In the next section, e-learning will be explored to determine whether this is a potential delivery system that will aid in improving medication calculation competence.

E-learning

An exploration into e-learning was completed to determine the efficacy of providing the medication calculation intervention in person versus in an online format. A description of the literature is provided relating to e-learning for teaching medication administration. In a systematic review and meta-analysis, Lahti, Hätönen, and Välimäki (2014) explored the impact of e-learning on student nurses' knowledge, skills, and satisfaction and reported that e-learning is not a superior method to traditional learning methods. Various studies that support this claim will be highlighted.

First, Van Lanker et al. (2016) explored the effectiveness of an e-learning course as compared with a face-to-face lecture on medication calculation in a stratified, clustered, quasi-experimental study conducted in Belgium that involved random selection of seven schools with 189 students in the intervention group receiving e-learning and six schools with 222 students in the control group receiving face-to-face instruction. The samples were stratified in an attempt to keep both groups balanced by school type as in Belgium there are two different types of schools: vocational and bachelors.

The intervention was an e-learning course on medication calculation that was 120 minutes in length (Van Lanker et al., 2016). This e-learning course was developed to address key areas that have been found problematic in the literature and in conjunction with the specific competencies expected of registered nurses. The course included the following content: (a) medication calculation, (b) calculation of doses such as infusion rates, (c) general practice, and (d) case-based practice. The content and design for the course was developed by a researcher and evaluated by an interprofessional team of experts. The course was Web based to enable student access. All students received course access for 120 minutes during a scheduled nursing course as well as throughout the semester.

The control group received a face-to-face lecture typical to this nursing program. The experiment involved a pretest, posttest, and then a delayed posttest three months later using a researcher-created medication calculation test (MCT). The MCT was created through use of the literature, and then Van Lanker et al. (2016) employed a Delphi procedure with experts to improve the test items. Next, they conducted a pilot study. The final instrument was a 16-item exam in which students were provided 30 minutes for completion. The scoring was one point per question. The use of calculators was allowed.

Descriptive analysis included frequencies, means, and standard deviations and demonstrated no significant difference between groups for age, gender, nursing degree, subjective computer skills, and access to a home computer. Nevertheless, there was a significant difference between the groups relating to secondary education. Next, Van Lanker et al. (2016) presented pretest data demonstrating no significant differences between the two groups with the control scoring (M = 11.68, SD = .21) out of 16 and the intervention group scoring (M = 11.53, SD = .22) on the 16-item exam. They reported the pretest mean difference between group scores was not significant .15 (95% [confidence interval [CI] –.47–.77, $p = .64$).

Key findings reported by Van Lanker et al. (2016) indicated that both groups improved, yet the control group improved more than the intervention group. A linear mixed-model analysis revealed a significant difference in medication calculation score between the intervention group and the control with a mean difference of .87 at the first posttest (95% CI .37–1.38; $p = .001$) and 1.37 for the second posttest (95% CI .77–1.96; $p = .0001$). The results of this work demonstrated that medication calculation courses had a positive effect on medication calculation performance for prelicensure nursing students with more improvement shown with face-to-face instruction when compared with e-learning.

Further exploring e-learning into the more complicated math seen in pediatrics, Lee and Lin (2013) reported on their work evaluating the effectiveness of an e-learning program on pediatric medication safety in a pretest–posttest intervention study with historical comparison. The sample for this study was drawn from the spring 2011 cohort as the comparison ($n = 80$) and students from the fall 2011 and spring 2012 cohorts as the intervention e-learning group ($n = 269$). The comparison group received the traditional instruction via lecture, and the intervention group was provided both the traditional lecture and access to a series of online learning modules.

Lee and Lin (2013) developed the online modules through a review of the literature, discussion with faculty, and students. The program was specifically designed to help students integrate content from multiple subjects and apply them to patient care. The online program was divided into eight specific modules that included (a) basic equipment related to pediatric medication administration, (b) pediatric medication routes, (c) principles of medication administration to children of varying ages, (d) medication dosage calculation, (e) educating parents about pediatric medication safety, (f) pediatric medication errors, (g) resources about pediatric medications, and (h) orientation to the clinical settings. These modules were available asynchronously so that students could work at their own pace and review the content as needed. Additionally, the researchers piloted the modules with seven students to ensure they were understandable and user friendly.

The instrument was a 50-item scale developed by Lee and Lin (2013) for this study. The instrument included 30 knowledge-based items relating to pediatric medication administration, whereas 20 items were specific to medication calculation. Each item was scored as two points with a total possible score of 100. The researchers reported the content validity to be over .80 and a Kuder–Richardson 20 score of .90 for the pilot test (N = 39). Additionally, the researchers created an evaluation form to determine how helpful the e-learning program was.

The initial descriptive statistics reported by Lee and Lin (2013) demonstrated differences between the two groups for age, nursing program, and graduation from a junior college. Nevertheless, they also demonstrated no significant differences between the groups on pretest, (t = 1.76, p = .080), posttest one (t = 1.10, p = .273), or posttest two (t = 1.57, p = .121). After controlling for age, nursing program, and having graduated from a junior college, however, the researchers reported a significant difference between the groups favoring the intervention group.

Key findings from Lee and Lin (2013) indicated that scores improved for both groups after they completed the clinical practicum, yet there was greater improvement in medication calculation for the intervention group when controlling for various factors. It would have been interesting to compare two groups who received an equal amount of instruction as the e-learning group had this instruction as extra and all groups received the base instruction. As a result, it was difficult to determine whether the improvement in scores was related to the format of instruction (e-learning) or to the extra time.

Further exploring the efficacy of e learning, Maag (2004) reported on the effectiveness of an interactive multimedia-learning tool on nursing students' math knowledge and self-efficacy. This study involved prelicensure nursing students at two universities in Northern California (N = 96). For this study, four groups were created: (a) text only, (b) text and images (TI), (c) text and images on a computer (TIA), and (d) text, images, and interactivity (TIAI) on the computer. For this study, the investigator created four different treatments that were one hour in duration. The first treatment group had a text-based instrument that was 24 pages long. This instrument included content on mathematical structures, metric and apothecary measurement conversions, and medication dosage calculation instructions. Next, the second group (TI) read the same modules enhanced with images. The third group (TIA) read the same modules presented on a computer screen. Lastly, the fourth group (TIAI) viewed the modules via an interlinked Web page where the modules had text, image, animation, and interactivity.

Two instruments were used for this study. First, Maag (2004) developed the math test (25 items) in conjunction with the literature. Professors of nursing and mathematics then reviewed the instrument. The researcher reported a test–retest reliability coefficient ranging from .77 to .82. Next, to measure self-efficacy, the researcher used the Mathematics Self-Efficacy Scale (MSES) developed in 1983 by Betz and Hackett.

Additionally, the researcher developed a student satisfaction survey.

For this study by Maag (2004), the measures included mathematical achievement and math self-efficacy one week before the treatment and at a two-week follow-up. The outcomes of the pretreatment math test and the self-efficacy test between the two universities determined no statistically significant differences, so they were combined for further analysis. The postintervention means favor the control group (*M* = 19.08, *SD* = 3.69) over the intervention group (*M* = 17.57, *SD* = 3.52) on this 25-point exam. The results of the work by Maag, therefore, demonstrated that e-learning might be undesirable for teaching medication calculation.

Thus far, then, the findings from the work on e-learning have not demonstrated success in the teaching of medication calculations to nursing students. Therefore, given these findings by Maag (2004) and those of Van Lanker et al. (2016) and Lee and Lin (2013), in this study, a face-to-face intervention was implemented. Next, an exploration of the research behind using dimensional analysis (DA) to solve medication calculation problems follows.

Dimensional Analysis

Dimensional analysis (DA) is a systematic problem-solving method that has been used in the sciences to solve complicated, multistep calculation problems. The outcomes of the research on nursing education show promise for DA as a solution strategy for complicated medication calculation problems. In this section, current work in DA as a mechanism for teaching nursing students how to perform medication calculations is highlighted.

The result of an exploration of the research demonstrates that dimensional analysis is a useful strategy for solving medication calculations. Early on, Craig and Sellers (1995) examined the effects of DA on the medication calculation abilities of nursing students in a quasi-experimental study using a convenience sample (*N* = 59) obtained from two different nursing schools. They obtained the control group (*n* = 29) from a local community college and the experimental group (*n* = 30) from a diploma program. The researchers hypothesized that the posttest scores of students taught DA would improve at a significantly higher rate when compared with those of the students taught the traditional problem-solving methods. Second, they hypothesized that students in the experimental condition (DA) would have higher posttest scores overall.

Craig and Sellers (1995) employed a researcher-generated instrument comprising 20 medication calculation problems created through a review of existing exams and faculty review of the instrument. The researchers reported a split-half reliability of .714. It was unclear as to why they performed the split-half reliability as mathematical items typically vary in complexity.

The two-hour educational intervention taught students dimensional analysis. The instructors first explained the process of DA and then demonstrated its use starting with simple problems and working into problems of increased complexity. They introduced the concepts behind each problem type and ensured students had ample time to practice prior to moving on to more complicated problem types. Additionally, Craig and Sellers (1995) provided students a take-home workbook to reinforce content throughout the duration of the semester. This workbook included several practice problems and answers but did not indicate the problem-solving method to be used. The control group received traditional instruction (ratio/proportion instruction solutions and dose/dose on hand methods) and received the researcher-developed workbook to ensure results were not biased toward the extra practice time provided by the workbook.

Craig and Sellers (1995) administered the pretest to both groups before medication administration and the posttest in the last month of the semester. The researchers allowed both groups to use a calculator and instructed them to show their work. Additionally, they provided both groups with a conversion table and a list of common abbreviations for use during the exam.

Craig and Sellers (1995) compared the mean differences between the two groups. The experimental group means on the 20-point exam (M = 5.167, SD = 4.504) for pretest and (M = 14.300, SD 4.721) for posttest demonstrate lower mean scores when compared with the control (M = 11.138, SD = 3.861) on the pretest and (M = 15.069, SD = 2.777) on the posttest. Next, the researchers performed an independent-samples t test of mean differences between the two groups and demonstrated a significant difference in score improvement favoring the experimental group ($\alpha = .05$, $p = .00001$).

As a result, Craig and Sellers (1995) demonstrated that DA is helpful in aiding students in how to solve medication calculation problems and can make up the differences between groups of varying abilities. A primarily limitation with this study was that the control group and the experimental group were very different. The intervention group students attended a diploma-nursing program, whereas the control students are enrolled in an associate degree program. The two types of programs were very different and required a significantly different level of mathematics preparation prior to program entry. Therefore, although the experimental group improved significantly more than the control group, it was not clear whether this is from the intervention, the type of nursing program the students attend, or simply from nursing education as a whole as the students had an entire semester of nursing education between pretest and posttest.

Rice and Bell (2005) further developed the research on DA in nursing school in a pilot study by exploring both numbers of errors and levels of student calculation ability confidence in a study of senior nursing students enrolled in their first clinical course (N = 107). At the beginning of the semester, students completed the normal course preclinical medication calculation quiz and a questionnaire asking whether they have used DA, their confidence in solving calculation problems, and demographic information. Students were then invited to participate in a DA workshop. Those who participated (n = 30) were invited to a 1.5-hour DA instructional session. For this instructional session, the instructors used problems typically found in the clinical setting, initiating instruction with simple calculations and moving on to complex calculations once students demonstrated mastery of the simple calculations. After the course, the researchers provided students with a 20-item practice test with an answer key for additional practice. One week later, the students took a 15-item posttest without aid of calculators.

Rice and Bell (2005) administered an end-of-the-semester survey to determine what effect using DA had on student confidence and ability to solve medication calculation problems. Dosage calculation questions from the preclinical quiz, instructional session posttest, and the three usual course examinations were compared for accuracy and type of calculation error (conceptual, computation, and conversion). These exams all included questions on oral, intramuscular, and intravenous medication calculation.

Rice and Bell (2005) reported that from the beginning of the semester survey that

25% (27) of the students indicated that medication calculation was confusing and stated an inability to memorize formulas as a key factor. Furthermore, the most common reason students gave for being unable to calculate correctly was an inability to set up the problem and difficulty remembering the formula.

Interestingly, the intervention group (*n* = 30) scored less on the preclinical quiz (79%) when compared with the 77 students who chose not to attend the DA workshop (93%), yet this group outperformed these students on postinstruction exams 92% compared with 90% (Rice and Bell, 2005). Although the differences in scores between these groups were significant (*p* = .00001) at pretest (favoring the comparison group), the posttest scores were not significant, which indicates stronger gains in the intervention group.

Lastly, there were differences between error types with the intervention group making more calculation errors (75%) than the control group (42%), yet the intervention group made less conceptual errors (20%) when compared with the control (56%). This led Rice and Bell (2005) to conclude that DA may help students close the gap on conceptual understanding with the computational error gap potentially narrowed through calculator use. Although this study was limited to a convenience sample in a single university, its findings lend useful information in the development of medication calculation programs that could be used at similar universities.

Greenfield, Whelan, and Cohn (2006) added to the work on DA in a study designed to reduce medication errors in a quasi-experimental pilot study of nursing students enrolled in a suburban New York university. The researchers expected to find that students in the DA group (*n* = 39) would solve medication calculation problems with greater accuracy than those in the control group (*n* = 26) taught the formula method. The sampling was a convenience sample, and group assignment was based on the student cohort with the two groups attending the program one year apart. Both groups had the same teacher for this course, and the first four weeks of instruction were the same with the exception of the problem-solving method. The instructor administered the medication calculation exam in the fifth week of the semester. The instrument was a 25-item exam traditionally used in this course. Calculators were permitted, and students had 50 minutes to complete the exam.

Data analysis involved performing *t* tests of student's grade-point average (GPA) and biophysical science grades to determine group equivalency. No statistically significant differences were found. The scores favored the experimental group (*M* = 92.20%, *SD* = 6.2%) as compared with the control group (*M* = 86.92%, *SD* = 14.5%). Next, a *t* test revealed these scores were statistically significant (*p* = .05). Interestingly, the control group's GPA and grades were higher than those of the experimental group. Although these findings reported by Greenfield et al. (2006) were not statistically significant, they may indicate the gains in the intervention group were larger than reported.

Koohestani and Baghcheghi (2010) explored the use of DA in their experimental study aimed at comparing the effects of DA and formula on rapid and sustained learning of nursing students. This study involved sampling nursing students in their third semester and randomly assigning them to two groups (*N* = 42). Both groups had the same instructor, took the same medication calculation exam, and were not allowed to use calculators. The researchers created the exam in conjunction with seven other academics and reference materials found in the literature and reported the Cronbach's alpha for the pilot at .81. Students took the same exam before the intervention, immediately after, and three months later.

Koohestani and Baghcheghi (2010) also reported descriptive analysis of frequency, percentage, mean, and standard deviation for demographic data and cited that the sample was 71.4% female divided evenly between the groups. The researchers presented the means and standard deviations for the control for the 20-point exam at pretest (M = 4.47, SD = 2.52), posttest one (M = 17.42, SD = 1.80), and posttest two (M = 14.28, SD = 1.82) and the experimental group on pretest (M = 3.90, SD = 3.06), posttest one (M = 17.04, SD = 2.06), and posttest two (M = 16.76, SD 1.94), demonstrating significant improvement for both groups compared with the pretest. Next, an independent-samples t test between the groups demonstrated no difference on pretest (t = .066, p > .05) or posttest one (t = –.630, p > .05) but a statistically significant difference on posttest two (t = –4.460, p < .05). Additionally, when looking at mastery, 3 (15%) of the students in the intervention group earned 100%, whereas in the control group, none did. These findings led the researchers to claim that the rate of decline in scores for the control group exceeded that of the experimental group. Thus, the learning for the experimental group was more stable when compared with that of the control group. Based on these findings, Koohestani and Baghcheghi suggested that students be taught DA. Nevertheless, they expressed concerns over the overall lack of mastery at the 100% mark. Given that the purpose behind the arithmetic was to determine the correct dose of medication, mastery at 100% was the goal in this study; very few students reached that mark. Therefore, the study authors suggested ongoing education, assessment, and reinforcement of information relating to medication calculation.

Further exploring the efficacy of DA for medication calculation, Kohtz and Gowda (2010) evaluated DA versus conventional methods such as use of formulas to prevent medication calculation errors among undergraduate nursing students. To obtain a large enough sample size, this study was conducted over the course of two years. Each group was a cohort of nursing students attending one of four semesters in either the spring or the fall of year one or year two. Students participated in the study for a single semester, the first of their junior year. During this semester, all students received medication calculation instruction. The control group was taught conventional methods such as use of formula and ratio/proportion, whereas the intervention group was taught DA. The content was delivered over the course of the respective semester for all four groups. Additionally, the researchers had clinical faculty take a 90-minute tutorial on DA such that they could reinforce this problem-solving method in the clinical setting.

The instrument designed by Kohtz and Gowda (2010) was a 24-item tool with a 90% passing mark. An ANOVA demonstrated no significant difference for age, yet a significant finding for GPA indicated that the GPA for the control group was significantly higher than the GPA for the experimental group. The mean scores for the two groups demonstrated no significant difference between the DA group (M = 20.92, SD = 4.252) and the control (M = 20.42, SD = 4.414).

Although the results reported by Kohtz and Gowda (2010) did not favor DA, they did demonstrate that DA was at least as good as the conventional instruction. Nevertheless, there were several confounding factors in this work. First, although the researchers educated clinical faculty in DA, it is not clear whether they indeed supported

DA as a solving technique throughout the semester. Second, the GPA for the DA group was significantly lower than for the control group, which could have also influenced the scores. In the end, even though DA may have proven useful, there is still significant work to be done as the results of this study demonstrated that after an entire semester of instruction, only 63% of students passed at the 90% mark. Clearly, there is a need to develop meaningful and effective learning experiences to promote accurate medication calculation among students.

Finally, Koharchik, Hardy, King, and Garibo (2014) also explored the efficacy of dimensional analysis by investigating the various approaches used to improve nursing student medication calculation proficiency. The authors reported on student use of DA for medication calculation. They taught DA to all students in the fall of their junior year. In the spring, Koharchik et al. provided students with the following three-item survey: (a) Did you use DA prior to junior year? (b) Did you find DA useful? (c) Will you use it again? The results indicated that 48 (62%) students used DA for solving medication calculations, 74 (96%) found this system useful, and 71 (92%) will use it again. Although Koharchik et al. did not investigate the effectiveness of DA, they did find that students find DA easy, useful, and a logical method for medication calculations, which supports its use as a tool in nursing education.

Overall, the findings from the work on use of dimensional analysis to solve medication calculation problems are promising. Craig and Sellers (1995) demonstrated that improvement in medication calculation scores could be obtained through a two-hour DA teaching intervention. Rice and Bell (2005) further determined that a single workshop teaching DA increased student scores especially in students who were struggling at the beginning of the semester with the DA group making more calculation errors and less conceptual errors. Moreover, the findings reported by Koohestani and Baghcheghi (2010) and by Kohtz and Gowda (2010) showed that DA was as effective a problem-solving method as alternative teaching strategies, and Koohestani and Baghcheghi (2010) demonstrated the power of DA on maintenance as students in their study had a smaller decline in scores on the second posttest when compared with those in the control group. Lastly, the findings reported by Koharchik et al. (2014) indicated that students find DA useful and easy to use once understood. For these reasons, in this research study, DA was chosen to be the problem-solving method.

Schema Theory

Schema theory shows promise in improving the medication calculation education of nursing students. A schema provides the problem-solving structure needed to solve complex problems (Powell, 2011). By providing a set schema for medication calculations, it is possible to provide students with the needed structure to solve math problems accurately.

Three primary research streams have developed schema-based instruction (SBI) in mathematics. First, Jitendra and colleagues' work spans over a decade and they provide a foundation for understanding the use of SBI in children (Jitendra, Dupuis, et al., 2013; Jitendra, Griffin, et al., 2007; Jitendra, Harwell, et al., 2015; Jitendra, Star, Dupuis, & Rodriguez, 2013; Jitendra, Star, Rodriguez, Lindell, & Someki, 2011; Jitendra, Star, Starosta, et al., 2009). Next, Fuchs and colleagues (Fuchs, Fuchs, Finelli, Courey, & Hamlett, 2004; Fuchs, Fuchs, Prentice, et al., 2004) developed the concepts of schema building in elementary students and explored specific educational strategies to improve transfer. Last, Kalyuga (2013) and Blissett, Calvalcanti, and Sibbald (2012) demonstrated the efficacy of SBI in university settings. These three areas of research are discussed in more detail in the next section.

Schema-based instruction

Jitendra et al. (2007) reported on research comparing a single instructional strategy, SBI, with multiple other teaching strategies in third-grade students' mathematical problem-solving. The primary goals of this work included how (a) to determine the effectiveness of SBI compared with multiple teaching strategies, (b) to see which strategy maintains better over time, (c) to determine whether the effects transfer to a statewide exam, and (d) to determine whether the computational skills improve from pretest to posttest.

This study by Jitendra et al. (2007) initially involved 94 third graders in five classrooms, yet six students dropped out as a result of either moving or missing one of the exams, leaving a final sample of 88 students. The sample was stratified to ensure a similar mixture of student demographics and abilities in each group, and then the students and teachers were randomly assigned to SBI treatment or the control.

For this study by Jitendra et al. (2007), all students were taught math five times a week using the district-adopted textbook. All students were taught to solve one-step and two-step word problems that set the foundation for the change, combine, and compare word problem types that were to be taught using SBI. The SBI instruction included instruction on solving one-step and two-step problems including a problem schema solution. For the problem schema phase, students were taught to identify the specific problem schema (change, group, or compare) and to represent the features on a schematic drawing. Students learned to identify relevant information and to discard unrelated information.

The second instructional phase involved problem solutions. During the solution phase, students learned to solve problems and were taught a four-step strategy: (a) Find the problem type, (b) organize the information, (c) plan to solve the problem, and (d) solve the problem. Instruction during the solve phases for all problem types included instruction on the reasonableness of the answer, asking students to think critically about the answer and to revisit the diagram if it did not make sense (Jitendra et al., 2007).

Jitendra et al. (2007) used several different measures in this study. First, participants completed the Stanford Achievement Test, ninth edition (SAT-9), at the beginning of the study to assess initial mathematics achievement. The SAT-9 is a group-administered, multiple-choice standardized exam with two different subgroups relating to mathematics: the SAT-9 MPSS and the SAT-9 MP with a reported internal consistency and reliability coefficients of .83 and .80. The second measure was a researcher-designed mathematical word-problem-solving test that included 16 problems selected from commonly used textbooks. Scoring included one point for the correct answer and one point for the correct number model. Cronbach alpha results were reported for the pretest, posttest, and maintenance test as .84, .86, and .86, respectively. Additionally, concurrent validity with the SAT-9 MPS was .64, .65, and .71, whereas the concurrent validity with the SAT-p MP was .57, .53, and .51, respectively. The final measure was the mathematics subset of the Pennsylvania System of School Assessment (PSSA). The PSSA is a group-administered, standards-based, criterion-referenced assessment used to measure student mathematic achievement. Cronbach's alphas in the technical manual were reported above .90. Last, as a result of the nature of the intervention, treatment fidelity was measured to ensure standardized instruction in both groups.

Initially, Jitendra et al. (2007) performed a one-way ANOVA and found no statistically significant differences between groups for age. They also performed a chi-square analysis and found no statistical significance for gender, ethnicity, and socioeconomic status. Next, the results of the analysis of covariance (ANCOVA) applied to the posttest scores demonstrated a statistically significant main effect for group [$F(1, 86) = 5.96$, $p = .02$, $\alpha = .05$]. Both the SAT-9 MPS [$F(1, 84) = 31.19$, $p < .000$] and the SAT-9 MP [$F(1, 84) = 7.56$, $p < .01$, $\alpha = .05$] were significant covariates, so they adjusted the mean scores and found a Cohen's *d* medium effect size (.52), demonstrating the SBI group significantly outperformed the control. Additionally, the researchers reported a statistically significant effect for group on the maintenance test scores [$F(1, 84) = 10.44$, $p = .002$, $\alpha = .05$] with the SBI group outperforming the control (effect size = .69).

The results of the ANCOVA applied by Jitendra et al. (2007) to the PSSA posttest scores demonstrated a statistically significant effect for group [$F(1, 83) = 9.20$, $p < .001$, $\alpha = .05$] with the SAT-9 MPS [$F(1, 84) = 25.79$ $p < .001$, $\alpha = .05$] significant and the SAT-9 MP not significant [$F(1\ 84) = .99$, $p = .32$ $\alpha = .05$]. Postadjustment, students in the SBI condition ($M = 1{,}410.05$, $SD = 192.83$) scored higher than did those in the control ($M= 1{,}280.66$, $SD = 288.40$) condition with a medium effect size (.65).

The primary purpose of this study was to assess the effectiveness of SBI on both acquisition and maintenance of third-grade students' problem-solving ability in math, and it was found that SBI was more effective in enhancing students' word-problem-solving skills. Key findings promoted the use of SBI for improving mathematical ability on both near and future exams. Additionally, these findings indicated that SBI was effective for invoking transfer to other question types that is a crucial feature needed when teaching medication administration calculation to nursing students.

Jitendra et al. (2009) continued their trajectory of work with a study aimed at exploring the role of SBI in improving ratio and proportion learning among seventh-grade students. They examined these strategies for students of varying abilities and expanded known research by including foundational concepts (ratios, equivalent fractions, rated fractions, and percentages) that were needed to solve ratio/proportion problems. Additionally, the researchers introduced the concept of adding multiple solution strategies and flexible application of these strategies to their instruction. The final change made for this study was to have the instruction provided by classroom teachers as opposed to by research assistants. The second stated purpose for this work was to assess maintenance over time. Lastly, the researchers aimed to generalize the results to a state mathematics test.

For this study by Jitendra et al. (2009), the sample was drawn from eight different classrooms in a public urban school. Students were grouped by ability into classrooms, and the classes represented varying levels of achievement that were grouped into *high*, *medium*, and *low*. The honors classrooms were excluded as they were learning advanced content. The researchers randomly assigned two sections of average, one high- and one low-ability classroom to both the control and intervention groups. The sample included students who were present for both the pretest and the posttest (N = 148).

Students in both conditions received instruction on ratio and proportion during the regularly scheduled mathematics instructional period (Jitendra et al., 2009). For the SBI condition, the researcher-designed unit replaced the standard unit. To ensure consistency of instruction, scripted lessons were prepared. Additionally, students were taught a four-phase, problem-solving technique (FOPS) that included *F*: find the problem type, O: organize the information using the diagram, P: plan to solve the problem, and S: solve the problem. The control group received the standard instruction outlined in the district-adopted curriculum. The lessons began with a real-life application of the mathematics and then involved several worked examples to expose students to the targeted problem types.

The instruments included a mathematical problem-solving test designed by Jitendra et al. (2009) with questions pulled from standard mathematics textbooks. This test was given before instruction, immediately after instruction, and four months later. This test consisted of 18 items. The researchers reported a Cronbach alpha of .73 for the pretest, .83 for the posttest, and .83 for the delayed posttest. Additionally, to test for generalizability, researchers compared student scores on the PSSA mathematics test that was a group-administered, standards-based, criterion-referenced assessment.

Jitendra et al. (2009) reported no significant differences between the two groups for age, gender, ethnicity, meal programs, or special education status. An ANOVA revealed no statistically significant main effect for group [$F(1,142) = 1.10$, $p = .30$]. Nevertheless, there is main effect for ability level [$F(2,142) = 27.69$, $p < .001$], which implied significant differences between the low-, average-, and high-performing students. The results of the ANCOVA applied to posttest scores demonstrate statistically significant effects for group [$F(1,141) = 6.30$, $p = .01$] and ability level [$F(2,141) =$

16.53, $p < .001$]. The pretest was found to be a significant covariate [$F(1,142) = 32.16$, $p < .001$]. The adjusted mean scores demonstrate that the SBI group outperformed the control with a small medium effect size of .45.

The results reported by Jitendra et al. (2009) from the delayed posttest indicated significant effects for group [$F(1, 135) = 8.99$, $p < .01$] and ability level [$F(2,135) = 24.16$, $p < .001$]. The pretest was a significant covariate [$F(1, 135) = 34.06$, $p < .001$]. The adjusted mean scores indicated that the SBI group outperformed the control group with a medium effect size (.56).

The results reported by Jitendra et al. (2009) for the PSSA posttest indicated that there was no statistically significant effect for group [$F(1, 132) = 97.33$, $p = .56$]. A post hoc Bonferroni conversion indicated that the mean PSSA scores were significantly different for ability levels (high > medium > low) but that no significant interaction was found.

This study by Jitendra et al. (2009) replicated and extended the earlier work by Jitendra et al. (2007) on SBI in mathematics with a focus on ratio and proportion problem types. The key findings indicated that SBI is a useful strategy and that SBI is a promising approach to teaching ratio and proportion work problems such as those needed to solve medication calculations in nursing. Additionally, for this study, the benefits of SBI persisted beyond four months and were not mediated by ability level that indicated that SBI may be helpful for students with varying ability levels. These findings indicated that SBI might be a useful strategy for nursing education.

Jitendra et al. (2011) further built on their prior work in a study designed to evaluate the effectiveness of SBI on seventh-grade students' ability to solve problems with ratios, rates, and percentages. For this work, the researchers addressed the limitations of their previous work by increasing the length of the intervention, increasing the length of teacher training, and testing in two different districts that had different mathematics curricula. The purpose of this study was to explore the effectiveness of SBI on problem-solving performance of ratios, rates, and percentages as well as to study the potential information transfer to novel problems. The research questions addressed by this study are as follows: (a) Does SBI lead to improved problem-solving performance as compared with school-based instruction? (b) Are the problem-solving skills maintained over time? (c) Does the effect of SBI transfer to novel problem types? This final research question was crucial for an exploration of methods to teach nurses medication calculation as transfer to the clinical setting is critical and problems of many different types are common.

Jitendra et al. (2011) employed a pretest–intervention–posttest design with a retention test conducted in three schools from two suburban school districts. Six teachers teaching 21 classrooms were randomly assigned to the conditions (SBI; n = 283, control; n = 153). The researchers reported no statistical significance between the groups.

Both groups received instruction on ratio, proportion, and percentage during their regularly scheduled mathematics instruction. Students assigned to the control condition received the regular instruction outlined in the district-adopted textbooks where the researcher-designed SBI program replaced the regular instruction for these modules for the experimental group (Jitendra et al., 2011).

The SBI consisted of a series of 21 instructional sessions that were scripted to ensure instructional consistency with a primary goal to teach students to identify the underlying problem type, use schematic diagrams to represent the problem, and solve the problem with an appropriate solution strategy. Additionally, as an instructional anchor, Jitendra et al. (2011) developed a four-step problem-solving procedure (D: discover the problem type, I: identify the information in the problem to represent the diagram, S: solve the problem, C: check the solution) for the experimental group.

The instrument used by Jitendra et al. (2011) was a 20-item experimenter-designed mathematics test modified from the test used in Jitendra et al. (2009). The coefficient alpha for the test was .68 for the pretest, .80 for the posttest, and .80 for the delayed posttest. Additionally, a researcher-designed transfer test included 18 items developed from the standardized Trends in International Mathematics Science Study (TIMMS), National Assessment of Educational Progress (NAEP), and state assessments. This test included novel and challenging content such as probability. Jitendra et al. (2011) indicated the coefficient alpha for the transfer test was at .70 for the pretest and at .73 for the posttest.

Furthermore, the results reported by Jitendra et al. (2011) indicated that gender, ethnicity, special education status, and free lunch were significant in impacting problem-solving pretest scores. After adjusting for pretest score, the Hedges's *g* effect score of .75 indicated a large effect and favored the SBI group. Interestingly, no significant findings were found for the delayed test or the transfer test.

This work by Jitendra et al. (2011) was aimed at extending Jitendra et al. (2009) by adding in work on percentages, increasing instructional time, including simple interest, providing more professional development to the teachers, and implementing the study in two different districts. The researchers found an initial improvement in student scores using SBI and concluded that with adequate time and teacher training, SBI can influence students' problem-solving performance. The results for extended testing and transfer from their prior work were not replicated as Jitendra et al. indicated that the curriculum sequencing in this study may be a confounding factor and they suggested a replication with a change in the curriculum sequencing that supports this module. Additionally, to aid in transfer, the researchers suggested training of a longer duration might be needed. These findings were important as transfer is a critical element needed when teaching nursing student medication administration because it is desired to have students transfer knowledge from instruction to the actual delivery of medications in the clinical setting.

Jitendra, Dupuis, et al. (2013) continued their work in SBI with this study aimed at improving student's proportional reasoning skills among at-risk, third-grade students in 28 classrooms in 9 schools in a large urban school district in the Midwest. As this work was focused on students with learning disabilities, there is questionable generalization to university-level nursing students. Nevertheless, this work was reviewed as a continuum of the Jitendra et al. research trajectory.

First, Jitendra, Dupuis, et al. (2013) used the school-administered Measures of Academic Progress (MAP) exam to select students whom the exam identified as having at least a second-grade reading level. Next, they selected students in two levels of math ability, high at risk and low at risk (*N* = 125). Next, the researchers randomly assigned students to either the SBI or the control using a random number table. As a result of dropouts for moving or absence, the final sample was 109.

The instruments of measure used by Jitendra, Dupuis, et al. (2013) were the MPS previously described in Jitendra et al. (2007) with the reported alpha in this study of .76, .75, and .80 for the pretest, posttest, and delayed posttest, respectively, and the measures of academic progress (MAP), an untimed, group-administered, norm-referenced, computer-adaptive test of students' academic performance. Mathematics achievement was measured for this study with the third-grade version of this test. The reliability coefficients of this test ranged from .92 to .95.

All students received 60 minutes of mathematics instruction per day with at-risk students receiving differentiated instruction from math tutors in either the control or SBI tutoring groups. On the MPS posttests, the results reported by Jitendra, Dupuis, et al. (2013) indicated a statistically significant treatment effect [$F(1.101) = 8.50$, $p = .004$] with the SBI students outperforming the control students ($g = .46$). Nevertheless, for the MPS delayed posttest, the treatment effect was not statistically significant [$F(1, 101) = 1.06$, $p = .305$]. For the MAP, there was a statistically significant treatment effect [$F(1,103) = 4.34$, $p = .040$] with the SBI students outperforming. The Hedges's *g* effect size was reported as .34. These results indicated that for this intervention, there was no significant effect over time, yet they were able to demonstrate improvement in both initial scores as well as on transfer. The researchers indicated that they felt the sample size was too small to detect effects, and thus, they continued their work in future studies (Jitendra et al., 2015).

Jitendra, Star, et al. (2013) extended the work of the Jitendra, Dupuis, et al. (2013) in a study designed to increase the number of students and to remove the level of direct involvement in the classroom by the researchers. The three questions were as follows: What is the effect of the SBI intervention on seventh graders' (a) problem-solving performance, (b) retention of problem-solving skills over six weeks, and (c) transfer of problem-solving skills?

This randomized, treatment-control, pretest–posttest study by Jitendra, Star, et al. (2013) was conducted in 3 different districts, 6 schools, with 5 teachers, 42 classrooms, and 1,163 students. Treatment included six weeks of instruction in five 45–50-minute classes over six weeks and was divided into four primary sections. The control group received the same length of treatment with the traditional curriculum. The primary measure was a 23-item, researcher-designed exam created from district textbooks that is aimed at measuring student ability to solve problems involving ratios, rates, and percentages (Jitendra et al., 2011). For this study, the reliability estimates were .69, .79, and .82 for the pretest, posttest, and delayed posttest, respectively. A second 18-item, problem-solving transfer test (Jitendra et al., 2011) consisted of items derived from the TIMSS, NAEP, and state assessments and included content not previously taught as a test of transfer.

The results of preliminary analysis conducted by Jitendra, Star, et al. (2013) determined no significant interaction between the treatment variable and pretest scores for any outcome variable. They indicated that students in the SBI condition scored on average 1.48 points higher than did the students in the control condition with a Hedges's *g* effect size of 1.24. For the delayed posttest, students in the SBI condition scored on average 1.17 points higher than did the students in the control condition (g = 1.27). These findings overall indicated that SBI was a useful instructional strategy for improving student scores initially and over time. Nevertheless, the results did not indicate a statistically significant effect for the treatment variable on transfer.

Jitendra, Star, et al. (2013) aimed to demonstrate positive results on transfer with the larger sample size. An *a priori* power analysis was performed, and its results demonstrated that the sample size was large enough to detect large effects. Therefore, this left the researchers to consider that the problems of transfer may relate to the test itself. Additionally, they discussed that transfer may be improved through a longer duration of instruction with an explicit connection to content outside of the instructional domain such as discussed in the work by Fuchs, Fuchs, Finelli, et al. (2004) and by Fuchs, Fuchs, Prentice, et al. (2004).

By building on prior work, Jitendra et al. (2015) increased the sample size of students and teachers to see whether the effects from their prior work hold under varying types of teachers, students, and curricula. The primary research questions were as follows: (a) Will SBI lead to improved proportional problem-solving performance when compared with the business-as-usual instruction control group? (b) Will these increases be maintained at a nine-week interval? (c) Will SBI result in increased achievement on overall mathematical performance after a focused period of time spent on ratios and proportions? (d) Will SBI moderate the effects of student-level background variables on mathematic problem-solving?

Jitendra et al. (2015) employed a prospective randomized cluster design with longitudinal data collection and involved 50 districts, 58 schools, 82 teachers, and 1,999 students. One classroom for each of the 82 teachers was randomly selected to participate in the study. Then each teacher and the participating class (cluster) were randomly assigned to either the treatment (n = 40) or the control (n = 42) condition. The unequal number of clusters was explained as one teacher was unable to attend the training, and thus, she was moved to the control condition before training.

The SBI intervention replaced two units in the normal curriculum for five days a week across six weeks. The SBI program was aligned with the state standards for math and covered the same content taught in seventh-grade classrooms. The instruction by Jitendra et al. (2015) replicated the instruction from Jitendra, Star, et al. (2013).

The primary measures included a 23-item, multiple-choice, researcher-developed exam (PPS) using the released items related to ratio, proportion, and percentage from the NAEP and TIMSS as well as questions from past state exams. This exam also included four short response items that were scored on a 0–2-point scale. The exam maximum score was 31 with a reported moderate reliability using estimated omega reliabilities of .69, .77, and .76 on pretest, posttest, and delayed posttest, respectively. In addition, the 30-item Group Mathematics Assessment and Diagnostic Evaluation (GMADE) standardized exam was used as a norm-referenced standardized assessment to allow Jitendra et al. (2015) to assess student abilities on general math concepts.

The key findings reported by Jitendra et al. (2015) indicated that SBI was a statistically significant predictor of posttest scores with SBI classrooms outperforming control classrooms with a standard effect size of .46. Additionally, the results for the delayed posttest indicated that the treatment variable was significant with a standard effect of .32 *SD*. Next, the researchers reported that SBI was not a predictor of success on the GMADE and did not moderate other variables such a low socioeconomic status, gender, and race on mathematical problem-solving. These results affirmed that SBI was effective instruction and improved student performance on the instructor-designed exam but not on the standardized exam. This is of concern as it is possible that the instructor-designed exam was biased toward the experimental group. Nevertheless, a review of the work on schema enhancing may lead to additional findings.

Schema-enhancing research

The findings reported by Fuchs and colleagues (Fuchs, Fuchs, Finelli, et al., 2004; Fuchs, Fuchs, Prentice, et al., 2004) demonstrate the potential effectiveness of schema induction strategies with elementary students. The primary difference between this research trajectory and that of Jitendra and colleagues (Jitendra, Dupuis, et al., 2013; Jitendra, Griffin, et al., 2007; Jitendra, Harwell, et al., 2015; Jitendra, Star, Dupuis, & Rodriguez, 2013; Jitendra, Star, Rodriguez, Lindell, & Someki, 2011; Jitendra, Star, Starosta, et al., 2009) is that Fuchs et al. explored explicit teaching of transfer strategies.

First, Fuchs, Fuchs, Finelli, et al. (2004) explored the methods of enhancing mathematical problem-solving in third graders with SBI and expanding SBI to add interventions specifically designed to develop knowledge transfer to novel problem types. For this study, the researchers included three transfer features: (a) irrelevant information, (b) combining of problem types, and (c) mixing of superficial features. They called this enhanced instruction “schema-based transfer instruction” (SBTI). They then contrasted expanded SBI against SBTI and the controlled classroom.

Transfer was measured in four different scenarios by Fuchs, Fuchs, Finelli, et al. (2004). Transfer one included problems similar to those that students had previously learned with a new cover story. Transfer two problems varied in format, vocabulary, or question. Transfer three involved the addition of a novel piece of information, combining of problem types, or varying of two transfer features in a novel way. Finally, transfer four was a measure of far transfer approximating real-life problem-solving that differed from the prior problems in many ways, including (a) format, (b) multiparagraph narrative, (c) missing information, and (d) extraneous information. Additionally, for transfer four, they included multiple pieces of irrelevant information and combined all four problems types and six transfer features. The three hypotheses proposed were as follows: (a) Both SBTI groups would perform comparably and outperform the control group on near transfer one and two; (b) the SBTI expanded group would outperform the SBI group on transfer three; and (c) the expanded SBTI group would outperform the SBTI group on transfer four.

This study by Fuchs, Fuchs, Finelli, et al. (2004) involved 24 teachers in 7 different schools stratified to ensure the condition was equally represented between schools. The teachers were randomly assigned to one of three groups: control, SBTI, and expanded SBTI. The sample consisted of 351 children who were present for both the pretest and the posttest. The researchers reported that a chi-squared test revealed that the children in the data set were demographically compatible for age, gender, subsidized lunch status, race, special education status, and English as a second language.

For this study by Fuchs, Fuchs, Finelli, et al. (2004), all students received the base treatment and used the same book and curriculum as designated by the school district. The control group received typical instruction using worked examples, guided group practice, and independent work. The SBTI group treatment included transfer instruction on how to change problems without changing the method of solving. Students were taught how problems can be altered such that the text is different, the vocabulary is different, and it can ask a different question yet be solved in the same fashion. The expanded SBTI included more challenging superficial problem features such as irrelevant information, combining of problem types, and mixing of superficial problem features.

The findings reported by Fuchs, Fuchs, Finelli, et al. (2004) supported hypothesis one in that for transfer one, the SBTI and expanded SBTI students outperformed the control [$F(2, 21) = 126.71$, $p < .001$]. This was followed up with Fisher's least significant difference (LSD) post hoc procedure that demonstrated the control group's improvement was less than that of SBTI (3.69) and expanded SBTI (3.72). Additionally, the Fisher's test demonstrated that the differences between SBTI and expanded SBTI were comparable (.03). Next, for transfer two [$F(2, 21) = 69.37$. $p < .001$], the SBTI and expanded SBTI students outperformed the control with the Fisher's LSD post hoc procedure score of 1.95 and 2.10, respectively, and the differences between SBTI and expanded SBTI were again comparable (.15).

As predicted, Fuchs, Fuchs, Finelli, et al. (2004) demonstrated the superiority of the expanded condition with far transfer. On transfer three [$F(2, 21) = 31.9$. $p < .001$], both conditions outperformed the control SBTI (Fisher's LSD pot hoc = 1.98) and expanded SBTI (Fisher's LSD pot hoc = 2.71), yet the differences between SBTI and expanded SBTI favored the expanded SBTI group (Fisher's LSD pot hoc = .72). Similar findings were discovered for transfer four with the two experimental groups outperforming the control [$F(2, 21) = 16.69$. $p < .001$] with the SBTI (Fisher's LSD pot hoc = .85) and expanded SBTI (Fisher's LSD pot hoc = 1.91). Once again, the expanded SBTI outperformed the SBTI group on far transfer (Fisher's LSD pot hoc = 1.06).

In looking at the development of the medication calculation workshop, these findings reported by Fuchs, Fuchs, Finelli, et al. (2004) indicated that explicit SBTI instruction with attention to varying problem types as well as including all six transfer features might be a useful instructional model. For this study, student performance was enhanced on complex real-life challenging transfer features designed to affect broader schemas for recognizing mathematical problems. Connecting to the real-world scenario of medication administration, the results of this work show promise in teaching medication calculation through enhanced schema-inducing instruction.

Meanwhile, Fuchs, Fuchs, Prentice, et al. (2004) explored SBI in third-grade students. They moved beyond their prior work (Fuchs, Fuchs, Finelli, et al., 2004) and attempted to determine whether the effects of SBI resulted in schema development. If this potential was realized, it could translate into long-term improvement of medication calculation abilities in nurses once an initial schema is taught. The researchers attempted to broaden the child’s schema by presenting problems that do not perfectly fit the already developed schema.

The results of this study by Fuchs, Fuchs, Prentice, et al. (2004) were novel as the use of multiple schemas was introduced as well as the use of expanding schema through superficial features. To develop the superficial features schema further, students received implicit instruction on the many different variables encountered in word problems and how these changes may appear to alter the problem, yet the problem type remains unchanged with the same problem-solving schema. The four superficial schemas Fuchs, Fuchs, Prentice, et al. taught were format, vocabulary, question, and scope. For this study, they asked students to identify the problem type schema as well as the superficial features present.

This study by Fuchs, Fuchs, Prentice, et al. (2004) involved 6 schools in a single geographic region and 24 third-grade teachers and 366 students. The sample was stratified to ensure equal representation of the conditions between the different schools.

Then the teachers were randomly assigned to one of three conditions: control, SBI, and SBI plus sorting. Students were divided into two groups. The control group received the standard instruction on four specific problem types, whereas the experimental groups received instruction on the same four problem types with instructional techniques focused on expanding the problem type schemas as well as the superficial problem features.

The measures were items developed by Fuchs, Fuchs, Prentice, et al. (2004). For immediate transfer, the items were very similar to those seen in class instruction. For near transfer, the items were similar but included a different cover story and one superficial feature. For far transfer, their exam included unfamiliar item types and cover stories.

For problem-solving, the results reported by Fuchs, Fuchs, Prentice, et al. (2004) demonstrated that the control group improvement was less than that of the SBI groups (Fisher's LSD pot hoc = 3.17) and the SBI group plus sorting (Fisher's LSD pot hoc = 3.47), yet the comparison between SBI and SBI plus sorting was not significant (Fisher's LSD pot hoc = .45). Next, for near transfer effects, the control group improvement was less than that of the SBI groups (Fisher's LSD pot hoc = 3.65) and the SBI group plus sorting (Fisher's LSD pot hoc = 3.10) and the comparison between SBI and SBI plus sorting was not significant (Fisher's LSD pot hoc = –.35). Last, for far transfer, the results demonstrated that the contrast group improvement was less than that of the SBI groups (Fisher's LSD pot hoc = 1.55) and the SBI group plus sorting (Fisher's LSD pot hoc = 2.29), and again, the comparison between SBI and SBI plus sorting was not significant (Fisher's LSD pot hoc = .65). The findings indicated support for SBTI as improving the mathematical performance of third graders on immediate, near, and far transfer problems, demonstrating that SBI with explicit teacher instruction had a very large impact as the SBI instruction groups developed stronger schemas relative to the control group.

In an expansion of earlier work, Fuchs et al. (2006) explored the use of real-life mathematical problem-solving in a randomized controlled study. They examined the use of real-life, problem-solving skills as an added benefit to schema broadening instruction. This study involved three different groups with comparable instructional time. The teacher-designed curriculum (control) was followed by the adopted district-wide curriculum. Next, two groups of SBI included one with SBI alone and a second group with explicit instruction on strategies involved in real-life settings.

This study by Fuchs et al. (2006) involved 30 classrooms and 445 students in a single district. The classrooms were stratified to ensure the condition was represented equally among the schools. The teachers were randomly assigned to one of the three demographically comparable groups (control, SBI, and SBI-RL). Each classroom received six 40-minute sessions on general problem-solving strategies. Next, both schema broadening conditions received 30 additional SBI-focused educational sessions on the four problems types as well as explicit instruction on real-life problem-solving skills (for the SBI–RL group only). The control received the same amount of instructional time through the district-based curriculum.

The SBI instruction conducted by Fuchs, Fuchs, Prentice, et al. (2004) was comparable with conducted that by Fuchs, Fuchs, Prentice, et al. (2004). A key feature of this instruction was explicit instruction on the meaning of the work transfer and the four superficial features that change a problem without altering its type or solution. The SBI–RL instruction was identical to the SBI instruction except for one session where students watched videos portraying the real-life problems depicted in the math problems. The teacher then guided students through a structured process. The solving strategies included (a) reviewing the real-life problem to identify relevant information, (b) considering any extra steps that may be needed, (c) identifying important information that comes without numbers, (d) searching for information not in the problem, (e) rereading the question, and (f) ignoring irrelevant information.

The results reported by Fuchs et al. (2006) supported the efficacy of SBI. On the experimenter-designed measures of immediate and medium work-problem transfer, both treatments outperformed the control (Fisher's LSD pot hoc = 3.59–6.84). On far transfer, the experimental groups outperformed the control with effect sizes ranging from .33 to 2.34. Last, the SBI–RL group (Fisher's LSD pot hoc = 1.83) outperformed the SBI group on one of the four measures that potentially demonstrated a benefit of real-world examples; nevertheless, this was not demonstrated on the other three measures of far transfer.

The results produced by Fuchs et al. (2006) were useful in determining a structure for a medication calculation workshop in ensuring that students first build a strong schema(s) for solving the varying types of problems and then explicitly teaching students to identify the irrelevant information in the questions as well as methods to determine that questions that are seemingly different are indeed similar to previously learned problem types.

Further exploring the use of SBI and moving toward university-level students, Kalyuga (2013) worked to enhance transfer in a study designed to see whether SBI improves retention for a task with low prior knowledge learners. For this study, 49 college students with low prior knowledge on water pumps and air conditioning volunteered to participate in this pretest–posttest study. The students were randomly assigned to one of four groups (SBI general to specific, SBI specific to general, non-SBI general to specific, and non-SBI specific to general).

For this study by Kalyuga (2013), students first took a pretest followed by an instructional phase where students read information relating to the specific teaching situation. For the SBI general to specific condition, students were provided hierarchically structured descriptions of the devices that started with a general description and proceeded to a detailed description. These lessons contained explicit general schematic frameworks of the technical systems. The content for the second condition was the same but started with highly detailed information and then moved to a general overview. The non-SBI conditions did not receive schematic framework information. These two groups included those whose instruction started general and then increased in detail compared with those in the second group whose information started highly detailed and then moved to general concepts. The participants had 20 minutes to read the information, and then they took the posttest. The posttest included transfer tasks that were not implicitly stated in the educational materials. The researcher measured pretest scores, posttest scores, and subjective ratings from the participants on the difficulty of the content.

Kalyuga (2013) presented results from a two-way ANCOVA by using pretest scores as a covariate [$F(1,44) = 12.8$, mean square error (MSE) = 32.08, $p = .001$, $\eta^2 = .225$] favoring the two schema-based instruction conditions. SBI outperformed non–schema-based instruction paired comparison $p = .003$ and .02 for the general to specific and specific to general conditions on a 36-item posttest. The researcher presented the following results for SBI general to specific (*M* = 16.38, *SD* = 7.58), SBI specific to general (*M* = 14.23, *SD* = 4.64), non-SBI general to specific (*M* = 11.58, *SD* = 7.24), and non-SBI specific to general (*M* = 7.88, *SD* = 2.57).

The key findings presented Kalyuga (2013) indicated that explicit SBI was beneficial for enhancing learning abilities to deal with newer problems. Additionally, Kalyuga found that there is a possible advantage of presenting general information first as the learners in the general to specific group may experience less cognitive load as compared with those in the specific to general group. These findings were important for the development of the medication calculation workshop used in the study presented here, with the workshop beginning with the general information and then moving into the specific details.

Next, Blissett, Cavalcanti, and Sibbald (2012) studied SBI in medical students in a study of case-based learning with a simulator. For this study, the 53 participants were divided into 14 different groups (to keep group size manageable). The sessions were randomized to control (*n* = 27) or intervention (*n* = 26) with the control receiving the traditional education and the intervention group taught a diagnostic schema. Both instructional frameworks had the same information, yet the schema framework was rearranged to show important connections relating to group diagnosis by key features based on murmur location and timing.

The learning instruction was divided into four key phases by Blissett et al. (2012). Phase one was the learning phase where instructors provided all key materials on murmur diagnosis. Students were to diagnose a heart murmur. The participants then received the correct diagnosis and were provided time to collaborate with peers on the correct answer.

They were then given 15 minutes to review the instructional framework: either traditional or schema. During this time, participants were instructed to discuss their findings with the members of their group. They were then given a 19-item written test that was divided into two key sections identified as structural knowledge and as factual knowledge. The exam included some items covered from the learning phase and some that were not covered in the learning phase (untaught lessons). Next participants had a practical exam with the use of a patient simulator where they needed to identify four different cardiac lesions. Two were taught in the prior session and two were not.

The findings reported by Blissett et al. (2012) indicated that SBI was associated with higher scores in structural knowledge (74% vs. 55%; $p < .0001$) but not in factual knowledge (62% vs. 62%). This result maintained over time with follow-up testing demonstrating similar results on structural knowledge (62% vs. 42%, $p = .001$) but not on factual knowledge questions (52% vs. 48%). Interestingly, SBI was associated with greater diagnostic accuracy (61% vs. 26%; mean difference = 35%, 95% CI 22–47; $t(205) = 5.40$, $p < .001$).

The results reported by Blissett et al. (2012) also revealed that students with SBI had higher diagnostic accuracy than did those taught using traditional methods. It was thought that schemas benefit learners by modifying knowledge organization and diagnostic reasoning strategies. Interestingly, for the untaught lessons, the SBI group was more accurate in diagnosis. Although Blissett et al. identified fewer features of the symptoms, they only identified those that were present on the schema and did not notice irrelevant symptoms resulting in increasingly accurate diagnosis. This finding is critical in transferring this information to medication calculation as it is imperative to teach nursing students to ignore irrelevant information and to focus on what is important.

Summary on schema research

Given the findings presented in the previous section, SBI may be very useful for helping students funnel down a large amount of information into smaller chunks so that the working memory can handle it better. This leads to long-term retention. In medication calculation, this is important as the solving framework may provide the needed structure by helping students to identify only what is needed to solve the problem and to ignore the irrelevant information.

The outcomes of the studies presented demonstrate that SBI may be an effective method for teaching medication calculation. As a result, the use of SBI with dimensional analysis as a method for improving first-time, test-taking performance on a medication calculation exam was explored in the study presented here. Future research beyond this study, however, should be aimed at continuing to explore this for nursing instruction with further studies designed to address maintenance and transfer.

Summary of Literature Review

This literature review covered three primary topics: numeracy, interventions aimed at improving medication calculation performance in nursing students, and a discussion on schema theory. The primary areas of difficulty include use of formulas, decimals, ratios and proportions, percentages, infusion rates, and fractions. Nevertheless, the findings also suggested some success with short-duration workshops as opposed to with semester-long, multiple step interventions. Focusing on a single intervention will aid in determining whether the intervention is successful. Thus, a schema-based medication calculation workshop was developed for this study that was three hours in length, included foundational mathematical concepts, and provided the patient care context. This instruction used *dimensional analysis* housed within the context of maternal–child nursing to develop the needed patient care context.

CHAPTER III

METHODOLOGY

In this study, outcomes on the Maternal Child Medication Calculation (Med Calc) exam were compared between the entire Senior One Fall 2016 nursing class who did not have access to the workshop (*n* = 99) and the entire Senior One Spring 2017 cohort who did have access to the workshop (*n* = 75). Additionally, outcomes were compared between spring students who completed the workshop (*n* = 42) and students who did not attend (*n* = 24). Nine students were excluded from this second comparison as they attended only a portion of the workshop—either the beginning or the end.

The intent of this research was to determine whether the combination of teaching a single method of medication calculation (dimensional analysis) in a single three-hour schema-based medication calculation workshop within the authentic context of maternal–child nursing care improved the medication calculation performance of prelicensure nursing students.

The research questions, as introduced in Chapter I, were as follows:

1. What is the effect of a schema-based dimensional analysis medication calculation workshop on the first-time pass rate on the Maternal Child Medication Calculation (Med Calc) exam for senior prelicensure nursing students?
2. To what extent does participation in a schema-based dimensional analysis medication calculation workshop influence the type and number of errors on the Med Calc among prelicensure nursing students?
3. To what extent does use of dimensional analysis on the Med Calc influence student performance on the Med Calc?

4. What are student perceptions of the schema-based dimensional analysis medication calculation workshop?

This chapter describes the study methodology including a description of the research design, sampling procedures, and procedures undergone to ensure the protection of human subjects. Additionally, this chapter describes the instrumentation and treatment and concludes with a description of data analysis procedures.

Research Design

This descriptive two group posttest study included comparing the historic performance on the Med Calc exam of prior semester nursing students (fall 2016) with current students (spring 2017) who had access to the workshop. Current students had the option to attend a medication calculation workshop, whereas the fall students did not. The first independent variable was attendance at a schema-based dimensional analysis medication calculation workshop that was offered in the spring of 2017 and not available to students in the fall of 2016. The dependent variables for these questions included (a) percentage of students achieving 100% on the first attempt of the Med Calc exam, (b) number of errors on the Med Calc exam, and (c) type of errors on the Med Calc exam. The second independent variable was the use of dimensional analysis on the Med Calc exam with the dependent variable being student accuracy on each item. Lastly, student perceptions of the workshop were analyzed through a researcher-created, Likert-style student survey. The length of this study was one week with the workshop on January 23, 2017 and the Med Calc on January 28, 2017. Figure 2 displays the study design, whereas Figure 3 identifies the data display for each research question.

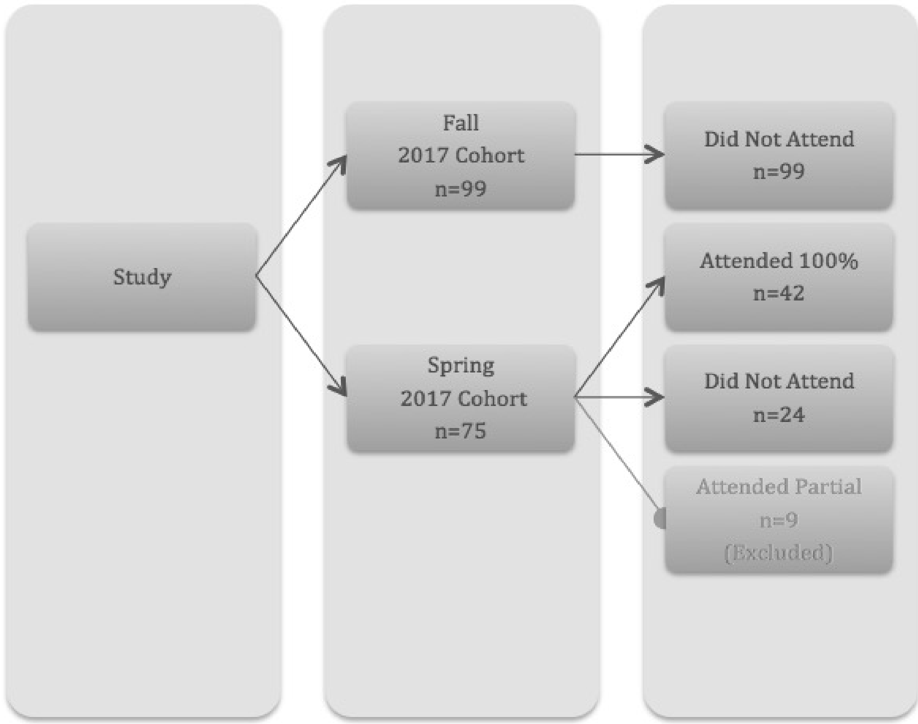


Figure 2. Research design.

Sample

The convenience sample was drawn from the Senior One prelicensure nursing students enrolled in the bachelor of science in nursing program at a four-year university in Northern California. This nursing school enrolls students in both the spring and fall semesters, and it has a program of study that is eight semesters in length. Study participants were in the seventh semester of nursing instruction. The comparison group was the entire class of students who were in the Senior One cohort in the fall of 2016 (n = 99). At that time, the workshop had not been developed, and thus, these students are used for comparison data. Students who were in the Senior One cohort in the Spring of 2017 were invited to attend the workshop (n = 75). Of the invited participants, 42 students attended and completed the entire workshop, 24 students did not attend, and 9 students attended a portion of the workshop either arriving more than 30 minutes late or leaving 30 minutes early. Students who attended a portion of the workshop were included in comparisons of the intact fall and spring cohort and were excluded from comparisons that related directly to workshop attendance.

For all groups, demographics were collected from the university's online database. Table 1 depicts the student demographic data including GPA, gender, age, and race. The fall 2016 cohort had a higher GPA than did the spring 2017 cohort (Cohen's *d* = .1), which favored the performance of this cohort over the spring one. The spring cohort had a higher percentage of males than did the fall cohort (*h* = .29), which favored the spring cohort.[1] Last, the fall cohort is younger than the spring cohort (Cohen's *d* = .55).

Protection of Human Subjects

An application for permission to perform this study was submitted to the institutional review board for the protection of human subjects (IRBPHS) at the host university after approval for the proposal was received. This was followed by a notification to the IRB that the researcher was also the course instructor. The IRBPHS declared this study to be exempt from review.[2] Additionally, to protect the privacy of participants, all participant data were stored on a password-protected encrypted computer

---

[1] *h* is a measure of the distance between two different proportions and is used in social science research to describe the distance as either *small*, *medium*, or *large* (Chen et al., 2010). As a result, an *ex post facto* analysis by gender was included in the analysis portion of this study.
[2] Although this study was discussed with the dean or the department chair, written approval was not obtained prior to data collection and both subsequently declined to provide *ex post facto* permission.

or filed in a locked cabinet.

Research question	Variables		Measures	Primary data display
	Independent	Dependent		
What is the effect of a Schema-Based Dimensional Analysis Medication Calculation Workshop on the first-time pass rate on the maternal–child exam among senior prelicensure nursing students?	Workshop attendance	Pass Rate on the Med Calc	% of students passing the Med Calc with 100%.	Tables 2 and 3
To what extent does participation in a Schema-Based Dimensional Analysis Medication Calculation Workshop influence the type and number of errors on the Med Calc among prelicensure nursing students?	Workshop attendance	Number of errors	Number of errors on the Med Calc	Tables 5–8 and a narrative discussion on type of error
		Type of errors	Identification of type of error	
To what extent does use of dimensional analysis on the Med Calc influence student performance on the Med Calc?	Use of dimensional analysis on the Med Calc	Student performance	Average pass rate on individual items and overall	Tables 9, 10 and 11
What are student perceptions of the Schema-Based Dimensional Analysis Medication Calculation Workshop?	Workshop attendance	Student perception of workshop quality	Scores from the workshop survey	Table 12

Figure 3. Research questions, variables, and data display.

Table 1

Demographics: Mean and Standard Deviations for GPA and Age, Percentages of Race and Gender Between Intact Spring and Fall Cohorts

	Mean GPA (*SD*)	Gender			Mean age (*SD*)	Race	
Fall 2016	3.57 (.26)	Females	79.8%	(*n* = 79)	23.0 (4.4)	Asian	34% (*n* = 34)
		Males	20.2%	(*n* = 20)		White	28% (*n* = 28)
						Hispanic	3% (*n* = 3)
						Black	3% (*n* = 3)
						Pacific Islander	1% (*n* = 1)
						Multiracial	20% (*n* = 20)
						Nonresident Alien	1% (*n* = 1)
						Unknown	9% (*n* = 9)
						Total	100% (*n* = 99)
Spring 2017	3.54 (.32)	Females	66.7%	(*n* = 50)	25.6 (5.0)	Asian	29% (*n* = 22)
		Males	33.3%	(*n* = 25)		White	47% (*n* = 35)
						Black	1% (*n* = 1)
						Multiracial	7% (*n* = 5)
						Nonresident Alien	3% (*n* = 2)
						Unknown	13% (*n* = 10)
						Total	100% (*n* = 75)

Instrumentation

Two different instruments, the Maternal Child Medication Calculation (Med Calc) exam and the medication calculation workshop evaluation form, were used in this study. A description of these two instruments follows.

Maternal Child Medication Calculation (Med Calc) Exam

The Med Calc exam was designed as an authentic assessment and was contextualized to maternal–child nursing care. The exam has been in use for six semesters and was initially constructed by expert didactic faculty who teach maternal–child nursing at the university (Appendix A). The exam was then reviewed by all clinical faculty members teaching at the Senior One level. These faculty members all concurred that the Med Calc exam was an accurate representation of the arithmetic needed in their clinical setting. Psychometric testing was not completed on this instrument as it was the instrument in use for this and several prior semesters and the intent of this study was to determine whether the workshop improved scores on this exam. This ten-item exam is contextual in nature, and thus, the information and calculations were housed within two case studies: (a) a five-year-old child with leukemia and (b) a postpartum patient. The exam is summarized in Figure 4. The use of this exam for this study was discussed with faculty teaching at this level. Nevertheless, written permission for use of the instrument was not obtained from the original exam authors.

Maternal Child Medication Calculation Exam		
Case Studies	Concepts	Items
Sadie - 5-year-old with leukemia – questions 1–5	Safe Dose Range	#1, 5
	Dilution/Concentration	#2, 4, 8
Caroline – Postpartum woman – questions 6–10	Fractional Dosing	#3, 5
	Medication Volume	#6
	Infusion Rate	#7, 9, 10
Item five is a multistep question.		

Figure 4. Med Calc item summary.

Workshop Satisfaction Survey

The second instrument was the researcher-created workshop satisfaction survey (WSS). This instrument was designed to gather feedback to improve future workshops. The WSS (Appendix B) consisted of 12 items. The first six items were related to workshop content and solicited ratings on content and activities by means of a Likert-like scale with scores ranging from 1 = *Strongly agree* to 5 = *Strongly disagree*. The next two items asked students about prior experience as well as about their plans to use dimensional analysis on the upcoming Med Calc. Item nine requested students to rate the workshop length as either *too short*, *right length*, or *too long*. Item 10 asked students to rate the workshop as *introductory*, *intermediate*, or *advanced*, whereas item 11 rated the visuals, acoustics, meeting space, handouts, and program on a five-point scale of *excellent*, *very good*, *good*, *fair*, or *poor*. Item 12 was an open-ended question asking students for any additional feedback on the workshop.

Treatment Description

The treatment consisted of a three-hour-long workshop held on January 23, 2017. The initial workshop announcement was sent via email to all students in the spring Senior One cohort (Appendix C). This email was followed up with a notification in the course learning management system, and then a verbal announcement was given in class to all students.

This workshop took place on a university campus in a single room. The room was set up with round tables. A large screen was present to allow students to view the presentation. The workshop was presented lecture style with breaks for student questions and guided practice.

The workshop opened with a description of the study purpose and overall workshop schedule. Students were then asked to sign the consent form (Appendix D). The next two hours included instruction on dimensional analysis that began with simplistic questions and evolved into questions of increased complexity.

Additionally, concepts of medication administration in the maternal–child setting were threaded throughout the lecture to provide the needed context for understanding the calculations. The final hour involved students completing a sample medication calculation examination with instructor guidance (Appendix E). Students then completed the student satisfaction survey. A detailed description of the workshop with the accompanying Microsoft® PowerPoint™ presentation is provided in Appendix F. Appendix G displays the workshop handout, which was researcher created as a visual aid for practicing dimensional analysis. This document was designed to help invoke, develop, and solidify the student's dimensional analysis medication calculation schema. Figure 5 depicts the workshop schedule.

Maternal Child Medication Calculation Workshop
Agenda

10:00 - 10:15	Introduction
10:15 - 10:45	Benny – Case Study
10:45 - 11:15	Pediatric Medication Administration
11:15 - 11:30	Break
11:30 - 12:00	Infusion Therapy
12:00 - 12:45	Open Practice Med Calculation Exam
12:45 - 1:00	Workshop Evaluation and Questions

Figure 5. Workshop agenda.

The workshop satisfaction survey was originally intended as a mechanism to take attendance at the workshop. Nevertheless, not all attendees returned the survey. As a result, a document was created and circulated among the students during class four days after the workshop. A comparison of this document is congruent with the student head count taken at the workshop.

Procedures

The following procedures were completed during this study. The researcher examined the Med Calc to ensure the content from the examinations matched the contextual information provided during the workshop. Next, all students enrolled in the Senior One cohort for the spring of 2017 were invited to attend the workshop via an email sent on January 6. The email included a description of the study as well as of the workshop. Students then attended the medication calculation workshop on Monday, January 23 from 10:00 am until 1:00 pm. On January 28, all students in the Senior One cohort took the Med Calc exam. The exam included ten items, was mandatory for all enrolled students, and required a 100% score for passage. The policy at this university is to allow two additional opportunities to pass this exam after individualized tutoring. As a result of the individualized nature of exam remediation, however, the results of exams two and three were not considered in this study. Students who do not master the exam on the third attempt receive a course failure and are in jeopardy of being disqualified from the nursing program.

The principle investigator and course instructor obtained student demographics through the university's Web service called "Banner." These demographic data were exported into a Microsoft® Excel™ spreadsheet and analyzed. The groups were sorted by cohort and means, and standard deviations were calculated for both GPA and age using the automated functions in Excel. Cohen's *d* was calculated to determine the level of difference between these groups. For gender and race, the overall percentage was calculated in Excel. To determine the significance between the groups, *h* scores were hand calculated. *h* is a measure of the distance between two different proportions and is used in social science research to describe the distance as either .2 small, .5 medium, or .8 large. Cohen's *h* is calculated by subtracting the Phi of proportion 1 from the phi of proportion 2 (Chen, Cohen, & Chen, 2010).

The data management procedures relating to research question four involved coding the items into an Excel spreadsheet. Items one through nine were entered as the number circled by the students from 1 = *Strongly agree* to 5 = *Strongly disagree*. Items for questions 9 and 10 were entered into separate columns in Excel and tallied, and then percentages were computed for each of the five items.

Data Analysis

The data analysis for this study involved two separate comparisons. First, the intact fall 2016 cohort was compared with the intact spring 2017 cohort. Second, students from the spring 2017 cohort who completed the workshop were compared with students from the same cohort who did not attend. Students who attended a portion of the workshop were excluded from this comparison. Student results on the Med Calc exam provided the basis for answering the first three research questions. An initial summary of the means and standard deviations for all groups is depicted below in figure 6 and is followed by a detailed description of the data analysis.

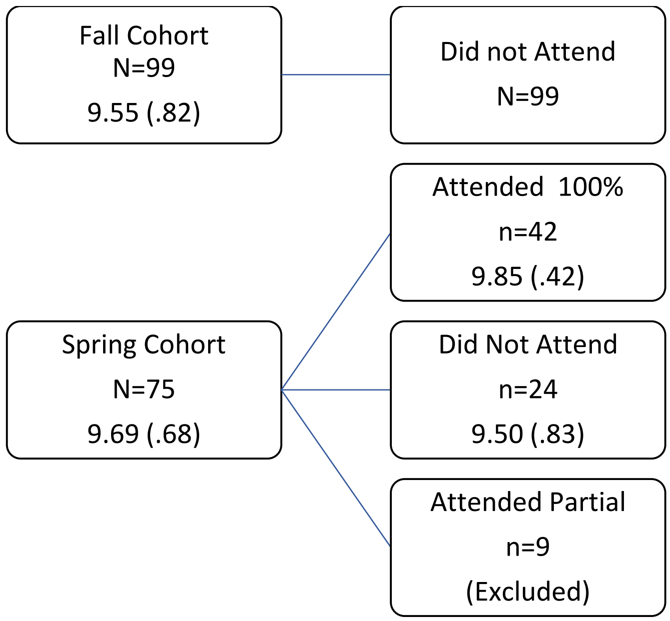


Figure 6. Initial means and standard deviations

Research question one

Data analysis for question one—*What is the effect of a schema-based dimensional analysis medication calculation workshop on the first-time pass rate on the Maternal Child Medication Calculation (Med Calc) exam for senior prelicensure nursing students?*—included calculating the first-time pass rate of each individual group, comparing the percentages of students passing, and calculating the effect size. First, the researcher calculated the percentage of students achieving a 100% score on the exam.

Next, Cohen's *h* was calculated.

Research question two

Research question two—*To what extent does participation in a schema-based dimensional analysis medication calculation workshop influence the type and number of errors on the Med Calc among prelicensure nursing students?*—involved three primary comparisons: (1) means, (2) error rates, and (3) an analysis of type of error for each question on the exam. First, the researcher compared the mean score between groups using Cohen's *d* as a measure of practical significance. Next, the researcher calculated the error rates by counting the number of students who had one to five errors on the exam. Then, the percentage of students in each of the aforementioned error rate categories was calculated. Cohen's *h* was hand calculated to determine whether there was a significant difference between groups. Last, individual exams were reviewed and errors were categorized as either (a) decimal, (b) calculation, (c) conceptual, (d) wrong setup, (e), conceptual and (f) other. Errors were coded as *decimal* when the decimal was inaccurately placed. Errors were coded as *calculation* when it appeared as though the error occurred in the calculator but the setup on the paper was correct. Items coded as *conceptual* involved the students inability to select the correct information to place into the equation. W*rong setup* errors were those where the numbers were not set up into the formula correctly. These errors typically involved inversion of the numerator and the denominator. *Rounding* errors included items where students were asked to round to one place and they rounded to the wrong place. For example, students rounded to the 100th place when they should have rounded to the 10th. Although these errors are not calculation related, they demonstrated the student's ability to follow directions accurately and thus were counted as a failed item in this university. Last, when the investigator could not code an item into one of the aforementioned categories, the error was coded as *other*.

Research question three

To answer research question three—*To what extent does use of dimensional analysis on the Med Calc influence student performance on the Med Calc?*—the researcher reviewed all exams from the spring 2017 cohort to determine the problem-solving method for each item. These methods were categorized as ratio/proportion, want/have, dimensional analysis, and unable to determine. Items were coded as *ratio/proportion* when they had two single fractions. Items were coded as *want/have* when they were labeled as “want/have” on the paper. Items were coded as *dimensional analysis* when they demonstrated the features of dimensional analysis: (a) a single equation with multiple conversions, (b) identified units throughout, (c) crossing out of units, and (d) units identified in the answer. Students who did not show ample work on their test papers were coded as *unable to determine*. Next, the data were further divided into either pass or fail. The percentages of students using each solving method were then calculated for each of the ten exam items.

Research question four

To answer research question number four—*What are student perceptions of the schema-based dimensional analysis medication calculation workshop?*—results from the researcher-created student satisfaction survey were consolidated and analyzed. The analysis included creating frequencies of student answers in each category.

Summary of study methodology

This study was designed to assess the effectiveness of a schema-based dimensional analysis medication calculation workshop on student performance on a Med Calc exam. This workshop included contextual information on the administration of medication to children and was focused on the teaching and practice of dimensional analysis. The entire cohort of Senior One nursing students was invited to participate in both the workshop and the study. The workshop was held six days before the Med Calc examination and was voluntary, yet highly recommended. All students in this cohort were required to take the Med Calc exam and pass the exam with 100%. The results from this cohort of students were then compared with the exam results from the fall cohort. The students in the fall of 2016 did not have access to the workshop. Their prep for the exam included reading the assigned chapters in the textbook and then completing the practice test. Additionally, the students in the experimental group also had access to the same study materials. Before this workshop, there had been no formal medication calculation instruction for the Senior One level. The study results are presented in the subsequent chapter.

CHAPTER IV

RESULTS

The findings from this research study are highlighted in this chapter. Each section is organized with findings for the corresponding research question followed by a brief summary of results. The study design included a comparison of students from the spring semester who completed a dimensional analysis workshop to students from the fall who did not have access to the workshop and students from the spring who chose not to attend the complete workshop. Figure 6 is included below as a refresher of the primary study design.

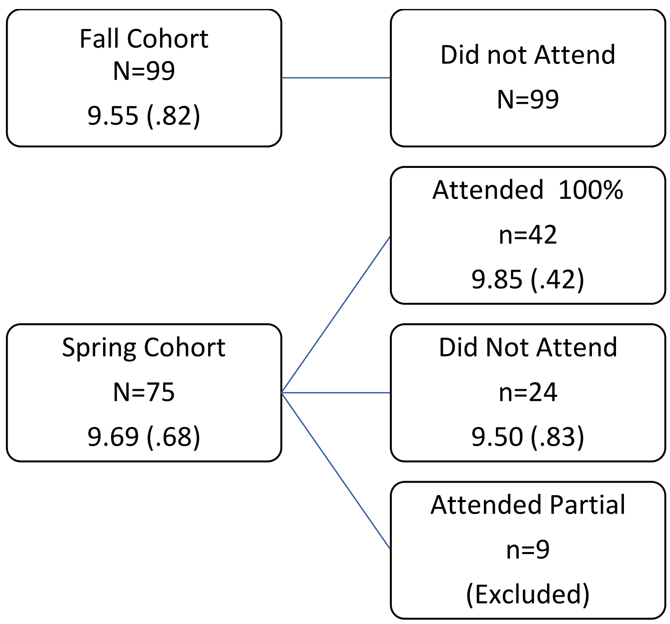


Figure 6. Study design with means and standard deviations

Research Question One

What is the effect of a schema-based dimensional analysis medication calculation workshop on the first-time pass rate on the Maternal Child Medication Calculation (Med

Calc) exam for senior prelicensure nursing students?

Table 2 presents the first-time pass rates between students who did not attend the workshop from both cohorts (fall of 2016 and the spring of 2017) and the spring 2017 who completed the workshop. As noted previously, student who attended a portion of the workshop but did not complete the training were excluded from analysis. The fall cohort is used for historic comparison as those students did not have access to the workshop, whereas spring students had the option to attend.

Table 2

Means, Standard Deviations, and First-Time Pass Rates on the Med Calc Between the Fall and Spring Cohorts

Student group	Mean score (*SD*)	# pass	Pass rate
Fall 2016 cohort *n* = 99	9.55 (.82)	68	68.7%
Spring 2017 cohort Completed workshop *n* = 42	9.85 (.42)	36	85.7%
Spring 2017 cohort *Did not complete workshop* *n* = 24	9.50 (.83)	16	66.7%

Note. Pass rate on the exam set at 100%.

As noted by Table 2, 68.7% (*n* = 68) of the students in the fall cohort passed on the first attempt while 66.7% (*n*=16) of spring students who did not attend the workshop passed on the first exam. Spring students who completed the workshop had a higher first-time pass rate (85.7%) when compared with both the fall students (68.7%) and spring students who did not to attend the workshop (66.7%). This difference demonstrates a small-to-medium effect size (Cohen's *h* = .41 & .45 respectively). Cohen's *h* is a measure of effect size that is used with proportions with .2 considered small, .5 medium, and .8 large (Chen et al. 2010). A small number of students (9) attended a portion of the workshop either arriving late or leaving early. The results from these students are excluded from these findings.

Next, as a result of the differences in gender documented in the literature favoring males over females in mathematics, an *ex post facto* analysis of results by gender was completed and is displayed in Table 3.

Table 3

Spring 2017 Results by Gender

Gender	Males		Females	
	#	Pass rate	#	Pass rate
	25	64% (16)	55	82% (41)

Overall, the females had a higher first-time pass rate (82%) as compared with the males (64%), which is contrary to much of the literature favoring males over females in mathematics.

Research Question Two

To what extent does participation in a schema-based dimensional analysis medication *calculation workshop influence the type and number of errors on the Med Calc among prelicensure nursing students?*

To answer this question, data analysis included comparing the overall mean score, error rates, and both number and type of errors for each incorrect answer on the Med Calc.

As reported in Table 2, an evaluation of means between the fall and spring cohorts demonstrated a mean of 9.55 (*SD* = .82) for the intact fall 2016 cohort compared with a mean of 9.85 (*SD* = .42) for the spring workshop attendess. The Cohen's *d* effect size was medium (.46) with an improvement in the mean favoring the spring workshop attendees. . Additionally, when the group mean score of those who completed the workshop (9.85, *SD* = .42) was compared with those who did not (9.5, *SD* = .83), a moderately higher mean was demonstrated for the students who completed the workshop. The Cohen's *d* effect size was medium (.53).

An exploration of the overall number of items missed between groups (displayed in Table 4) illustrates that the fall cohort, on average, missed more items than did the spring cohort with 31% of fall students missing at least one item as compared with 33% of the spring students who did not attend the workshop. IN comparision, only 14% of spring studetns who attended the workshop missed items on the exam. This finding is statistically significant with a small to medium effect size for fall students *h* = .45 and spring students *h* = .41. Additionally, only 2% (*n* = 1) of students who completed the workshop missed two or more items on the exam, whereas 10% (*n* = 3) of the fall students and 12% (*n* = 3) of the spring students who did not attend the workshop missed more than two items. The Cohen's *h* was small for the fall (.36) and spring (.43).

Table 4

Number of Students Missing Items on the Med Calc

Student group	Number of items missed: 0	1	2	3	4	5
Fall cohort *n* = 99	69% (*n* = 68)	21% (*n* = 21)	8% (*n* = 8)	1% (*n* = 1)	0	1% (*n* = 1)
Spring cohort—No WS *n* = 24	67% (*n* = 16)	21% (*n* = 5)	8% (*n* = 2)	4% (*n* = 1)	0	0
Spring cohort—100% WS *n* = 42	86% (*n* = 36)	12% (*n* = 5)	2% (*n* = 1)	0	0	0

Examination of the individual questions on the Med Calc exam demonstrated noteworthy differences in both the numbers and the types of errors completed by the students. Table five presents the percentages of students who missed specific items on the medication calculation exam. This table highlights the results from students in the fall who did not have access to the workshop, the spring students who did not attend the workshop, and those who completed the workshop.

Table 5

Percentage of Students Missing Items on the Med Calc Between Spring and Fall Intact Cohorts

Item number	Fall cohort No WS n = 99	Spring cohort No WS n = 24	Spring cohort 100% WS n = 42	h
1	1.01% (n = 1)	4.17% (n = 1)	4.76% (n = 2)	.25, .01
2	2.02% (n = 2)	4.17% (n = 1)	0	.28, .20
3	12.00% (n = 12)	0	2.38% (n = 1)	.51, .08
4	2.02% (n = 2)	4.17% (n = 1)	0	.28, .20
5	0 (n = 0)	8.33% (n = 2)	0	.00, .28
6	1.01% (n = 1)	4.17%(n = 1)	0	.20, .20
7	2.02% (n = 2)	4.17%(n = 1)	0	28, .20
8	2.02% (n = 2)	0	0	.28, .00
9	4.04% (n = 4)	4.17%(n = 1)	2.38% (n = 1)	.20, .20
10	14.14% (n = 14) [a]6.06% (n = 6) 8.08% (n = 8)	[a]12.50% (n = 3)	[a]4.76% (n = 2)	[a]..32, .29

[a] These errors are related to improper rounding to the hundredths as opposed to the tenths. The reported *h* excludes items related to rounding and presents the h comparing the fall cohort compared to the spring cohort with workshop attendance followed by a comparison between the spring cohort who did not attend with those who completed the workshop.

Next, each error committed by students was coded into one of four error types. First, *calculation* errors involved a correct set up and incorrect answer indicating the error most likely occurred within the calculator. Items coded as *conceptual* involved the students inability to select the correct numbers to place into the equation. W*rong setup* errors were those where the correct numbers were chosen but they were not set up into the formula correctly. These errors typically involved inversion of the numerator and the denominator. *Rounding* errors included items where students were asked to round to one place and they rounded to the wrong place. Table six below depicts the numbers and types of errors committed by students from the fall, spring NO WS, and spring WS groups.

Table 6

Types of Errors on the Medication Calculation Exam

Item	1	2	3	4	5	6	7	8	9	10
Rounding										
Fall										
Spring No WS		1		1						
Spring WS										
Calculation										
Fall										
Spring No WS										
Spring WS			1						1	
Set Up										
Fall	1		2	1		1	2	2	3	7
Spring No WS	1						1		1	
Spring WS										
Conceptual										
Fall		1	10	1						1
Spring No WS					2	1				
Spring WS										
Decimal										
Fall		1							1	
Spring No Ws										
Spring WS										

The Med Calc exam uses two case studies as the context for the exam. The case study and 1–5 are presented in Figure 7 for context.

Sadie is a 5-year-old (23kg) who has been admitted to the pediatric unit with

leukemia.

<u>Orders:</u>

> Ampicillin 1150 mg IV q6h (safe dose range 100-200mg/kg/day in divided doses, final maximum concentration not to exceed 30mg/ml, given IV over 15-30min)
>
> Meropenum 450 mg IV q8h (safe dose range 10-40mg/kg/dose given every 8 hours, final maximum concentration not to exceed 50mg/ml, given over 15-30 minutes.
>
> Methylprednisolone 32 mg IV once a day. (safe dose range is .5-1.7mg/kg/dose, final max not to exceed 125mg/ml, given over 15 min)

Exam Questions:

1. The safe dose range of ampicillin for Sadie is _____ to ___ mg/dose.

2. The ampicillin dose as ordered above must be diluted in at least ____ ml? (Round to the nearest tenth).

3. The ampicillin dose as ordered above must be diluted in at least ____ ml? (Round to the nearest tenth).

4. The meropenum that was ordered arrives from pharmacy in a 25 ml piggyback bag.
What is the concentration of meropenum in this premixed piggyback bag? ________mg/ml. Does this premixed bag of medication exceed the final maximum concentration allowed? _______ (yes/no).

5. The safe dose range of methylprednisolone for Sadie is ____ to _____ mg/dose. (Round to the nearest tenth). The RN will draw up ________ml of the methylprednisolone. (Round to the nearest tenth).

Figure 7. Med Calc exam items 1–5.

Item one

The first question on the exam was a simple safe dose question. One fall student, one spring student who did not attend the workshop, and two workshop attendees missed this item. Of the spring students, three had attended the workshop. After analyzing the exams, it was clear that students confused the problem setup and confused dose per day versus dose per dose. None of the students attempted dimensional analysis on this question.

Item two

The second question on the exam was related to dilution: This item is also simple as demonstrated by student performance. In the fall, two students missed this item, whereas in the spring, one student who did not attend the workshop missed this item. None of the students who completed the workshop missed this item. The fall students had one error categorized as conceptual in nature and the other related to decimal placement. In the spring, there was one rounding error from a student who did not attend the workshop. None of the workshop attendees missed this question.

Item three

The third item increased in complexity as demonstrated by student results. Overall, 12.12% (*n* = 12) of fall students missed this item. The most common error was coded as conceptual with a number of students inverting the numerator and the denominator as well. For the spring cohort, 2.38% (*n* = 1) of the students in the workshop group missed this question. The difference between these scores demonstrates a small to medium effect size (*h* = .43). In looking at the spring exams, the error appears to be calculator related as the student's setup was correct.

Item four

The fourth item on the exam was a concentration question. Students in both cohorts performed well on this item. For this item, one fall student struggled with problem setup while another had a rounding error. One spring student who did not attend the workshop missed this item as a result of an error in rounding. The error was not related to arithmetic.

Item five

Item five included two questions. The first question was a safe dose range question, whereas the second part asked students to calculate the actual amount of medication to administer. Students in both cohorts performed well on this item with 100% of the fall cohort as well as 100% of the spring workshop attendees being 100% accurate. Nevertheless, 8.33% (*n* = 2) of the spring students who did not attend the workshop missed this item as a result of conceptual errors. .

Figure 8 depicts the scenario and items 6–10.

Caroline is 6 hours post-partum and is suffering from severe preeclampsia. She has a peripheral IV with .9%NS infusing.

Orders:
Hydralazine 6 mg IV now (recommended dose is 5-10 mg IV given over 10 minutes)

Loading dose: Magnesium sulfate 6 grams IV in 250 ml over 20 minutes (magnesium sulfate must be diluted to a final maximum concentration not to exceed 60mg/ml)

Magnesium sulfate 2 grams IV per hour after loading dose has infused.

6. Using the vial of Hydralazine pictured here, how much solution will you draw up? (Round to the nearest tenth).

7. When following the recommended infusion time, how many mg/minute of Hydralazine will you administer? (Round to the nearest tenth).

8. The magnesium sulfate loading dose arrives premixed as 6 grams in a 250 ml bag of .9%NS. The concentration of drug in this bag is _______ mg/ml. Does this premixed bag of medication exceed the final maximum concentration allowed? __________ (yes/no).

9. When giving report, the oncoming nurse asks about the magnesium sulfate, asking "What is the IV loading dose rate in grams per hour?" ____?

10. After the loading dose has infused, the magnesium sulfate must be infused at 2 grams per hour. Using the same IV bag (6 grams in 250 ml .9%NS), the rate should be set at __ ml/hour. (Round to the nearest whole number).

Figure 8. Med Calc exam items 6–10.

Item six

Item six was a simple calculation question that students performed well on. Student performance on item number six demonstrated that 100% of the spring workshop attendees accurately answered this question, whereas one fall student missed this item as a result of an error setting up the conversion. Additionally, one spring student who did not attend the workshop committed a conceptual error on this item.

Item seven

Item seven was a question concerning infusion rate: Two (2.02%) fall students and one spring student who did not attend the workshop missed this item as a result of improper setup.

Item eight

The eighth item on the exam was a question on concentration: In the spring, 100% of students answered item eight accurately. Nevertheless, in the fall, 2.02% (n = 2) of the students missed the item as a result of improper setup.

Item nine

Item nine proved challenging for the students as many struggled with conversion of grams and thus had tenfold errors. In all, 4.04% (n = 4) of the fall students missed the item with multiple errors that included improper use of decimals that led to a tenfold error and improper setup. In the spring, two students missed this item as a result of improper setup. One student had completed the workshop, whereas one had not.

Item ten

Item ten proved challenging for many students, yet many of the errors were related to rounding as opposed to arithmetic. A total of 14.00% (*n* = 14) of the fall students missed this item. Nevertheless, 6.06% (*n* = 6) of these errors were not related to arithmetic and were errors relating simply to rounding to the wrong place (100ths instead of 10ths). Of these arithmetic errors, 8.08% (*n* = 8) were coded either decimal and improper setup. None of the spring students had an arithmetic error on this question. The difference on this item between the spring students who completed the workshop and fall students was significant with a small effect size (*h* = .32). An example of dimensional analysis is included below and depicts the benefit of dimensional analysis in the aligning of units and then the cancelling of units to ensure that the numerator and denominators are set up accurately.

$$\frac{250\text{ ml} \quad 2\ \cancel{\text{Grams}}}{6\ \cancel{\text{Grams}} \quad 1\text{ Hour}} = 83.3\text{ ml/hour}$$

Research Question Three

To what extent does use of dimensional analysis on the Med Calc influence student performance on the Med Calc?

To answer this question, Table 7 presents the preferred problem-solving method for all students in the spring cohort. This information is not presented for the fall cohort as a negligible number of students used dimensional analysis on that exam. In all, ratio/proportion was the most used method for approaching the Med Calc exam.

Nevertheless, it is interesting to note that many of the students started the exam using a different method, yet many of the students who passed the exam converted to the use of dimensional analysis for the more complex problem types, whereas those who failed did not. For example, for item number one, which was classified as a safe dose question, 56.0% (n = 42) of students used the ratio/proportion problem-solving method as compared with 30.7% (n = 23) of the students who used dimensional analysis. For the more complicated problems such as item 10, however, 44.0% of the students attempted dimensional analysis, whereas 42.7% used ratio/proportion. Some solving methods were not able to be determined as a result of students not showing their work.

Table 8 presents results from students who were accurate on the item and highlights the successful solving methods by question number. For every item, students who used dimensional analysis as their problem-solving method were more accurate than students who used any other solving method. With a goal of 100% accuracy, dimensional analysis is the only solving method that reached this mark. Looking further at the two items with the highest error rates further identifies differences in student results.

Table 7

Student Solving Methods Comparing Students Who Passed the Exam With Those Who Did Not

Item	Ratio/Proportion		Want/Have		Dimensional analysis		Unable to determine	
	Pass	Fail	Pass	Fail	Pass	Fail	Pass	Fail
1	41.3% (n = 31)	14.7% (n = 11)	(n = 0)	(n = 0)	26.7% (n = 20)	4.0% (n = 3)	8.0% (n = 6)	5.3% (n = 4)
2	34.7% (n = 26)	14.7% (n = 11)	(n = 0)	(n = 0)	34.7% (n = 26)	4.0% (n = 3)	6.7% (n = 5)	5.3% (n = 4)
3	33.3% (n = 25)	14.7% (n = 11)	4.0% (n = 3)	2.7% (n = 2)	32.0% (n = 24)	2.7% (n = 2)	6.7% (n = 5)	4.0% (n = 3)
4	58.7% (n = 44)	16.0% (n = 12)	4.0% (n = 3)	2.7% (n = 2)	4.0% (n = 3)	(n = 0)	9.3% (n = 7)	5.3% (n = 4)
5	37.3% (n = 28)	14.7% (n = 11)	2.7% (n = 2)	1.3% (n = 1)	25.3% (n = 19)	1.3% (n = 1)	10.7% (n = 8)	6.7% (n = 5)
6	38.7% (n = 29)	13.3% (n = 10)	5.3% (n = 4)	2.7% (n = 2)	24.0% (n = 18)	1.3% (n = 1)	8.0% (n = 6)	6.7% (n = 5)
7	65.3% (n = 49)	18.7% (n = 14)	2.7% (n = 2)	2.7% (n = 2)	1.3% (n = 1)	(n = 0)	6.7% (n = 5)	2.7% (n = 2)
8	41.3% (n = 31)	17.3% (n = 13)	(n = 0)	2.7% (n = 2)	29.3% (n = 22)	(n = 0)	5.3% (n = 4)	4.0% (n = 3)
9	29.3% (n = 22)	14.7% (n = 11)	1.3% (n = 1)	4.0% (n = 3)	40.0% (n = 30)	1.3% (n = 1)	5.3% (n = 4)	4.0% (n = 3)
10	22.7% (n = 17)	20.0% (n = 15)	2.7% (n = 2)	1.3% (n = 1)	42.7% (n = 32)	1.3% (n = 1)	8.0% (n = 6)	1.3% (n = 1)

Table 8

*Percentages of Students Who Answered Correctly on Each Item,
Sorted by Calculation Method*

Item	Dimensional analysis	Ratio/Proportion	Want over have	Unable to determine
1	86.96% (*n* = 20)	73.81% (*n* = 31)		60.00% (*n* = 6)
2	89.66% (*n* = 26)	70.27% (*n* = 26)		55.56% (*n* = 5)
3	92.31% (*n* = 24)	69.44% (*n* = 25)	60.00% (*n* = 3)	62.50% (*n* = 5)
4	100.00% (*n* = 3)	78.57% (*n* = 44)	60.00% (*n* = 3)	63.64% (*n* = 7)
5	95.00% (*n* = 19)	71.79% (*n* = 28)	66.67% (*n* = 2)	61.54% (*n* = 8)
6	94.74% (*n* = 18)	74.36% (*n* = 29)	66.67% (*n* = 2)	54.55% (*n* = 6)
7	100.00% (*n* = 1)	77.78% (*n* = 49)	50.00% (*n* = 2)	71.43% (*n* = 5)
8	100.00% (*n* = 22)	70.45% (*n* = 31)		57.14% (*n* = 4)
9	96.77% (*n* = 30)	66.67% (*n* = 22)	25.00% (*n* = 1)	57.14% (*n* = 4)
10	96.97% (*n* = 32)	53.13% (*n* = 17)	66.67% (*n* = 2)	85.71% (*n* = 6)

Item three

Item three was missed by 12.00% (n = 12) of fall students and by 1.33% (n = 1) of spring students. This indicates that the item was challenging. Looking at student solving methods, 48.0% (n = 36) of the students used the ratio/proportion method, whereas 34.7% (n = 26) used dimensional analysis. Of the students using ratio/proportion, 69% (n = 25) passed. For students using dimensional analysis, 96% (n = 24) passed. The effect size is large (h = .78).

It is these specific errors that dimensional analysis is designed to prevent. Below is a worked example for item three demonstrated the prevention of an inversion error. By aligning the conversions with the units, as long as students can cancel the units, they will not invert the numerator with the denominator.

$$\frac{1150\ \cancel{\text{mg}} \qquad 1\text{ml} \qquad = \qquad 38\text{ml}}{\text{Dose} \qquad 30\cancel{\text{mg}} \qquad\qquad\qquad\qquad}$$

Item ten

Item ten also proved challenging for the students. Many missed this item as a result of rounding. As this error is not related to calculation, those errors are excluded from this analysis. Absent those errors, 32 (97%) students using dimensional analysis on item ten passed the item, whereas only 17 (53%) students using the ratio/proportion method passed. The effect size for this measure is large (h = 1.66).

Table 9

Student Satisfaction Survey Results

Survey item	Student ranking				
	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
The content was well organized	57.4% (*n* = 27)	29.8% (*n* = 14)	2.1% (*n* = 1)	10.6% (*n* = 5)	0
The content increased my ability to calculate medications	38.3% (*n* = 18)	27.7% (*n* = 13)	25.5% (*n* = 12)	8.5% (*n* = 4)	0
The hands on activities were helpful	53.2% (*n* = 25)	31.9% (*n* = 15)	8.5% (*n* = 4)	6.4% (*n* = 3)	0
The practice questions were helpful	53.2% (*n* = 25)	27.7% (*n* = 13)	10.6% (*n* = 5)	6.4% (*n* = 3)	2.1% (*n* = 1)
The content increased my ability to calculate medications	34% (*n* = 16)	31.9% (*n* = 15)	29.8% (*n* = 14)	4.3% (*n* = 2)	0
The workshop increased my ability to calculate medications	34.8% (*n* = 16)	37% (*n* = 17)	17.4% (*n* = 8)	10.9% (*n* = 5)	0
I had tried dimensional analysis before this workshop	31.9% (*n* = 15)	19.1% (*n* = 9)	10.6% (*n* = 5)	17% (*n* = 8)	21.3% (*n* = 10)
I will use dimensional analysis for the medication exam	40.4% (*n* = 19)	12.8% (*n* = 6)	25.5% (*n* = 12)	12.8% (*n* = 6)	8.5% (*n* = 4)
		Too short	Right length	Too long	No response
Given the topic, was this workshop:		0% (*n* = 0)	89% (*n* = 42)	9% (*n* = 4)	2% (*n* = 1)
1n your opinion, was this workshop:		Introductory	Intermediate	Advanced	No response
		26% (*n* = 12)	64% (*n* = 30)	6% (*n* = 3)	
Please rate the following:	Excellent	Very good	Good	Fair	Poor
Visuals	44.7% (*n* = 21)	34% (*n* = 16)	17% (*n* = 8)	4.3% (*n* = 2)	0
Acoustics	44.7% (*n* = 21)	36.2% (*n* = 17)	17% (*n* = 8)	2.1% (*n* = 1)	0
Meeting space	68.1% (*n* = 32)	23.4% (*n* = 11)	8.5% (*n* = 4)	0	0
Handouts	55.3% (*n* = 26)	19.1% (*n* = 9)	23.4% (*n* = 11)	0	2.1% (*n* = 1)
The program overall	42.6% (*n* = 20)	34% (*n* = 16)	21.3% (*n* = 10)	2.1% (*n* = 1)	0

Research Question Four

What are student perceptions of the schema-based dimensional analysis medication calculation workshop?

As noted in Table 9, most students either agreed or strongly agreed that the content was well organized, increased their ability to calculate medications, had helpful activities, had helpful practice questions, and increased their ability to calculate medication. Nevertheless, students had mixed reports on the use of dimensional analysis with a middle range response to the questions on prior dimensional analysis use as well as on their plans to use it for the Med Calc exam. Interestingly, 25 (53%) workshop attendees indicated they would use dimensional analysis on the medication calculation exam while 33 (53%) students in the spring cohort used dimensional analysis on the exam. Additionally, most students felt the workshop was of the correct length and at an either introductory or an intermediate level. Most students rated the visuals, acoustics, meeting space, handouts, and overall program as either *excellent* or *very good*. Though the survey included areas for open-ended responses, very few of them were collected and none of the responses indicated changes or enhancements needed for future workshops.

Overall, the workshop was well liked by students and returned promising results. The findings demonstrated an improvement in the test scores and first-time pass rates for students who attended the complete workshop. These findings seem to indicate that the schema-based dimensional analysis workshop intervention had an overall positive influence on Med Calc exam results. The following chapter explores the implications of these findings and presents recommendations for teaching medication calculation as well as suggestions for future research on this topic.

CHAPTER V

SUMMARY, LIMITATIONS, DISCUSSIONS, AND IMPLICATIONS

This study was aimed at improving the medication calculation competence of nursing students through a schema-based workshop in which dimensional analysis was used as the calculation method within the context of maternal–child nursing. The overreaching goal of this work was to improve the teaching of medication calculation in nursing education and to prevent future medication errors. A summary of the study and results is presented followed by a discussion of limitations and findings. Recommendations for future research as well as implications for educational practices are also presented.

Summary of Study

In the United States, medication errors are far too common as estimates indicate they injure at least 1.5 million people every year (Weeks, Clochesy, Hutton, & Moseley, 2013). These medication errors lead to at least 7,000 deaths and exceed $2 billion in unnecessary health-care expenditures annually (Athanasakis, 2012). Although medication administration is multifactorial and includes several different processes and personnel, it is ultimately the nurse as the last link in the chain who either places the medication in the patient's hand or injects it into the patient. This responsibility is onerous and requires absolute accuracy in each of the multiple steps involved. A primary phase in medication administration involves the calculation of the appropriate dose as many medications administered in the hospital do not come in pill form. In those cases, it is up to the nurse to determine the appropriate concentration, dilution, and amount of medication to administer, which requires the ability to perform complicated mathematics. The results reported in the literature provide support for assertions that calculation errors translate to the bedside and nurses need to improve their arithmetic skills to safeguard against medication error (Sherriff, Wallis, & Burston, 2011) as estimates into medication errors suggest that up to 11% to 14% of all medication errors relate to incorrect calculation (Fleming, Brady, & Malone, 2013). Additionally, the findings reported in the literature demonstrate limited success in improving a nursing student's ability to perform medication calculations accurately (Bagnasco et al., 2016; Stolic, 2014).

Although the significance of medication calculation has been clearly identified in the literature, the results of differing educational approaches have been met with mixed results and demonstrate difficulty in teaching medication calculation (Stolic, 2014). The educational approaches center on two primary themes: solving methods and instructional approaches to teaching medication calculation.

Three differing approaches to solving medication calculation problems have been described in the literature: formulas, ratio/proportion, and dimensional analysis. The formula method is a systematic problem-solving method that requires student memorization of primary formulas. Nevertheless, as indicated in the literature, formula use in medication calculation leads to errors as students often struggle with formula memorization (Coyne, Needham, & Rands, 2013; Harvey et al., 2010; Stolic, 2014). Second, the ratio/proportion method requires students to convert units into the same unit of measure before performing the calculations (Hunter-Revell & McCurry, 2013). This method, however, has also been demonstrated to be problematic (Hunter-Revell &

McCurry, 2013). Lastly, dimensional analysis is a method for solving complex medication calculations, and several researchers have found decreased student errors associated with its use (Koharchik & Hardy, 2013; Koharchik, Hardy, King, & Garibo, 2014; Stolic, 2014).

Next, in looking at specific methods for improving medication calculations in nurses, several scholars have reported on educational interventions aimed at improving student performance on medication calculation exams (Coyne et al., 2013; Ramjen et al., 2014; Stolic, 2014). Some have revealed positive findings with improved scores (Coyne et al., 2013), 100% passing rates (Ramjen et al., 2014), and decreased number of errors (Wright, 2007, 2008); none of these studies, however, had a comparison group and all were employed with multiple methods of instruction, making it difficult to determine which methods contributed to student improvement (Stolic, 2014). Additionally, many of the studies involved several interventions over the course of an entire semester, yet students remained unable to master the calculations (Coyne et al., 2013; Wright, 2005, 2007, 2008; Stolic, 2104). As a result, the study presented here was focused on a single short intervention as a starting point to determine effective measures aimed at aiding students to develop accurate medication calculation skills.

Theoretical framework

The theoretical framework for this research is schema theory with a focus on schema-based instruction (SBI). This research was aimed at developing a medication calculation schema that involved identifying needed information, use of dimensional analysis for solving, and placing the problems in the context of maternal–child nursing.

A schema is a knowledge structure that provides an organizational system for the storage of information (Driscoll, 2005). These storage containers, when used correctly, aid in retention of information and improve recall and accuracy. SBI has been used successfully in other areas of education and is a promising approach to teaching ratio and proportion work problems such as those needed to solve medication calculations in nursing (Jitendra et al., 2009).

In nursing education, the use of SBI may aid in developing a medication calculation schema for students that is more accurate. This schema involves identifying necessary information, using dimensional analysis, and determining the fit of the answer in the context of the patient. These steps should develop an accurate and effective method for medication calculation in the nursing student. This development of a robust medication administration schema will help ensure students accurately calculate and understand the medication in the context of patient care.

Study purpose

The purpose of this study was to determine the effectiveness of using a schema-based workshop, a single method of medication calculation, *dimensional analysis*, within the context of maternal–child medication administration to develop the nursing students' medication calculation schema further into a systematic method for solving medication calculation problems. Although each of these components has been studied individually, the combination is unique and demonstrates promise in the creation of a schema for nursing students that will provide them with long-term medication calculation abilities that are transferable specifically to various other types of medication calculation.

Methodology

The study design included two distinct comparisons. First, a historical comparison was completed between students from the prior semester (fall 2016) and current students (spring 2017) who had access to the workshop. Current students had the option to attend a medication calculation workshop, whereas the fall students did not. Second, as a portion of students did not choose to attend the workshop, a comparison between spring students who attended and spring students who did not was completed. Primary comparisons were of (a) percentage of students achieving 100% on the first attempt of the Maternal Child Medication Calculation (Med Calc) exam, (b) number of errors on the Med Calc, and (c) type of errors on the Med Calc. The second independent variable was the use of dimensional analysis on the Med Calc exam with the dependent variable being student accuracy on each item. Lastly, student perceptions of the workshop were analyzed through a researcher-created, Likert-style student survey. The length of this study was one week with the workshop held on January 23, 2017, and the Med Calc proctored on January 28, 2017.

The sample was a convenience sample drawn from the Senior One prelicensure nursing students enrolled in the bachelor of science in nursing program at a four-year university in Northern California. This nursing school enrolls students in both the spring and fall semesters and has a program of study that is six semesters in length. Study participants were in the fifth of the six semesters of nursing instruction. The comparison group was the entire class of students who were in the Senior One cohort in the fall of 2016 (n = 99). At that time, the workshop had not been developed, and thus, these students are used for comparison data. Students who were in the Senior One cohort in the spring of 2017 were invited to attend the workshop (*n* = 75). A total of 42 students attended and completed the entire workshop, 24 students did not attend, and 9 students attended a portion of the workshop.

Research questions

This study was designed to explore the impact of a schema-based dimensional analysis medication calculation workshop on student performance on the Med Calc exam. The research questions were designed to build on prior research in this area and to fill in some of the gaps in the literature. This study proposed to answer four key questions:

1. What is the effect of a schema-based dimensional analysis medication calculation workshop on the first-time pass rate on the Maternal Child Medication Calculation (Med Calc) exam for senior prelicensure nursing students?
2. To what extent does participation in a schema-based dimensional analysis medication calculation workshop influence the type and number of errors on the Med Calc among prelicensure nursing students?
3. To what extent does use of dimensional analysis on the Med Calc influence student performance on the Med Calc?
4. What are student perceptions of the schema-based dimensional analysis medication calculation workshop?

Summary of Findings

The results indicate that the spring students who attended the workshop had the best results on the Med Calc exam as 85.7% of spring students who completed the workshop passed on the first attempt as compared with 66.7% of spring students who did not attend the workshop and with 68.7% of fall students. Next, a comparison of the means between groups demonstrated that the spring cohort who completed the workshop was the highest (9.85, *SD* = .42) when compared with the fall cohort (9.55, *SD* = .82) and with the spring students who did not attend the workshop (9.5, *SD* = .83). Additionally, only one (2%) spring student who completed the workshop missed more than one item on the exam compared with three (13%) spring students who did not attend the workshop and with ten (10%) fall students.

Research question one

What is the effect of a schema-based dimensional analysis medication calculation workshop on the first-time pass rate on the Maternal Child Medication Calculation Exam (Med Calc) exam for senior prelicensure nursing students?

As a result of the significance of medication calculation errors, the first-time pass rate for this exam was set at 100% mastery. Any item missed on the medication calculation exam could have led to an error in the clinical setting. Therefore, for all results on this exam, there was no tolerance for error.

In the fall, 68.7% (*n* = 68) of the students passed on the first attempt, whereas only 66.7% (*n* = 16) of the spring cohort who did not attend the workshop passed. These pass rates are similar and indicate that the performance on this exam between the fall students and the spring students who chose not to attend the workshop were similar (*h* = .04). Cohen's h is a measure of effect size that is used with proportions. With .2 considered small, .5 medium, and .8 large (Chen et al. 2010).

Spring students who completed the workshop had a higher first-time pass rate (85.7%) when compared with students who did not to attend the workshop (66.7%). This difference demonstrates a small-to-medium effect size (*h* = .43). These findings indicate that there is a difference in medication calculation performance between students who completed the workshop and those who did not.

Research question two

To what extent does participation in a schema-based dimensional analysis medication calculation workshop influence the type and number of errors on the Med Calc among prelicensure nursing students?

To answer this question, data analysis included comparing the overall mean score, error rates, and an analysis of the number and type of errors for each incorrect answer on the Med Calc between students who attended 100% of the workshop and those who did not. First, after evaluating the means, a higher score was found for students who completed the workshop (9.85, *SD* = .42) when compared with students who took the same exam in the fall (9.55, *SD* = .82). Cohen's *d* effect size was moderate (.46). Cohen's *h* was .43.

Additionally, when comparing spring students who attended the entire workshop with those who did not, the spring full workshop attendees outperformed those who did not. The mean for students who attended the entire workshop was (9.85, *SD* = .42) as compared with those who did not attend (9.50, *SD* = .83) (*d* = .52). The Cohen's *d* effect size for all comparisons is moderate, indicating that the students who attended 100% of the workshop in the spring performed better on the Med Calc when compared with their peers.

Next, an exploration into the overall number of items missed between groups illustrates that the fall cohort, on average, missed more items than did those who attended the workshop in the spring with 31% of fall students and 33% of spring non workshop students missing at least one item as compared with 14% of the students who attended the complete workshop in the spring (*h* = .41, .45).

Additionally, the analysis demonstrates that only 2% (*n* = 1) of the spring full workshop attendees missed two or more items on the exam, whereas 10% (*n* = 10) of the fall students and 12% (*n* = 3) of the spring students who did not attend missed more than two items. Furthermore, the result of an exploration of individual items on the exam demonstrates noteworthy differences in both the numbers and the types of errors committed by the students.

Item one was easy as demonstrated by the student results. Only one fall student missed this question, whereas four spring students missed this question. Of the spring students, three had attended the workshop. After analyzing the exams, it was found that students confused the problem setup and confused dose per day versus dose per dose. None of the students attempted dimensional analysis on this question. Interestingly, this item is the only item where the spring workshop attendees underperformed the fall students.

For many students, errors were associated with the inability to set up the problem correctly. In some cases, this was a result of the student not being able to determine which information from the question was needed to solve the problem (*conceptual*) or a result of the student using the correct information but making errors in the setup, such as inverting the denominator and the numerator (*setup*).

These conceptual and setup errors were common with questions two, four, five, six, and eight. Although these questions were easy and most students in all groups performed well, the goal of 100% accuracy mandates exploration into these errors. On these questions, fall students who missed these items had errors categorized as *conceptual*, *setup*, or *decimal placement*. Spring students who did not attend the workshop had problems categorized as *conceptual*, *setup*, and *rounding*. Students who completed the spring workshop calculated these items with 100% mastery.

Item three proved challenging for the fall students.. Overall, 12.12% (n = 12) of fall students missed this item. The most common error involved the students inverting the numerator and the denominator. For the spring cohort, 2.38% (n = 1) of the students in the workshop group missed this question. The difference between these scores demonstrated a small-to-medium effect size (h = .36). In looking at the spring exams, this error appeared to be calculator related as the student's setup was correct.

Item ten demonstrated worrisome errors from the fall cohort. Absent rounding errors, the fall cohort made eight errors on item ten that were all related to decimals. These errors can lead to tenfold errors and can demonstrate that the students did not use the correct conversion.

Research question three

To what extent does use of dimensional analysis on the Med Calc influence student performance on the Med Calc?

Many students used ratio/proportion for the easier problems on the exam but then converted to the use of dimensional analysis for the more complicated questions. Comparing the two most difficult questions reveals key findings.

Item three

First, item three was missed by 12% (n = 12) of fall students and by 2.38% (n = 1) of spring students. Therefore, the item was challenging. Looking at student solving methods, 48.0% (n = 36) of the students used the ratio/proportion method whereas 34.7% (n = 26) used dimensional analysis. Of the students using ratio/proportion, 69% (n = 25) passed. Of the students using dimensional analysis, 96% (n = 24) passed. The effect size was large (h = .78).

Item ten

Many students also struggled with item ten. Initially, many failed the item as a result of rounding errors that were not related to calculation. Nevertheless, once the student results for rounding were removed, 32 (97%) students using dimensional analysis passed item ten compared with 17 (53%) students using the ratio/proportion method. The effect size for this measure was large (h = 1.16).

Research question four

What are student perceptions of the schema-based dimensional analysis medication calculation workshop?

Most students either agreed or strongly agreed that content was well organized, increased their ability to calculate medications, and included activities and questions. Students indicated that the workshop increased their ability to calculate medication. Students were divided, however, on the importance of the use of dimensional analysis as well as on their plans to use it as a solving method for the upcoming Med Calc exam. Most students also reported that the workshop was of the correct length and at either an introductory or an intermediate level with excellent or very good visuals, acoustics, meeting space, handouts, and overall program.

Overall, the workshop was well liked by students and returned promising results. The findings demonstrated an improvement in the test scores and first-time pass rates for students who attended the complete workshop. These findings seem to indicate that the schema-based dimensional analysis workshop intervention had an overall positive influence on medication calculation exam results.

Limitations

This research study had some inherent limitations. First, this study was not an experimental design. It was a posttest study comparing two groups of students from differing semesters. Therefore, it is possible that gains in student scores were related to variables other than the independent variable. Next, the lack of recording attendance at the event may have led to inaccurate assignment of students into study groups. Although the investigator collected information on student's attendance four days later, it is possible that students were inaccurate in their representation of workshop attendance. As the investigator was also the students instructor, it is possible that students misrepresented their workshop attendance in order to please the instructor. Additionally, there could be underlying factors such as motivation that influenced students to not attend or attend a portion that influenced the scores more than the workshop.

This study was conducted at a single university in Northern California. The sample was a convenience sample of students enrolled in the maternal–child course taught by the investigator. Therefore, the study findings may not be generalizable beyond this sample. The students' instructor was the investigator, so social desirability may have influenced both the survey results and the decision to participate in the workshop

Furthermore, it is possible that the Med Calc exam is not an accurate reflection of the medication calculations required of a practicing nurse. This exam was designed to be an authentic assessment of the student's ability to calculate in the clinical setting. As a result, there is no psychometric testing or construct analysis for this exam. It is noted that the research questions were designed to measure performance on this exam; as an authentic assessment, however, it is hoped that the student's ability to calculate in the clinical setting was also measured through the exam. Given the limitations of the exam, no claims can be made as to student performance outside of the classroom.

Additionally, there are limitations concerning the intervention. First, workshop participation may have been influenced by extraneous factors. The workshop was scheduled at the start of the spring semester when the students did not have any scheduled nursing courses, yet some could not attend because of scheduling of courses outside of the nursing department, and some may have chosen not to attend for other reasons. Second, the researcher is also the instructor for the course so students may have felt coerced or obligated to attend the workshop. Next, the Med Calc exam is an authentic, high-stakes assessment, so students may have participated in the workshop solely to improve exam performance and not to learn dimensional analysis. Additionally, the intervention itself was a short, one-shot intervention without follow-up and may not have been enough to develop a medication calculation schema. Lastly, there is no direct measure of schema formation. Therefore, it is difficult to make assertions as to whether the students indeed improved their medication calculation schema. Given these limitations, the findings indicate that the students who attended the entire workshop had less errors on the Med Calc when compared with all other groups.

Discussion of Findings

The findings seem to indicate that workshop attendance and use of dimensional analysis have a positive impact on student performance on the Med Calc exam. Key findings indicated that the intervention was successful in improving the first-time pass rate, mean scores, and student performance on difficult items.

The first-time pass rate for students attending the workshop was significantly higher than for all other groups with 85.7% of the students who attended the workshop passing on the first attempt as compared with 68.7% of the fall cohort (Cohen's h = .39) and 66.7% of the spring cohort (Cohen's h = .43) who did not attend the workshop.

The effect size comparison was moderate to large for all comparison groups. These findings indicate that there is a positive relationship between attending the workshop.

The mean score for each group demonstrated that the intervention group performed moderately better (*M* = 9.85, *SD* = .42) than did the fall 2016 students (*M* = 9.55, *SD* = .92, *d* =.46) and spring 2017 who did not attend the workshop (*M* = 9.50, *SD* = .83, *d* = .52). The result of the analysis of individual items also indicates that the workshop attendees had less conceptual errors, less setup errors, and performed better on items of increased complexity. These findings indicate that there is a difference in medication calculation performance between students who completed the workshop and those who did not.

In looking more specifically at the use of dimensional analysis, the findings support the use of dimensional analysis over the other solving methods. Students who used dimensional analysis on the exam had significantly less errors. Additionally, for several items on the exam, all students using dimensional analysis were accurate. This is not true of any other problem-solving method. This shows promise for future use of dimensional analysis as an accurate problem-solving method.

Dimensional analysis proved especially beneficial for the more complicated multistep conversions that students typically have difficulty with. On this exam, the most difficult items were number 3 and 10. For item 3, 36 students used ratio/proportion problem solving and had a 69% rate of accuracy compared with 26 students who used dimensional analysis whose accuracy rate was 92%. This finding indicates a large effect size (*h* = .61). Dimensional analysis proved beneficial for item 10 as well with only 17 (53%)

students accurate on this item as compared to the 32 dimensional analysis students who had a 97% accuracy rate. Dimensional analysis outperformed all other methods. However, the most significant gains were on the more complex, multistep items. These findings lead to the conclusion that dimensional analysis is superior method for solving medication calculation problems.

Nevertheless, even in the most successful group, 6 of the 42 students failed the Med Calc exam. Therefore, there is ongoing work to be done to address the issue of medication calculation education.

Implications for Research

The purpose of this study was to fill gaps in the prior literature as well as to improve medication calculation education with an over-reaching aim of preventing medication calculation errors that result in medication administration errors. Much of the medication calculation research was descriptive and lacking a comparison group (Coyne, Needham, & Rands, 2013; Ramjan et al., 2013; Stolic, 2014). Absent the comparison, there is no true baseline and thus it was difficult to infer the ability of the intervention influence student test scores. Therefore, this study included two distinct comparisons. First, the study compared test results between intact cohorts from the fall of 2016 and the spring of 2017. Fall students who did not have access to the workshop were used to establish a baseline of average first-time scores among like nursing students. Bagnasco et al., 2016 reported pass rates ranging from 62%-65% across the curriculum which mirrored the baseline mean from the fall group (68.7%). Next, spring exam scores from students who completed the workshop were compared with the scores of students who did not. This comparison demonstrated that the workshop may have positively influenced student test scores.

This research study aimed to demonstrate the effectiveness of a single, short intervention as prior research implemented multiple interventions over the course of an entire semester (Coyne, Needham, & Rands, 2013; Ramjan et al., 2013; Stolic, 2014). The findings indicated that it is possible to improve student test scores with a single intervention, however, some students continued to make errors. Additionally, the improved pass rate of spring students who attended the workshop (85.7%) mirrors results from the dimensional analysis research conducted by Koohestani and Bachcheghi (2010) who demonstrated mean scores of 85% for students taught DA. However, these marks continued to fall short of 100% mastery. As this study was conducted with students who were in the 5th of 6 semesters of study, it would be prudent at this point to conduct research with students earlier in their studies to determine if the creation of a solid medication calculation schema at the onset of nursing education would further improve the ability of students to master medication calculation.

One limitation for this study was the absence of psychometric testing and use of instructor-created conceptualized exams (Stolic, 2014). Future research would be aided by the creation of a psychometrically sound exam as a standardized assessment of student performance on medication calculation. The lack of standardization on exams makes it difficult to compare and contrast results from multiple schools. Creation of this examination could also be used to test if the student's inability to pass at the 100% mark was related to the exam or student ability.

An additional research need is for longitudinal work that connects the teaching of medication calculation from the beginning of the nurse's education and includes the practicing nurse. One suggestion would be to teach dimensional analysis at the very beginning of nursing education then supporting that dimensional analysis throughout the full length of their education.

Implications for Practice

The field of nursing education is charged with implementing evidence-based practice. Therefore, nurse educators should be implementing evidence-based teaching pedagogy in the classroom. Medication calculation is a high-risk task that is difficult and rife with anxiety for the student. Providing the student with consistent and systematic methods for solving medication calculation questions should both decrease student calculation error that then will decrease the incidence of medication errors caused by inaccurate calculation. Implications for nursing education point to the importance of developing the nursing student's medication calculation schema.

Based upon the study findings, suggestions for teaching medication calculation include the use of teaching dimensional analysis early on in the nursing students career to develop a sound and accurate medication calculation schema. As dimensional analysis outperforms all other methods for items of varying difficulty, it should be used and taught as the sole problem-solving strategy. Additionally, as much of the research supports multiple interventions that include online learning, workbooks, case studies (Stolic, 2014), supporting this instruction with multiple interventions is recommended.

Many schools teach multiple approaches to performing medication calculation (Stolic, 2014), however, due to the strength of research on dimensional analysis, the research indicates that DA should be the exclusive method taught (Kohtz and Gowda, 2010; Koharchick and Flavin, 2017; Koohestani & Bachcheghi, 2010; Rice and bell, 2005). However, many faculty do not teach dimensional analysis. Though the reasons are not defined in the literature, it can be inferred that some faculty may not be comfortable with the use and teaching of dimensional analysis. Therefore, education of nursing faculty is an important first step to improving the medication calculation success in nursing students.

In closing, this study asserts the importance of teaching dimensional analysis in nursing schools. Additionally, teaching within the context of patient care and providing hands on practice will further aid in the development of the context of medication administration. These instructional strategies will then develop and enhance the medication calculation schema. This schema, if developed accurately improve the student's calculation accuracy over time and thus decrease the incidence of medication errors resulting from medication calculation.

Final Summary

This researcher set out to test whether a schema-based dimensional analysis would improve performance on the Med Calc exam among prelicensure nursing students at a single university. The results are promising and seem to demonstrate the workshop improved student scores.

REFERENCES

Agency for Healthcare Research and Quality Patient Safety Network. (2015). Medication errors; Patient safety primers. https://psnet.ahrq.gov/primers/primer/23/medicaton-errors

Athanasakis, E. (2012). Prevention of medication errors made by nurses in clinical practice. *Health Science Journal, 6*, 773–783.

Bagnasco, A., Galaverna, L., Aleo, G., Grugnetti, A. M., Rosa, F., & Sasso, L. (2016). Mathematical calculation skills required for drug administration in undergraduate nursing students to ensure patient safety: A descriptive study: Drug calculation skills in nursing students. *Nurse Education in Practice*, *16*, 33–39. doi:10.1016/j.nepr.2015.06.006

Betz, N. E., & Hackett, G. (1983). The relationship of mathematics self-efficacy expectations to the selection of science-based college majors. *Journal of Vocational Psychology, 23*, 329–345.

Blissett, S., Cavalcanti, R., & Sibbald, M. (2012). Should we teach using schemas? Evidence from a randomized trial. *Medical Education 2012, 46*, 815–822.

Chen, H., Cohen, P., & Chen, S. (2010). How big is a big odds ratio? Interpreting the magnitudes of odds ratios in epidemiologic studies. *Communications in Statistics – Simulation and Compliation*, 39, 860-864.

Cookson, K. L. (2013). Dimensional analysis: Calculate dosages the easy way. *Nursing, 43*(6), 57–62. doi:10.1097/01.NURSE.0000428696.87216.e1

Coyne, E., Needham, J., & Rands, H. (2013). Enhancing student nurses' medication calculation knowledge: Integrating theoretical knowledge into practice. *Nurse Education Today*, *33*, 1014–1019. doi:10.1016/j.nedt.2012.04.006

Craig, G., & Sellers, S. (1995). The effects of dimensional analysis on the medication dosage calculation abilities of nursing students. *Nurse Educator, 20*(3), 14–18.

Driscoll, M. P. (2005). *Psychology of learning for instruction* (3rd ed.). San Francisco, CA: Pearson.

Fleming, S., Brady, A., & Malone, A. (2014). An evaluation of the drug calculation skills of registered nurses. *Nurse Education in Practice, 14*, 55–61. doi:10.1016/j.nepr.2013.06.002

Fuchs, L. S., Fuchs, D., Finelli, R., Courey, S. J., & Hamlett, C. L. (2004). Expanding schema-based transfer instruction to help third graders solve real-life mathematical problems. *American Educational Research Journal, 41*, 419–445.

Fuchs, L. S., Fuchs, D., Finelli, R., Courey, S. J., Hamlett, C. L., Sones, E. M., & Hope, S. K. (2006). Teaching third graders about real-life mathematical problem-solving: A randomized controlled study. *Elementary School Journal*, *106*, 293–312.

Fuchs, L. S., Fuchs, D., Prentice, K., Hamlett, C. L., Finelli, R. & Courey, S. J. (2004). Enhancing mathematical problem-solving among third-grade students with schema-building instruction. *Journal of Educational Psychology, 96*, 635–647.

Grandell-Niemi, H., Hupli, M., Puukka, P., & Leino-Kilpi, H. (2006). Finnish nurses' and nursing students' mathematical skills. *Nurse Education Today*, *26*, 151–161.

Greenfield, S., Whelan, B., & Cohn, E. (2006). Use of dimensional analysis to reduce medication errors. *Journal of Nursing Education, 45*(2), 91–94.

Gregory, D., Guse, L., Davidson, D., Davis, P., & Russell, C. (2009). What clinical learning contracts reveal about nursing education and patient safety. *Canadian Nurse*, *105*(8), 20–25.

Grugnetti, A. M., Bagnasco, A., Rosa, F., & Sasso, L. (2014). Effectiveness of a clinical skills workshop for drug-dosage calculation in a nursing program. *Nurse Education Today*, *34*, 619–624. doi:10.1016/j.nedt.2013.05.021

Harvey, S., Murphy, F., Lake, R., Jenkins, L., Cavanna, A., & Tait, M. (2010). Diagnosing the problem: Using a tool to identify pre-registration nursing students' mathematical ability. *Nurse Education in Practice*, *10*(3), 119–125. doi:10.1016/j.nepr.2009.04.007

Hunter-Revell, S. M., & McCurry, M. K. (2013). Effective pedagogies for teaching math to nursing students: A literature review. *Nurse Education Today*, *33*, 1352–1356. doi:10.1016/j.nedt.2012.07.014

Institute for Medication Safety Practice. (2015, September 23). Quarterly watch annual report issue. Retrieved from https://www.ismp.org/QuarterWatch/pdfs/2014Q4.pdf

Jitendra, A. K., Dupuis, D. N., Rodriguez, M. C., Zaslofsky, A. F., Slater, S., Cozine-Corroy, K., & Church, C. (2013). A randomized controlled trial of the impact of schema-based instruction on mathematical outcomes for third-grade students with mathematics difficulties. *Elementary School Journal*, *114*, 252–276.

Jitendra, A. K., Griffin, C. C., Haria, P., Leh, J., Adams, A., & Kaduvettoor, A. (2007). A comparison of single and multiple strategy instruction on third-grade students' mathematical problem-solving. *Journal of Educational Psychology*, *99*, 115–127.

Jitendra, A. K., Harwell, M. R., Dupuis, D. N., Karl, S. R., Lein, A. E., Simonson, G., & Slater, S. C. (2015). Effects of a research-based intervention to improve seventh-grade students' proportional problem-solving: A cluster randomized trial. *Journal of Educational Psychology*, *107*, 1019–1034.

Jitendra, A. K., Star, J. R., Dupuis, D. N., & Rodriguez, M. C. (2013). Effectiveness of schema-based instruction for improving seventh-grade students' proportional reasoning: A randomized experiment. *Journal of Research on Educational Effectiveness, 6*(2), 114–136.

Jitendra, A. K., Star, J. R., Rodriguez, M., Lindell, M., & Someki. F. (2011). Improving students' proportional thinking using schema-based instruction. *Learning and Instruction*, *21*, 731–745.

Jitendra, A. K., Star, J. R., Starosta, K., Leh, J. M., Sood, S., Caskie, G., & ... Mack, T. R. (2009). Improving seventh grade students' learning of ratio and proportion: The role of schema-based instruction. *Contemporary Educational Psychology*, *34*, 250–264.

Jukes, L., & Gilchrist, M. (2006). Concerns about numeracy skills of nursing students. *Nurse Education in Practice, 6*(4), 192–198.

Kalyuga, S. (2013). Enhancing transfer by learning generalized domain knowledge structures. *European Journal of Psychology of Education, 28*, 1477–1493.

Keers, R. N., Williams, S. D., Cooke, J., & Ashcroft, D. M. (2013). Prevalence and nature of medication administration errors in health care settings: A systematic review of direct observational evidence. *Annals of Pharmacotherapy*, *47*, 237–256. doi:10.1345/aph.1R147

Koharchik, L., Hardy, E., King, M., & Garibo, Y. (2014). Evidence-based approach to improve nursing student dosage calculation proficiency. *Teaching & Learning in Nursing, 9*(2), 69–74. doi:10.1016/j.teln.2013.12.003

Koharchik, L. S., & Hardy, E. C. (2013). As easy as 1, 2, 3! Dosage calculations. *Nursing Made Incredibly Easy, 11*(1), 25–29. doi:10.1097/01.NME.0000424170.34092.7a

Koharchik, L., & Flavin, P. M. (2017). Teaching students to administer medications safely. *AJN American Journal of Nursing, 117*(1), 62–66.

Kohtz, C., & Gowda, C. (2010). Teaching drug calculation in nursing education: A comparison study. *Nurse Educator, 35*(2), 83–86. doi:10.1097/NNE.0b013e3181ced8a8

Koohestani, H., & Baghcheghi, N. (2010). Comparing the effects of two educational methods of intravenous drug rate calculations on rapid and sustained learning of nursing students: Formula method and dimensional analysis method. *Nurse Education in Practice, 10*, 233–237. doi:10.1016/j.nepr.2009.11.011

Lahti, M., Hätönen, H., & Välimäki, M. (2014). Impact of e-learning on nurses' and student nurses' knowledge, skills, and satisfaction: A systematic review and meta-analysis. *International Journal of Nursing Studies*, *51*(1), 136–149. doi:10.1016/j.ijnurstu.2012.12.017

Lee, T., & Lin, F. (2013). The effectiveness of an e-learning program on pediatric medication safety for undergraduate students: A pretest–post-test intervention study. *Nurse Education Today*, *33*, 378–383. doi:10.1016/j.nedt.2013.01.023

Maag, M. (2004). The effectiveness of an interactive multimedia learning tool on nursing students' math knowledge and self-efficacy. *Computers, Informatics, Nursing, 22*(1), 26–33.

McMullan, M., Jones, R., & Lea, S. (2010). Patient safety: Numerical skills and drug calculation abilities of nursing students and registered nurses. *Journal of Advanced Nursing*, *66*, 891–899. doi:10.1111/j.1365-2648.2010.05258.x

Institute for Medication Safety Practice. (2015, September 23). Quarterly watch annual report issue. Retrieved from https://www.ismp.org/QuarterWatch/pdfs/2014Q4.pdf

National Coordinating Council for Medication Error Reporting and Prevention. (2017). About med errors. Retrieved from http://www.nccmerp.org/about-medication-errors

Pierce, R., Steinle, V., Stacey, K., & Widjaja, W. (2008). Understanding decimal numbers: A foundation for correct calculations. *International Journal of Nursing Education Scholarship*, *5*(1), 1–15.

Powell, S. (2011). Solving word problems using schemas: A review of the literature. *Learning Disabilities Research & Practice*, *26*(2), 94–108.

Ramjan, L. M., Stewart, L., Salamonson, Y., Morris, M. M., Armstrong, L., Sanchez, P., & Flannery, L. (2014). Identifying strategies to assist final semester nursing students to develop numeracy skills: A mixed methods study. *Nurse Education Today*, *34*, 405–412. doi:10.1016/j.nedt.2013.03.017

Rice, J., & Bell, M. (2005). Using dimensional analysis to improve drug dosage calculation ability. *Journal of Nursing Education*, *44*, 315–318.

Sherriff, K., Burston, S., & Wallis, M. (2012). Effectiveness of a computer based medication calculation education and testing programme for nurses. *Nurse Education Today, 32*(1), 46–51. doi:10.1016/j.nedt.2011.01.020

Sherriff, K., Wallis, M., & Burston, S. (2011). Medication calculation competencies for registered nurses: A literature review. *Australian Journal of Advanced Nursing, 28*(4), 75–83.

Stolic, S. (2014). Educational strategies aimed at improving student nurses' medication calculation skills: A review of the research literature. *Nurse Education in Practice*, *14*, 491–503. doi:10.1016/j.nepr.2014.05.010

Van Lanker et al. (2016). The effectiveness of an e-learning course on medication calculation in nursing students: a clustered quasi-experimental study. *Journal Of Advanced Nursing*, *72*(9), 2054-2064. doi:10.1111/jan.12967

Weeks, K. W., Clochesy, J. M., Hutton, B., & Moseley, L. (2013). Safety in numbers 4: The relationship between exposure to authentic and didactic environments and nursing students' learning of medication dosage calculation problem-solving knowledge and skills. *Nurse Education in Practice, 13*(2), e43–e54. doi:10.1016/j.nepr.2012.10.010

Wright, K. (2005). An exploration into the most effective way to teach drug calculation skills to nursing students. *Nurse Education Today*, *25*, 430–436.

Wright, K. (2007). Student nurses need more than math to improve their drug calculating skills. *Nurse Education Today*, *27*, 278–285.

Wright, K. (2008). Can effective teaching and learning strategies help student nurses to retain drug calculation skills? *Nurse Education Today*, *28*, 856–864.

APPENDICES

Appendix A

Maternal Child Medication Calculation Exam

University of San Francisco, School of Nursing
Medication Dosage Calculation Competency
(#1) Senior 1: NURS428 Pediatric/Obstetric
Clinical

Student Name (print): ____

Clinical Faculty Name: ____

Date: ____________________

- No assistance/coaching permitted by faculty or other students during the exam. Students must adhere to the USF Academic Honesty Policy.
- Students must earn 100% in order to "pass" and administer medications.
- Students must show their work to earn credit.
- Round as directed and place zeroes in the proper locations to earn credit.
- A calculator is permitted….no smart phones or devices.

I have read and understand the directions:

____

(student signature)

Sadie, a 5-year-old (23kg), has been admitted to the pediatric unit with leukemia.

Orders:

- Ampicillin 1150 mg IV q6h (safe dose range 100-200mg/kg/day in divided doses, final maximum concentration not to exceed 30mg/ml, given IV over 15-30min)
- Meropenum 450 mg IV q8h (safe dose range 10-40mg/kg/dose given every 8 hours, final maximum concentration not to exceed 50mg/ml, given over 15-30 min)
- Methylprednisolone 32 mg IV once a day. (safe dose range is 0.5-1.7mg/kg/dose, final max not to exceed 125mg/ml, given over 15 min)

1) The safe dose range of ampicillin for Sadie is__________to________mg/dose.

2) The ampicillin dose as ordered above must be diluted in at least __ml? (Round to the nearest tenth)

3) In order to reconstitute the ampicillin from a 2 gram vial of powder to a liquid, the RN will add 6.8 ml of sterile water as directed in the chart. To give the ordered dose, the RN will then draw up ____________________ ml of ampicillin from the reconstituted vial. (Round to the nearest tenth)

Label Claim	Recommended Amount of Diluent	Withdrawable Volume	Concentration (in mg/mL)
125 mg	1.2 mL	1 mL	125 mg
250 mg	1 mL	1 mL	250 mg
500 mg	1.8 mL	2 mL	250 mg
1 gram	3.5 mL	4 mL	250 mg
2 gram	6.8 mL	8 mL	250 mg

4) The Meropenum that was ordered arrives from pharmacy in a 25 ml piggyback bag. What is the concentration of meropenum in this premixed piggyback bag __mg/ml? Does this premixed bag of medication exceed the final maximum concentration allowed?___(yes/no)

5) The safe dose range of methylprednisolone for Sadie is______ to____ mg/dose. (Round to the nearest tenth). The RN will draw up________ml of the Methylprednisolone pictured here. (Round to the nearest tenth)

40mg/ml

Caroline, 26-years old, is 6 hours post-partum and is suffering from severe pre-eclampsia. She has a peripheral IV infusing 0.9% NaCl.

<u>Orders:</u>

- Hydralazine 6 mg IV now (recommended dose is 5-10 mg IV given over 10 minutes)
- Loading dose: Magnesium sulfate 6 grams IV in 250 ml over 20 minutes (magnesium sulfate must be diluted to a final maximum concentration not to exceed 60mg/ml)
- Magnesium sulfate 2 grams IV per hour after loading dose has infused.

6) Using the vial of Hydralazine pictured here, how much solution will the RN draw up?____(Round to the nearest tenth)

7) When following the recommended infusion time, how many mg/minute of Hydralazine will be administered__? (Round to the nearest tenth).

8) The magnesium sulfate loading dose arrives premixed as 6 grams in a 250 ml bag of 0.9% NaCl. The concentration of drug in this bag is ____________mg/ml. Does this premixed bag of medication exceed the final maximum concentration allowed? __(yes/no).

9) When receiving report, the oncoming nurse asks about the magnesium sulfate by saying, “What is the IV loading dose rate in grams per hour?” The nurse knows that the patient is receiving __grams/hour.

10) After the loading dose has infused, the magnesium sulfate must be infused at 2 grams per hour. Using the same IV bag (6 grams in 250 ml 0.9% NaCl), the rate should be set at___ml/hour. (Round to the nearest whole number)

Appendix B

Workshop Satisfaction Survey

Medication Calculation Workshop
Evaluation Form

Please return this form to the instructor or organizer at the end of the workshop. Thank you.

	Strongly agree				Strongly disagree
1. The content was well organized	1	2	3	4	5
2. The content increased my ability to calculate medications	1	2	3	4	5
3. The hands on activities were helpful	1	2	3	4	5
4. The practice questions were helpful	1	2	3	4	5
5. The content increased my ability to calculate medications	1	2	3	4	5
6. The workshop increased my ability to calculate medications	1	2	3	4	5
7. I had tried dimensional analysis before this workshop	1	2	3	4	5
8. I will use dimensional analysis for the med calc exam	1	2	3	4	5

9. Given the topic, was this workshop: ☐ a. Too short ☐ b. Right length ☐ c. Too long

10. In your opinion, was this workshop: ☐ a. Introductory ☐ b. Intermediate ☐ c. Advanced

11. Please rate the following:

	Excellent	Very Good	Good	Fair	Poor
a. Visuals	☐	☐	☐	☐	☐
b. Acoustics	☐	☐	☐	☐	☐
c. Meeting space	☐	☐	☐	☐	☐
d. Handouts	☐	☐	☐	☐	☐
e. The program overall	☐	☐	☐	☐	☐

12. What did you most appreciate/enjoy/think was best about the course? Any suggestions for improvement?

____

____

____

____

Thank you!
Please return this form to the instructor or coordinator at the end of the workshop.

Appendix C

Study Announcement Letter

Dear Student:
I wanted to take this time to introduce myself. My name is Professor Laureen Turner and I will be teaching Maternal Child Nursing in the spring. I am also a doctoral student in the School of Education. For my dissertation, I am doing a study on medication calculation hoping to improve the first time pass rate on the Senior One medication calculation exam through the use of an interactive workshop.

I am asking you to participate in this research study. However, whether or not you choose to participate in the study, I am also inviting you to participate in the Medication Calculation Workshop on January 23 from 10:00 – 1:00 in MC250. This workshop is highly recommended for all Senior One students.

You will take your med calc exam on Saturday January 28. After the exam, I will collect information from your exam that includes the number and type of errors – if any. This will be so that I can improve the workshop for future nursing cohorts.

Your scores will be kept confidential. No individual identities will be used in any reports or publications resulting from the study. Study information will be coded and kept in locked files or an encrypted computer at all times. Only the lead researcher (myself) will have access to the files. Your original exam will remain securely stored in the department chairs office. Individual results will not be shared with any other students, faculty, or staff at the University of San Francisco.

While there are no direct benefits to you participating in this study, the anticipated benefit of this study is that you will gain a better understanding of how to perform a variety of the calculations needed in maternal/child nursing. This may improve your confidence and help prevent medication errors. There will be no cost to you as a result of taking part in this study.

If you have questions about the research, you may contact me via email at lturner@usfca.edu. If you have further questions about the study, you may contact the IRBPHS at the University of San Francisco, which is concerned with protection of volunteers in research projects. You may reach the IRBPHS office by calling (415) 422-6091 and leaving a voicemail message, by e-mailing IRBPHS@usfca.edu, or by writing to the IRBPHS, Department of Psychology, University of San Francisco, 2130 Fulton Street, San Francisco, CA 94117-1080.

PARTICIPATION IN RESEARCH IS VOLUNTARY. You are free to decline to be in this study, or to withdraw from it at any point. The University of San Francisco is aware of this study but does not require that you participate in this research and your decision as to whether or not to participate will have no influence on your present or future status as a student at The University of San Francisco.

Thank you for your attention. Whether you agree to participate in the study or not, I encourage you to attend the workshop. Consent forms will be available at the workshop and you will be able to choose whether or not to participate in the study at that time.

Sincerely,
Laureen Turner MSN, RN, CNE
Learning and Instruction Doctoral Student
University of San Francisco

Appendix D

Consent for Study Participation

INFORMED CONSENT FORM

UNIVERSITY OF SAN FRANCISCO
CONSENT TO BE A RESEARCH SUBJECT

Purpose and Background

Laureen Turner, a doctoral student, in the School of Education at the University of San Francisco is doing a study on medication calculation in prelicensure nursing education. The indicates that this intervention may improve student ability to calculate medication.

Procedures

If I agree to be a participant in this study, the following will happen:

1. I will complete attend the Medication Calculation Workshop
2. I will complete the Workshop Satisfaction Survey
3. I will take the previously scheduled Senior One Medication Calculation Exam

Risks and/or Discomforts

1. It is possible that some of the content may be challenging or overwhelming at times. It is possible that this will cause stress and/or anxiety. I am free to decline to answer any questions I do not wish to answer or to stop participation at any time.

2. Participation in research may mean a loss of confidentiality. Student records will be kept confidential. No individual identities will be used in any reports or publications resulting from the study. Study information will be coded and kept in locked files at all times. Only study personnel will have access to the files.

Benefits

The anticipated benefit of this study is that the students will learn several new strategies that may improve accuracy of medication calculation.

Costs/Financial Considerations

There will be no financial costs to me as a result of taking part in this study.

Questions

I have talked to Professor Turner about this study and have had my questions answered. If I have further questions about the study, I may email her at lturner@usfca.edu. If I have any more questions or comments about participation in this study, I should first talk with the researcher, Laureen Turner. If for some reason I do not wish to do this, I may contact the IRBPHS, which is concerned with protection of volunteers in research projects. I may reach the IRBPHS office by calling (415) 422-6091 and leaving a voicemail message, by e-mailing IRBPHS@usfca.edu, or by writing to the IRBPHS, Department of Psychology, University of San Francisco, 2130 Fulton Street, San Francisco, CA 94117-1081.

Consent

I have been given a copy of the “Research Subject’s Bill of Rights” and I have been given a copy of this consent form to keep. PARTICIPATION IN RESEARCH IS VOLUNTARY. I am free to decline to be in this study, or to withdraw from it at any point. My decision as to whether or not to participate in this study will have no influence on my present or future status as a student at the University of San Francisco.

My signature below indicates that I agree to participate in this study.

____

Subject’s Signature | Date of Signature

____

Signature of Person Obtaining Consent | Date of Signature

Appendix E

Practice Exam

University of San Francisco, School of Nursing
Medication Dosage Calculation Competency
Senior 1: Pediatrics and OB

Student Name: ____ Date_________
Clinical Faculty Name: ____

- No assistance/coaching permitted by faculty or other students during the exam.
- Students must earn 100% in order to “pass” and administer medications.
- Students must show their work, round to the nearest tenth correctly, and place zeros in the proper locations to earn credit.
- A calculator is permitted.

The first 5 questions pertain to this pediatric case scenario:

Jess is a 2-year-old who has been admitted to the pediatric unit with fever, pneumonia, dehydration and wheezing. Weight is 22 pounds.
<u>Orders:</u>
- D_5 0.45% NS at “1½ maintenance rate”
- Albuterol 0.5% 0.5ml in 0.5ml NS via nebulizer q2h
- Ampicillin 450mg IV q6h (safe dose range 100-200mg/kg/day in divided doses, final maximum concentration not to exceed 30mg/ml, given IV over 15-30min)
- Methylprednisolone 17 mg IV once a day. (safe dose range is 0.5-1.7mg/kg/dose, final max not to exceed 125mg/ml, give over 15-30 min)
- Ibuprofen 80 mg po q6-8h prn temp >38.5 (safe dose range is 4-10mg/kg/dose)

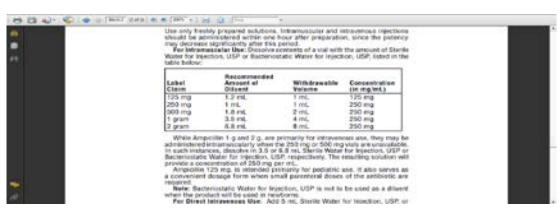
1) In order to deliver the ordered IV fluid, the IV will be set at _________ ml/hr.

2) Using the ampicillin package insert pictured here, the RN will choose the 500 mg vial and add ______ ml of diluent in order to create a concentration of ____________mg/ml.

Then the RN will draw up _______ml in order to administer the correct dose.

The RN calculates that the ampicillin must be diluted in at least _______ ml?

3) The RN decides to add the ampicillin to a 25 ml piggyback bag of 0.9%NS. In order to administer the medication plus the mandatory 20 ml flush in 30 minutes, the IV should be set: ____________ volume, _____________ rate (ml/hr).



Use only freshly prepared solutions. Intramuscular and intravenous injections should be administered within one hour after preparation, since the potency may decrease significantly after this period.

For Intramuscular Use: Dissolve contents of a vial with the amount of Sterile Water for Injection, USP or Bacteriostatic Water for Injection, USP, listed in the table below:

Label Claim	Recommended Amount of Diluent	Withdrawable Volume	Concentration (in mg/mL)
125 mg	1.2 mL	1 mL	125 mg
250 mg	1 mL	1 mL	250 mg
500 mg	1.8 mL	2 mL	250 mg
1 gram	3.5 mL	4 mL	250 mg
2 gram	6.8 mL	8 mL	250 mg

While Ampicillin 1 g and 2 g, are primarily for intravenous use, they may be administered intramuscularly when the 250 mg or 500 mg vials are unavailable. In such instances, dissolve in 3.5 or 6.8 mL Sterile Water for Injection, USP or Bacteriostatic Water for Injection, USP, respectively. The resulting solution will provide a concentration of 250 mg per mL.

Ampicillin 125 mg. is intended primarily for pediatric use. It also serves as a convenient dosage form when small parenteral doses of the antibiotic are required.

Note: Bacteriostatic Water for Injection, USP is not to be used as a diluent when the product will be used in newborns.

For Direct Intravenous Use: Add 5 mL Sterile Water for Injection, USP, or

4) What is the safe dose range of methylprednisolone for Jess?______ to ______mg/dose (round to the nearest tenth).

The RN will draw up ___________ml of methylprednisolone (round to the nearest tenth).

5) In order to deliver the methyprednisolone the RN will inject the drug into the first port and administer the medication via the antegrade method. The tubing label states that the first port is 1ml from the tip. In order to deliver the medication in 30 minutes, the RN will set the IV volume at ________ml and the IV rate at _________ml/hour (whole numbers).

For the next five OB questions, round to the hundredths place.

6) Baby girl Santana weighed 7lbs, 12oz at birth. On day 3, she weighs 7lbs, 4oz. The percentage of weight lost is:___________________________%

7) A preterm labor patient has the following order:

Bolus 500 mL of lR over 30 min. IV STAT

The IV tubing has a drip factor of 10 gtts/mL, You will set your IV drip rate at ________gtts/min?

8) The Preterm labor patient continues to have mild contractions,

Orders: 0.20 mg. subcutaneous Terbutaline q 1 hour until the contractions cease.
Available Concentration: 1 mg/mL Terbutaline ampules.

How much will you draw up for the ordered amount? _________________mL

9) A mother in labor has the following orders:

Primary IV: D5LR IV @ 225 ml/hr continuous.
Secondary IV: Pitocin 20 ml/1L of lactated Ringers IV @ 125 mL/hr continuous.
PiggyBack IV: Kefzol 5 mg/100 ml of Normal Saline IV (to be given 1 times in your 12 hour shift)

Assuming that you correctly maintain the patient's IVs through your 12 hour shift, replacing IV bags as needed, the patient's total IV intake for the 12 hours will be _______________ mL.

10) Postpartum patient with Pregnancy Induced Hypertension (PIH).

Protocol: The $MgSO_4$ protocol calls for an IV solution of 40 Gm $MgSO_4$ in 500 mL D5W

The $MgSO_4$ that you have on hand is in vials of 10 mL each. The label on the vial states: "500 mg $MgSO_4$/mL".

How many vials will you need to give 40 grams? _____________________ vials

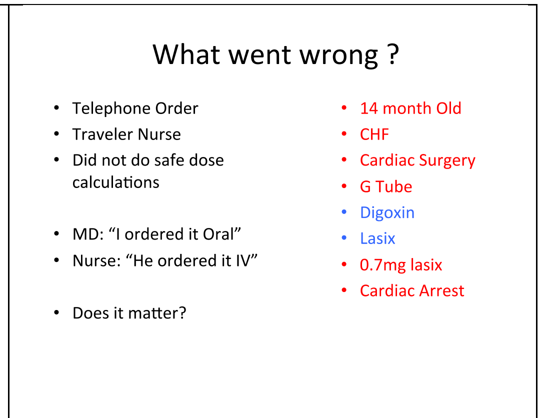
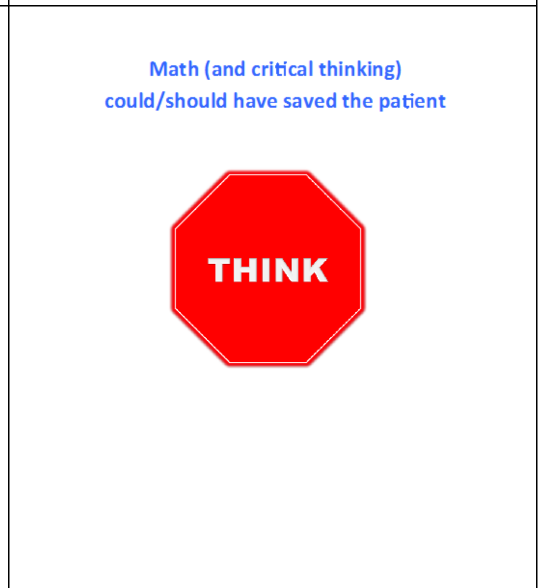
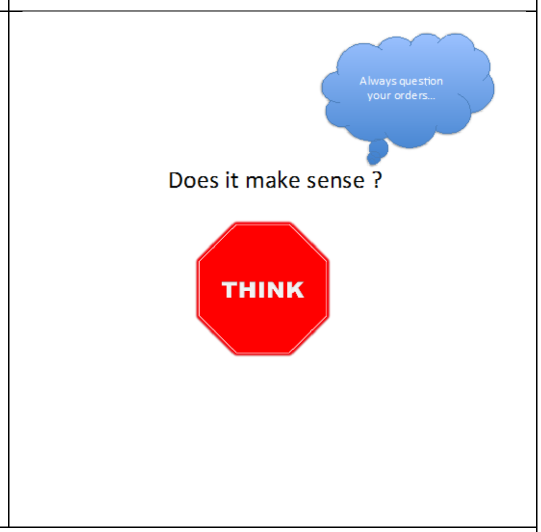
How much will you draw up to equal 40 grams? ______________________ mL

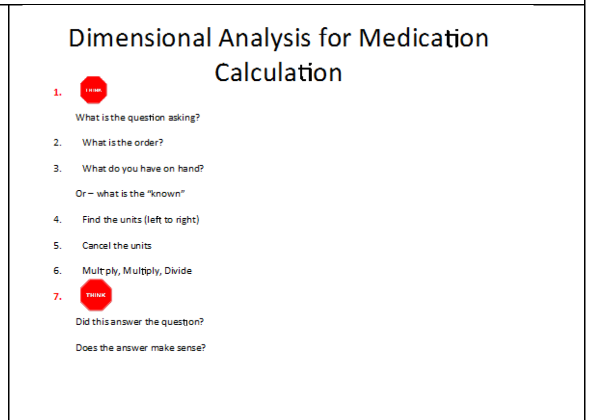
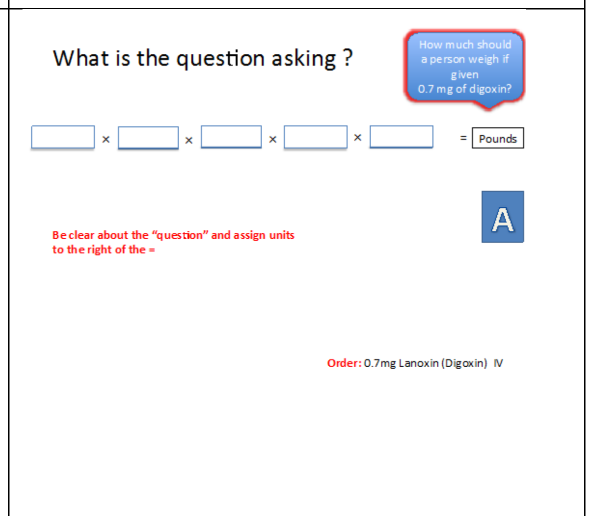
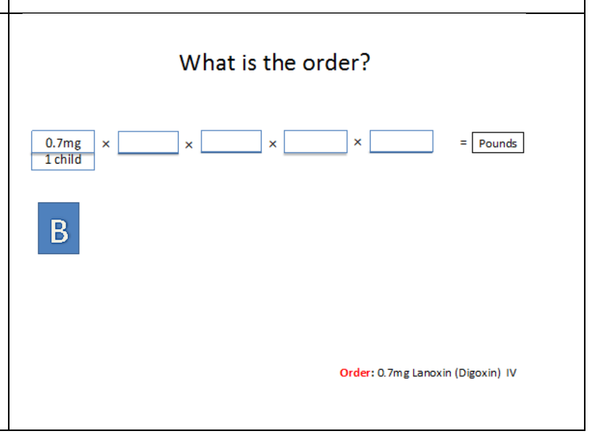
Appendix F

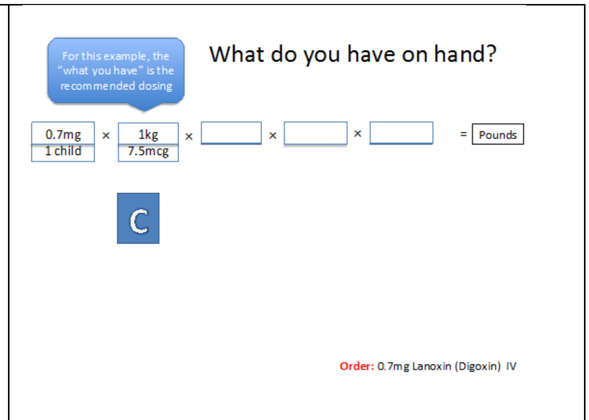
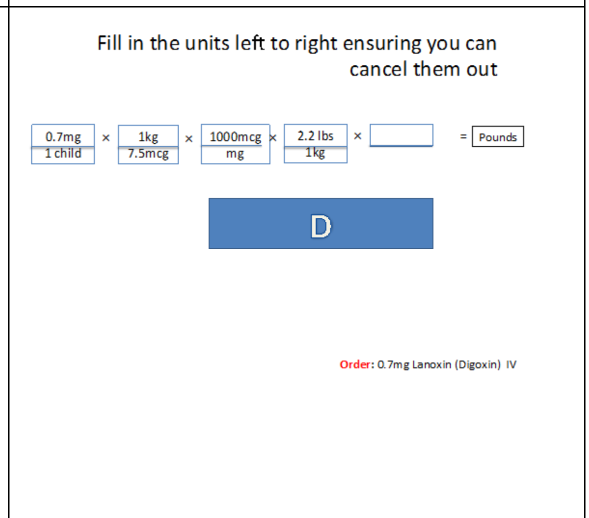
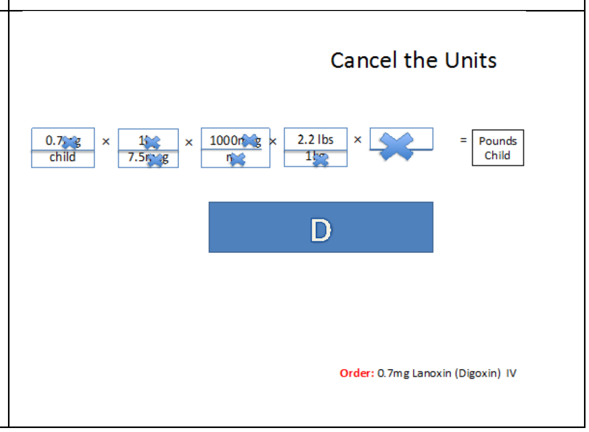
PowerPoints and Detailed Lesson Plan From the Workshop

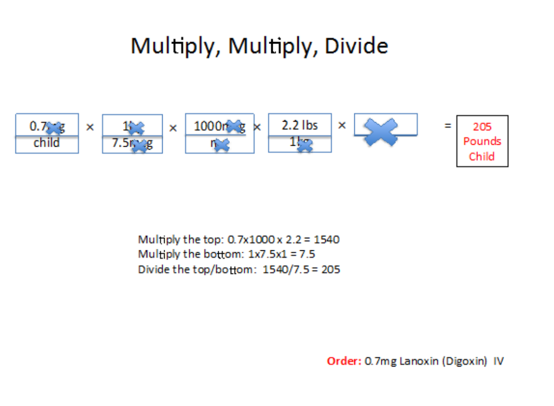
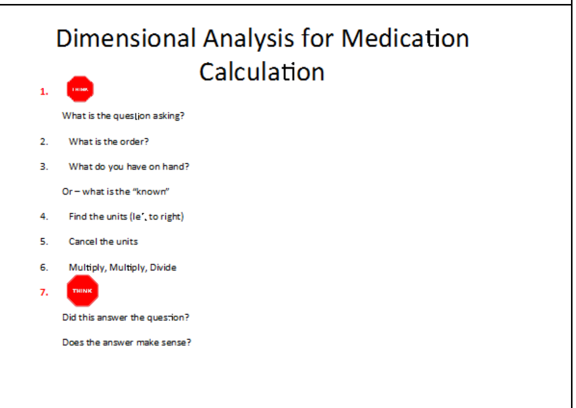
This slide introduces the topic and the definition of dimensional analysis as a structured approach to solving medication calculation problems. This approach is the medication calculation schema that is to be developed over the course of the workshop.	Medication Calculation Using Dimensional Analysis Laureen Turner EdD(c), RN, CNE In partial fulfillment for the Doctor of Education Degree University of San Francisco
The purpose of this slide is to introduce the purpose of the study.	This Workshop • Research Study • Improve Medication Calculation Competence • Primary Measure: first time pass rate • Participation is voluntary • Survey is voluntary • In conjunction with Dr Susan Prion as dissertation chair • Yes – you get a copy of this ppt…. ☺
To invoke schema and place instruction in context, you need to get the student to see why something matters. The workshop begins with asking students the relevance of why medication calculation matters.	Medication Calculation Why Should We Care? 
Instruct students to put pencils down and just listen/interact until instructed otherwise. For the next few slides, students should listen to the story and then engage in the aspects of the case study that were preventable.	

This story places the importance of medication calculation into the awareness of the student and reminds them of the significance of medication errors. Additionally, as an introduction to pediatrics, this story demonstrates the importance of weight-based dosing.	Benny was a **14-month-old** white male who was admitted to the pediatric intensive care unit (PICU) of a suburban hospital with an admitting diagnosis of **congestive heart failure (CHF)** and **upper respiratory infection**. The chief complaint at admission was a 2-week history of increased respirations, wheezing, weight loss, and generalized agitation. Benny had a past medical history of **cardiac anomalies**. Past surgeries included **open heart surgery** for repair of the congenital heart defect and **gastrostomy tube** placement.
	During his inpatient course of stay, Benny was treated with intravenous antibiotics for the upper respiratory infection and with oral **Furosemide (Lasix)** and **Lanoxin** (Digoxin) for his **CHF**. His congestive heart failure slowly improved, however, he had persistent vomiting with his feedings and, was having trouble maintaining his weight. On his ninth day of admission, a radiographic study of his upper gastrointestinal system with contrast media was performed. He arrived back from radiology at 10 a.m. quite restless, and he appeared to be in discomfort.
	The nurse who took report on Benny called the attending physician, and documented three verbal orders; one of them was to administer **0.7 mg of digoxin** intravenously. Within two hours after the **digoxin** had been administered, Benny began vomiting and went into respiratory distress, with arrhythmias ranging from bradycardia to ventricular fibrillation, and subsequently went into **cardiac arrest**.
This slide introduces the red “think” as a part of the medication calculation schema that asks students to critically think through the answer at both the beginning and the end of the calculations to determine if the answer they have calculated is appropriate.	

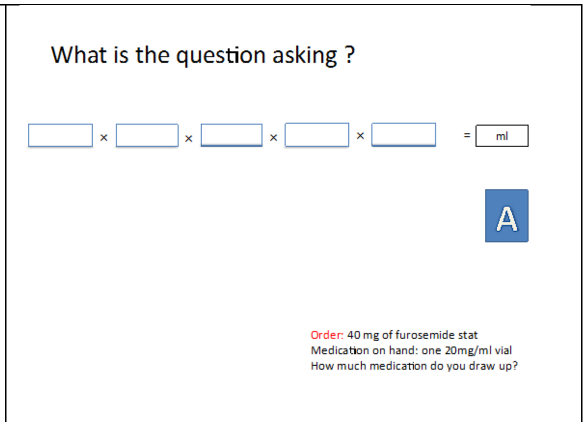
<table>
<tr>
<td>The next slide connects the story with the content for the day and connects the importance of accuracy and a systematic method for calculation.</td>
<td>
</td>
</tr>
<tr>
<td>This slide is a second presentation of the think stop sign as a part of the medication calculation schema. Use of this graphic throughout the presentation and in the workshop materials is intentionally designed to develop the student’s medication calculation schema to include a step of estimation at the beginning and a step of critical thinking at the end.</td>
<td>
</td>
</tr>
<tr>
<td>This slide further develops the medication calculation schema. With this slide, the importance is to instruct students that they need to think through their answers when they are not realistic to the patient situation. This step further develops the critical thinking aspect of the dimensional analysis medication calculation schema (DAMCS).</td>
<td>
</td>
</tr>
<tr>
<td colspan="2">This next set of slides guides the students through the basic steps of dimensional analysis using Benny’s story. Each step will be explained in further detail in later steps. The intent of</td>
</tr>
</table>

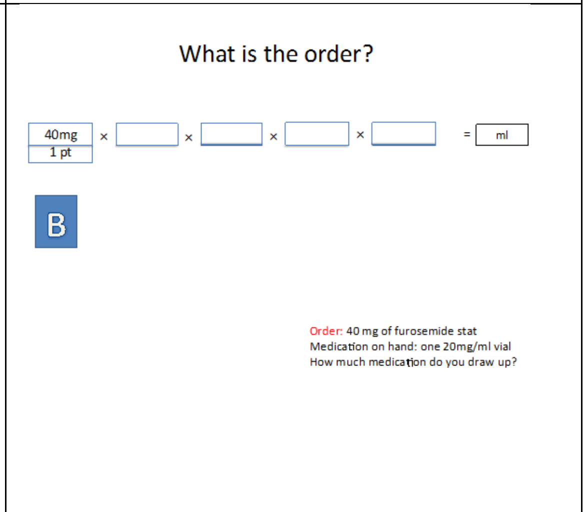
<table>
<tr><td colspan="2">these slides is to further grab student attention, place math in the context of patient care, and demonstrate to the students that a simple calculation and critical thinking could have saved the patient’s life.</td></tr>
<tr><td>The following slide depicts the basic steps involved in the dimensional analysis medication calculation schema (DAMCS).</td><td>
</td></tr>
<tr><td>The first step of dimensional analysis is to identify exactly what the question is asking and then identify the appropriate units. In the case of this example, we want to know the weight of a patient who receives a .7 mg dose of digoxin.</td><td>
</td></tr>
<tr><td>The next step is to identify the “order” and place the information on the first cell. For the in class example, place the 7mg of digoxin over one child.</td><td>
</td></tr>
</table>

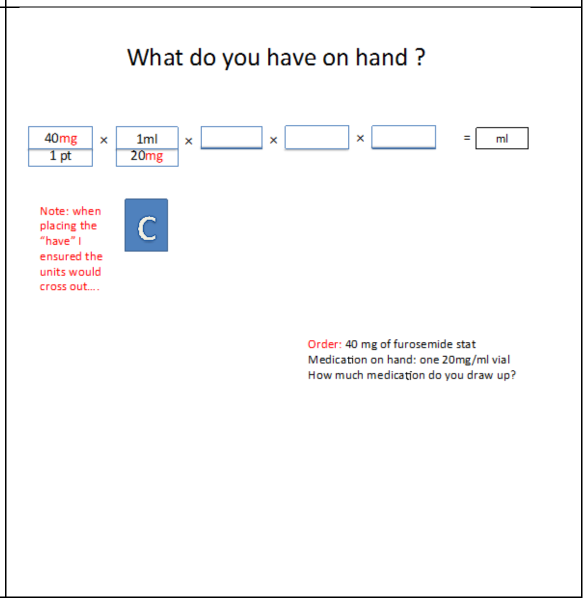
The next step is to identify the known information or what is on hand. For this example, the “known” is the recommended weight-based dosing for digoxin - 7.5mcg/kg.	
Next, determine the appropriate conversion factors. First, to cancel out the mg unit, a conversion is needed. 1000 mcg/mg cancels out both the mcg and the mg units. Next, the kg units should be cancelled by adding in the conversion of 2.2 pounds per kg.	
Next, cancel out each of the units and ensure that the only units remaining are the units needed to answer the question.	

<table>
<tr>
<td>The next step is the actual arithmetic. For this step, students need to multiply the numbers above the line, multiple the numbers below the line and then divide the top into the bottom.</td>
<td>
</td>
</tr>
<tr>
<td>This next slide is the critical thinking piece of the schema and asks the students to thin if the answer makes sense. In the case of our Benny example, the dose given to the patient was an appropriate dose for a 205-pound person that is clearly not this appropriate size for a small child. The picture displayed on the screen is roughly the same size as Benny would have been and is presented to provide the students context.</td>
<td>
</td>
</tr>
<tr>
<td>The next slide takes the student through the steps of dimensional analysis again. At this point, students should be listening and not writing.</td>
<td>
</td>
</tr>
</table>

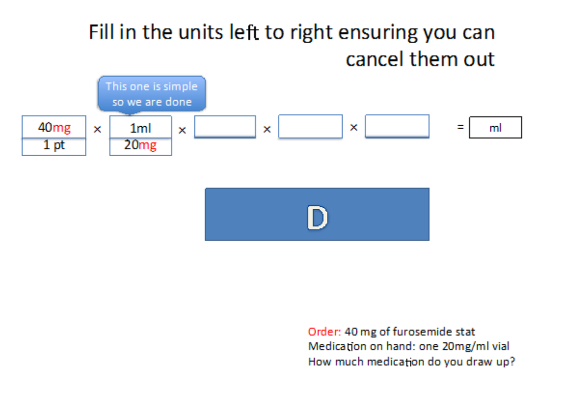
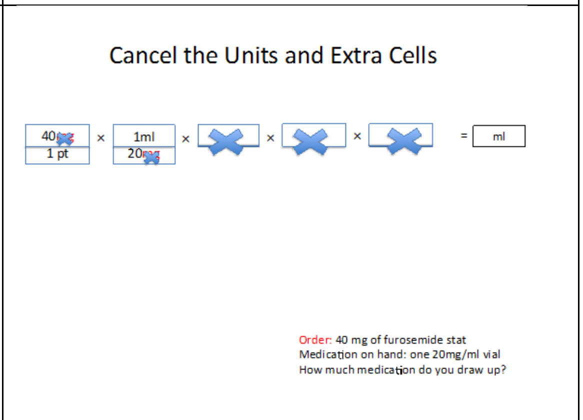
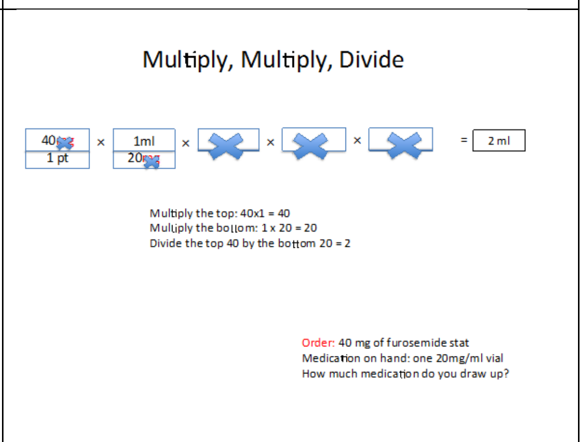
Now, we have an example that the students will work through. It is very easy and can readily be done without a calculator. The purpose of this is to slowly establish the use of dimensional analysis and build up student confidence before moving on to the more difficult calculations.	Your post partum patient is in fluid overload Order: 40 mg of furosemide stat Medication on hand: one 20mg/ml vial How much medication do you draw up?
Instruct students it is now time to work along and to please pick up a pencil and paper….	
Provide students with paper versions of the DAMC handout to work along on this problem. With this slide, ask the students to write down what the question is asking in units to the right of the = sign.	What is the question asking ? Note: "how Much" questions are VOLUME questions × × × × = Be clear about the "question" and assign units to the right of the = A Order: 40 mg of furosemide stat Medication on hand: one 20mg/ml vial How much medication do you draw up?

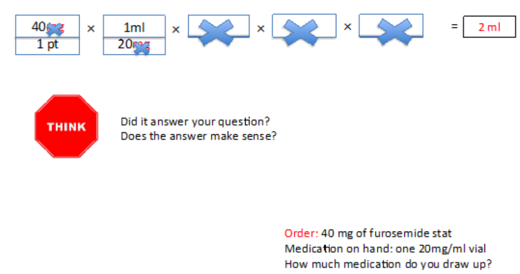
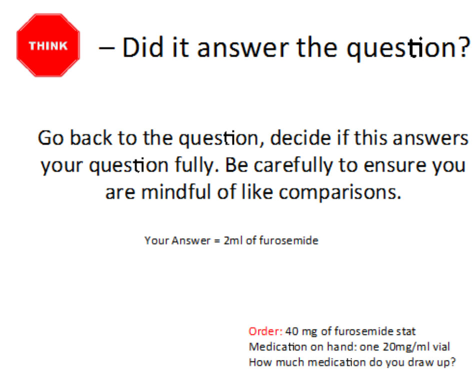
<table>
<tr>
<td>Question the students to ensure this is what they wrote down. Work with them to ensure they are using the worksheet.</td>
<td>


</td>
</tr>
<tr>
<td>Next, identify the order. In this case, the order states give 40mg of medication. This slide demonstrates how to set this problem up. Do not display this slide until the students have written on their papers and then ask them if they placed the same information in the squares.</td>
<td>


</td>
</tr>
<tr>
<td>The next step is to fill in the known quantities. For this example, we have 20 mg/ml. Make sure to align the units so that they will cancel out. Give students time to write this in on their paper and then show this slide. Providing the students with time to use this tool helps build and then solidify the medication calculation schema.</td>
<td>


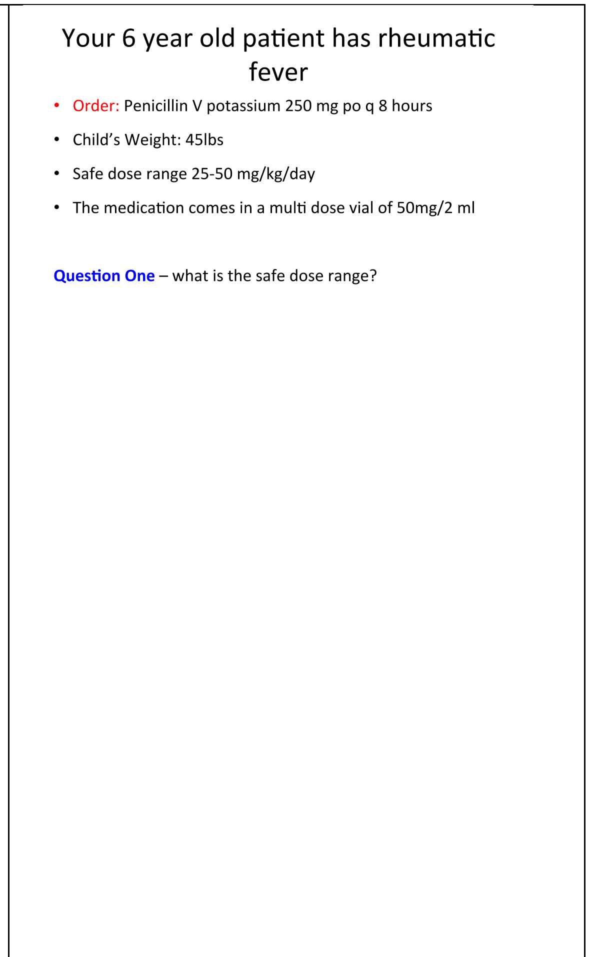
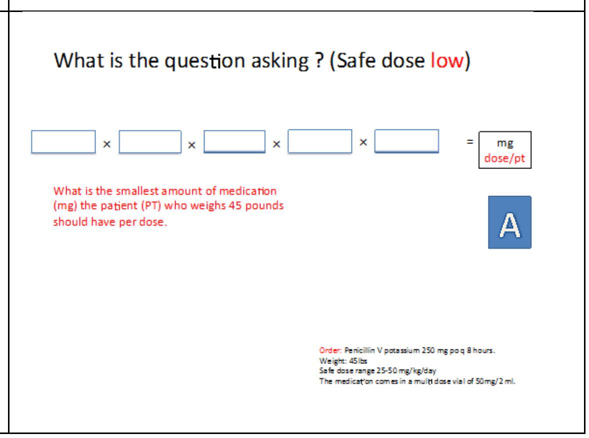
</td>
</tr>
</table>

<table>
<tr>
<td>This example is easy so there are no more units to fill in. Demonstrate on the overhead that the only units remaining are the ml and the patient.</td>
<td>
</td>
</tr>
<tr>
<td>Ask students to physically cancel out their units on their papers and to get in the habit of this. This will further develop the schema.</td>
<td>
</td>
</tr>
<tr>
<td>The next step is to multiply the top – ask the students to do that and write down the result or 40. Then have them do the same for the bottom 20. Then they should divide 40/20. Ask them to do this systematically and avoid shortcuts to develop the schema.</td>
<td>
</td>
</tr>
</table>

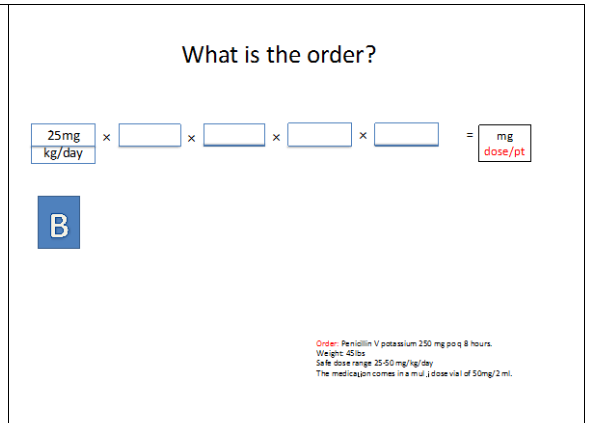
Here is where you work to develop the critical thinking part of the schema. The following slides are designed to break down this stage.	
Take them through the critical thinking questions. First, did we answer the correct question using the correct units? Second, does this answer make sense?	
Spend some time here going over ensuring that you are answering the correct question. Give an example of what might be the wrong question. For example, if the question asks you how many ml to give, the answer should not be in mg.	

This part of the lesson is crucial and where the instructor has the ability to correct faulty schema. Additionally, this is the part of the workshop to ensure students understand the patient care context in which the calculations reside. For example, if the answer was 200, the nurse should question the order as 00 ml is quite large for an oral dose.	THINK – Does the answer make sense? 1. Go back to the question, what answer were you expecting? 2. Is this answer reasonable for the patient? ie – are you asking a patient to swallow 20 tablets or 2? Order: 40 mg of furosemide stat Medication on hand: one 20mg/ml vial How much medication do you draw up?
Tell the students now to practice dimensional analysis for the following simple questions. Ask them to set up the questions using dimensional analysis on the workshop handout. Tell them you will give them two minutes and then ask for the answer. While they are working on this, roam the room and aid with problem set up. This timing of this step is critical as it is important to ensure students have the basic components of use of the DAMC and dimensional analysis before moving on to complicated problems.	Your post partum patient is complaining of cramping pain and is hypokalemic Order: 400 mg of motrin Medication on hand: 200mg of motrin/tablet How many tablets do you need? Order: 40 meq of potassium PO Medication on hand: 100meq/5ml How many ml to give?

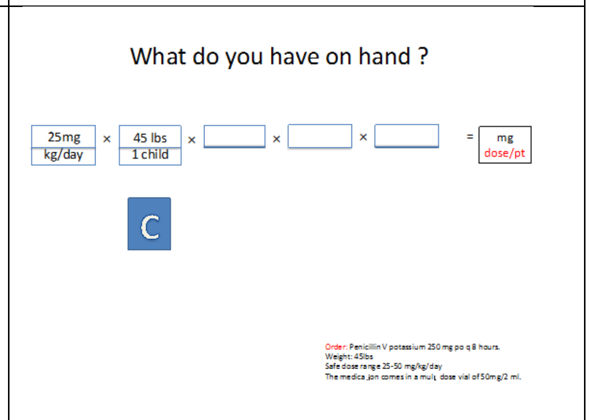
Wait for the students to answer 2 tablets per 2 ml and then give them a break. When they return, ask for questions or clarifying information. Then move on to the concepts of pediatric medication administration.	
This next slide introduces the concepts needed for pediatric medication administration.	Important Concepts • Safe Dose Range • Infusion – Reading Labels – Mixing Medications – Rate of Infusion – Dilution/Concentration – Drip Rate 
Explain the purpose of safe dose range.	Safe Dose 
	Safe Dose Low – therapeutic dose High – safe dose Meds must be in range 3 calculations 1. Therapeutic Level (low) 2. “safe” level (high) 3. How much to administer

This slide aims to provide the needed context for the arithmetic. First, review the patient care scenario with students. Then, ask the students to attempt calculating the safe dose range for the patient. Give them 5 minutes. While they are calculating, roam the room and aid with set up. Ensure students are using the DAMCS paper to set up problems and ensure the setup is accurate. If students revert back to prior solving methods, ask them to attempt both. At the end of the five minutes go through the next several slides that demonstrate this calculation.	
This slide demonstrates the first step of DAMC for this question.	

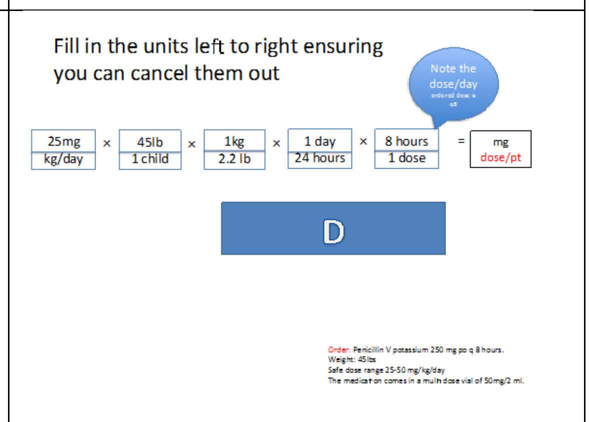
This slide demonstrates how to set up the order for this problem.



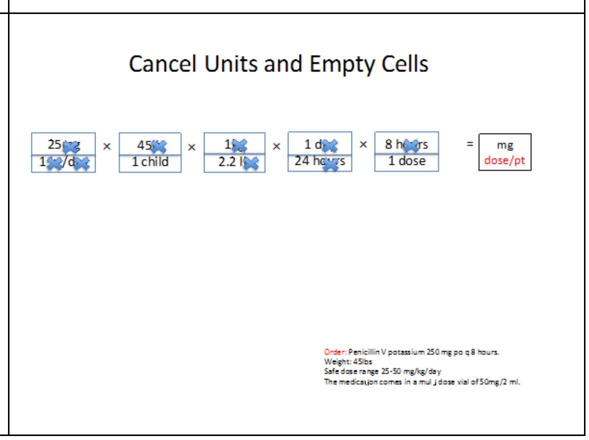
This slide demonstrates how to set up the "known" for this calculation.

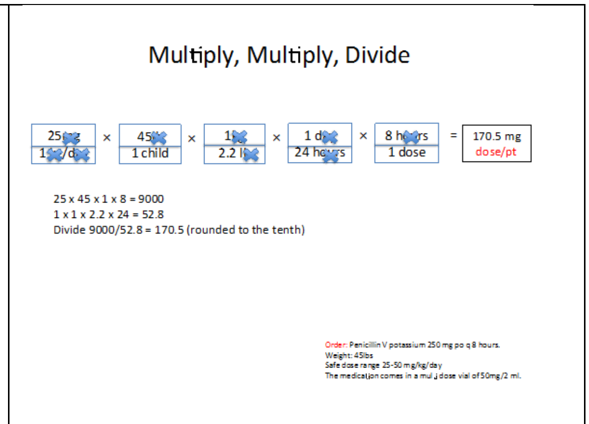
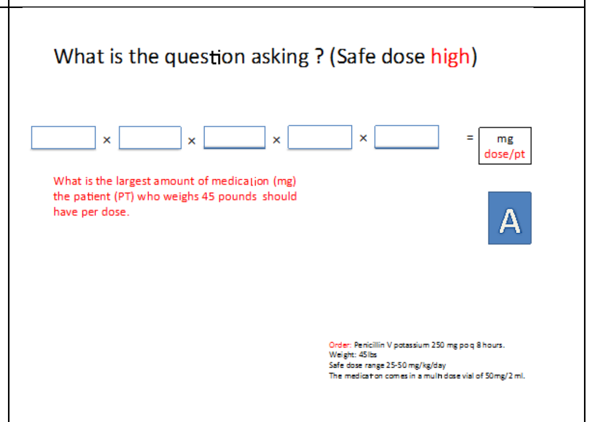
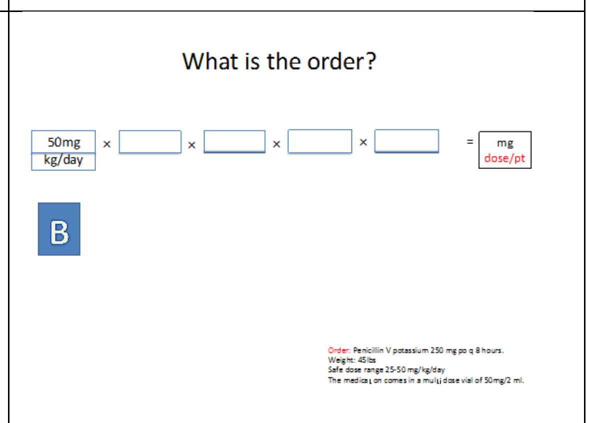
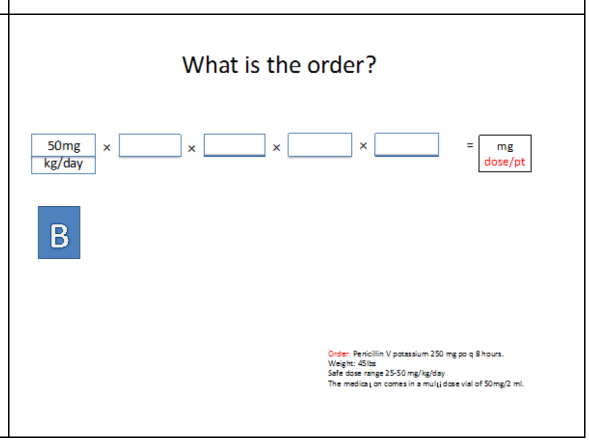


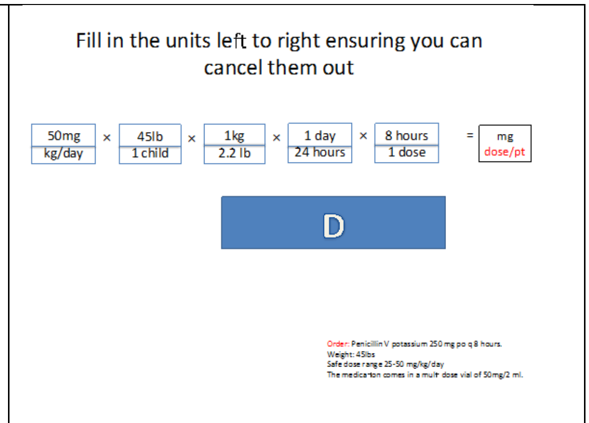
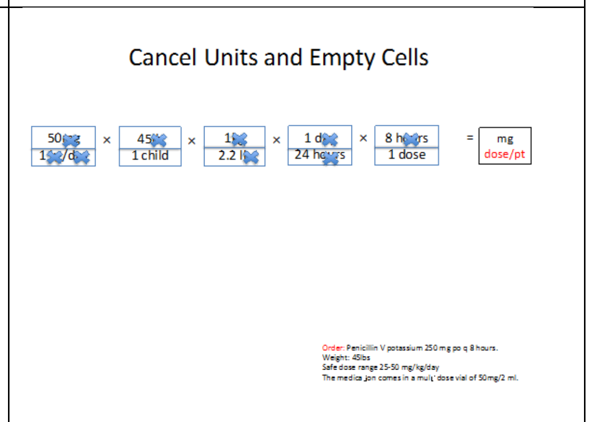
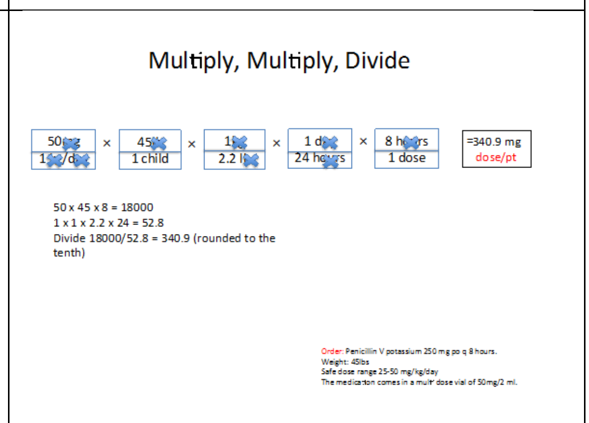
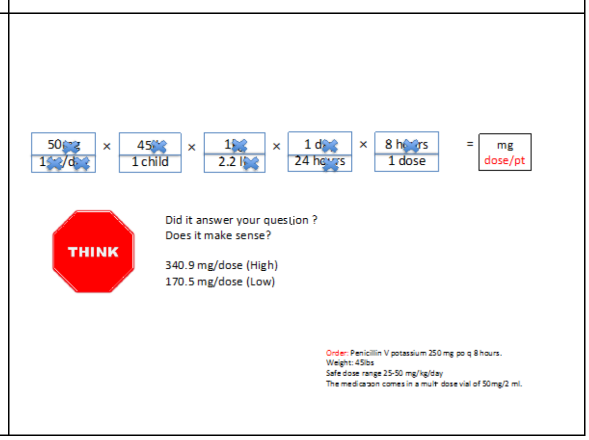
This slide demonstrates how to add in "needed units"



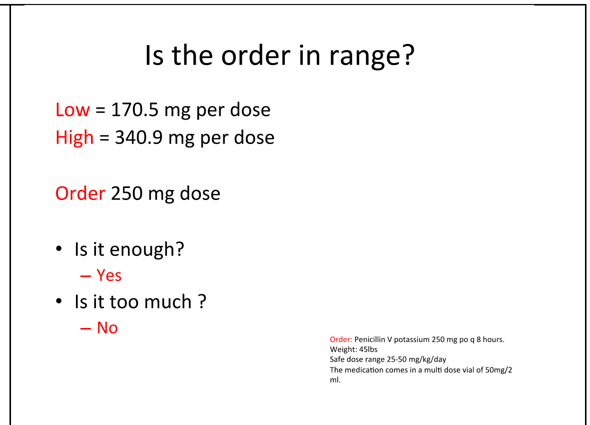
This slide demonstrates cancelling the units.



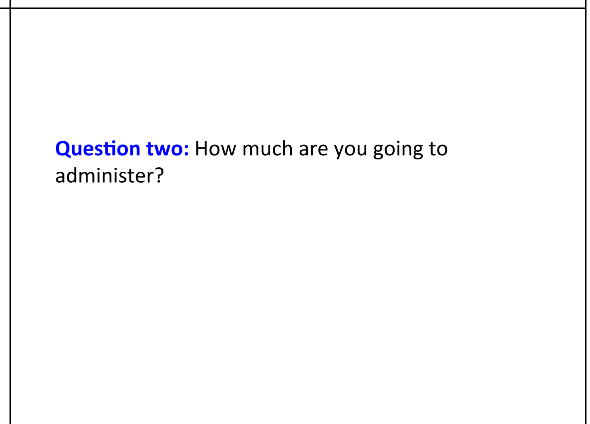
<table>
<tr><td>This slide demonstrates how to perform the needed arithmetic.</td><td>
</td></tr>
<tr><td>This slide demonstrates the first step of DAMC for this question.</td><td>
</td></tr>
<tr><td>This slide shows how to set up the order for this problem.</td><td>
</td></tr>
<tr><td>This slide demonstrates how to set up the “known” for this calculation.</td><td>
</td></tr>
</table>

<table>
<tr>
<td>This slide demonstrates how to add in “needed units.”</td>
<td>
</td>
</tr>
<tr>
<td>This slide depicts canceling the units.</td>
<td>
</td>
</tr>
<tr>
<td>This slide demonstrates how to perform the needed arithmetic.</td>
<td>
</td>
</tr>
<tr>
<td>The next two slides then incorporate the critical thinking portion of the schema. It is important to ask the students to think about whether or not the original question was answered and if the answer is appropriate for</td>
<td>
</td>
</tr>
</table>

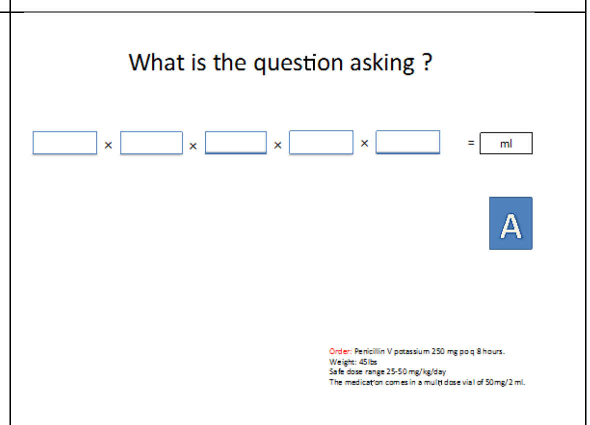
the specified patient.

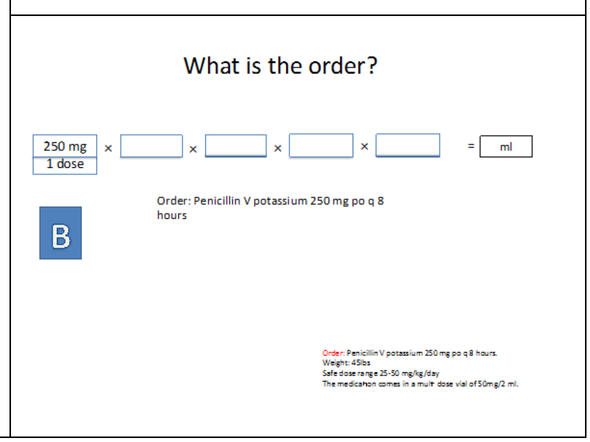


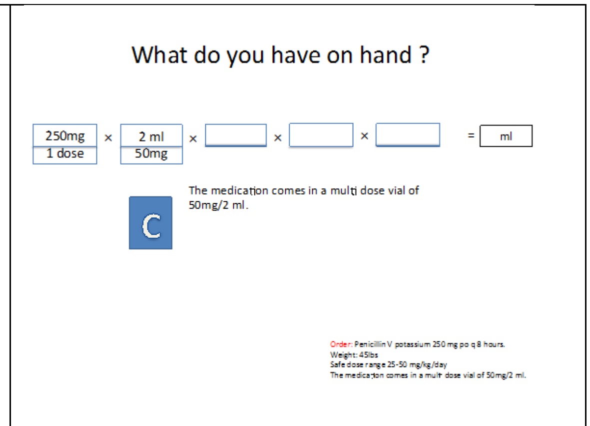
Have the students work out the next question. As in the example above, give them 3 minutes and then go over the set up on the overhead display slide by slide.

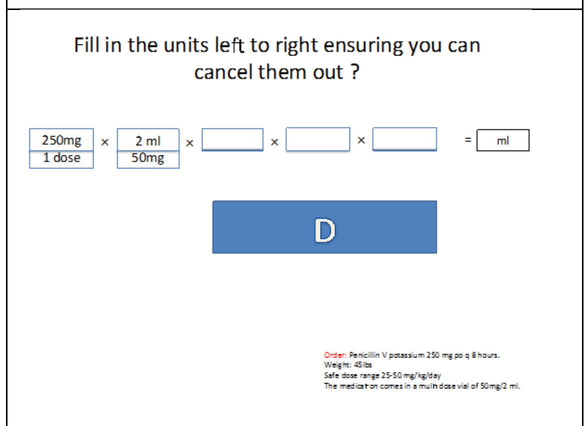


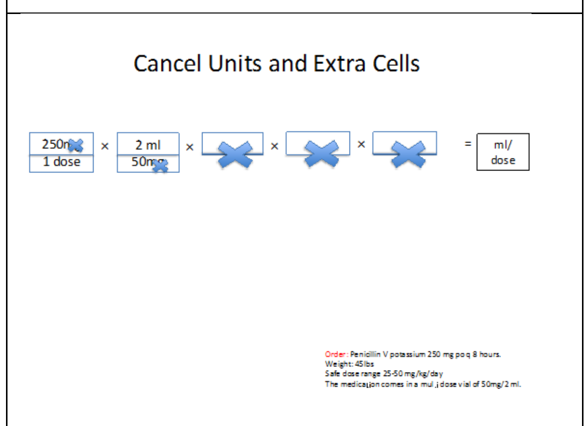
The following several slides take the students step by step through the process of solving the question listed above.

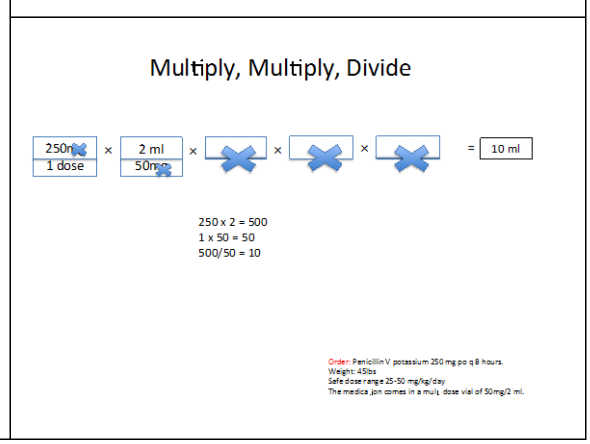


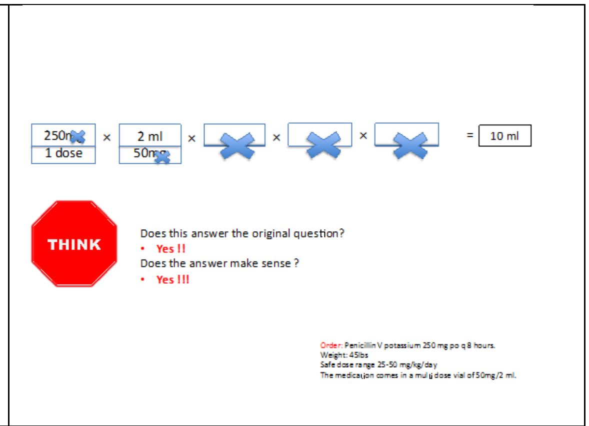


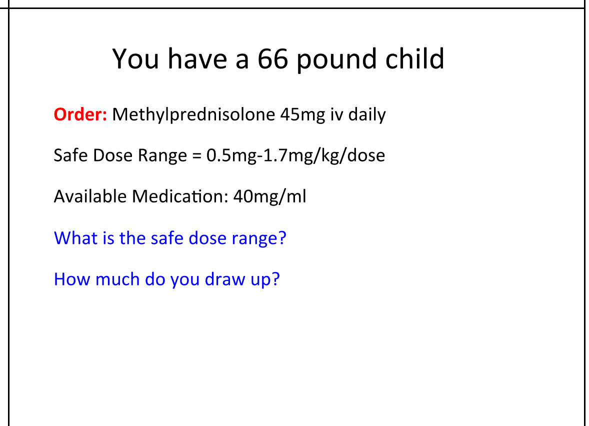

What do you have on hand ?
250mg
1 dose
×
2 ml
50mg
×
×
×
=
ml
The medication comes in a multi dose vial of 50mg/2 ml.
C
Order: Penicillin V potassium 250 mg po q 8 hours.
Weight: 45lbs
Safe dose range 25-50 mg/kg/day
The medication comes in a multi dose vial of 50mg/2 ml.

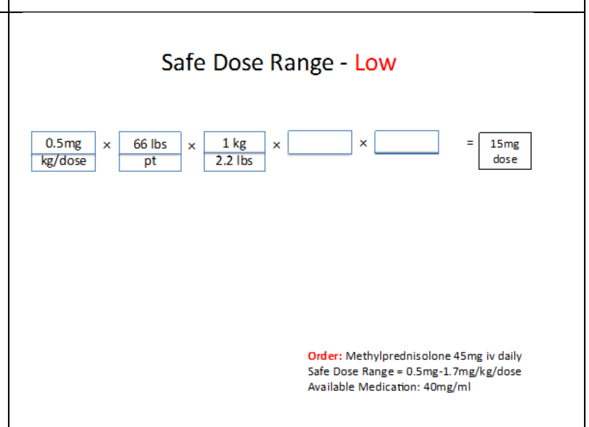

Fill in the units left to right ensuring you can cancel them out ?
250mg
1 dose
×
2 ml
50mg
×
×
×
=
ml
D
Order: Penicillin V potassium 250 mg po q 8 hours.
Weight: 45lbs
Safe dose range 25-50 mg/kg/day
The medication comes in a multi dose vial of 50mg/2 ml.

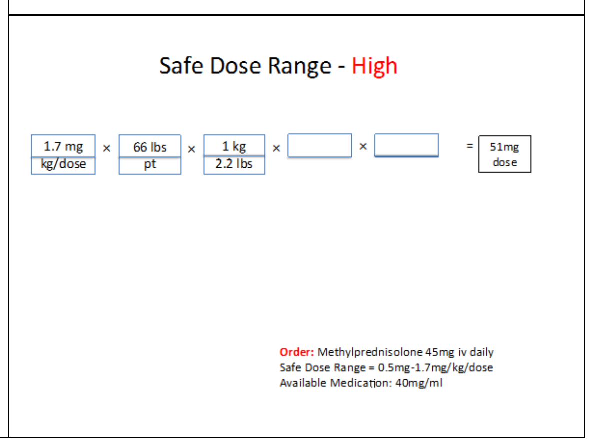

Cancel Units and Extra Cells
250mg
1 dose
×
2 ml
50mg
×
×
×
=
ml/
dose
Order: Penicillin V potassium 250 mg po q 8 hours.
Weight: 45lbs
Safe dose range 25-50 mg/kg/day
The medication comes in a multi dose vial of 50mg/2 ml.


Multiply, Multiply, Divide
250mg
1 dose
×
2 ml
50mg
×
×
×
=
10 ml
250 x 2 = 500
1 x 50 = 50
500/50 = 10
Order: Penicillin V potassium 250 mg po q 8 hours.
Weight: 45lbs
Safe dose range 25-50 mg/kg/day
The medication comes in a multi dose vial of 50mg/2 ml.

<table>
<tr>
<td></td>
<td>


</td>
</tr>
<tr>
<td>Give the students 5 minutes to work out the question. Next, ask the students the following questions: (1) what is the range? (2) what is the amount? and then ask for questions.</td>
<td>


</td>
</tr>
<tr>
<td>Quickly go over the next several slides to show the students the set up. Ask them if that is how they set up their problems. Ask questions and clarify understanding before moving on to questions that are more complicated.</td>
<td>




</td>
</tr>
</table>

<table>
<tr>
<td></td>
<td>
How much to draw up

$\frac{45\text{ mg}}{\text{dose}} \times \frac{1\text{ ml}}{40\text{mg}} \times \square \times \square \times \square = 1.1\text{ml}$

Order: Methylprednisolone 45mg iv daily
Safe Dose Range = 0.5mg-1.7mg/kg/dose
Available Medication: 40mg/ml
<hr>


What is the safe dose range? 15 – 51 mg/ dose

How much do you draw up? 1.1 ml

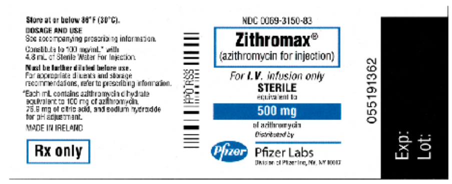
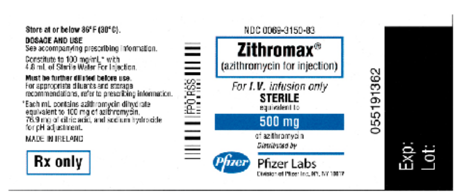
Is your question answered?

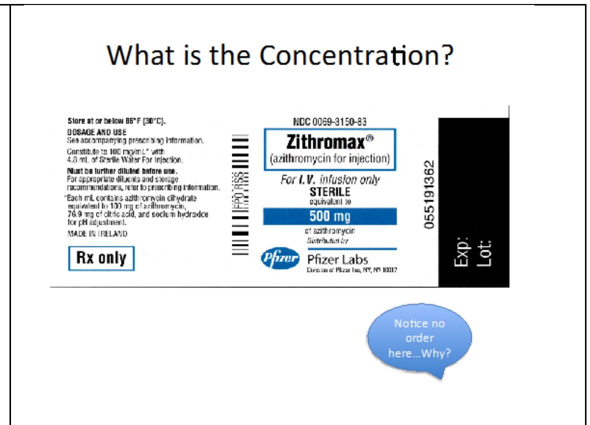
Does the answer make sense?

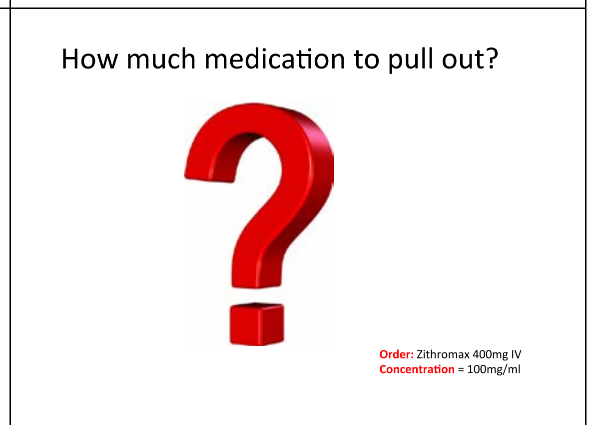
Order: Methylprednisolone 45mg iv daily
Safe Dose Range = 0.5mg-1.7mg/kg/dose
Available Medication: 40mg/ml
</td>
</tr>
<tr>
<td>Provide the context of infusion therapy and talk through the basic concepts of infusion therapy including concentration and rate. Let the students know you will go over each of these concepts one by one and then cover each concept.</td>
<td>
Infusion Therapy

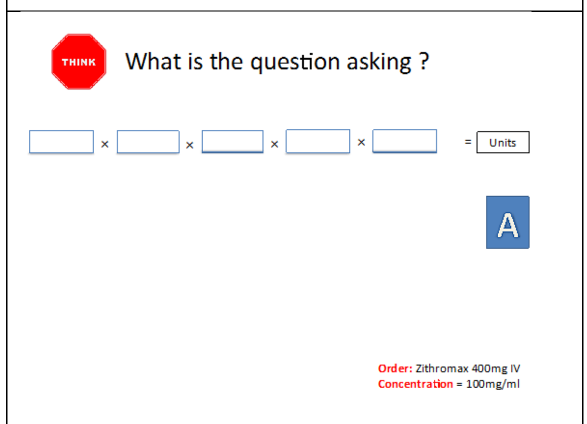
• Reading the label
• How much diluent
• Concentration
• Rate of Infusion

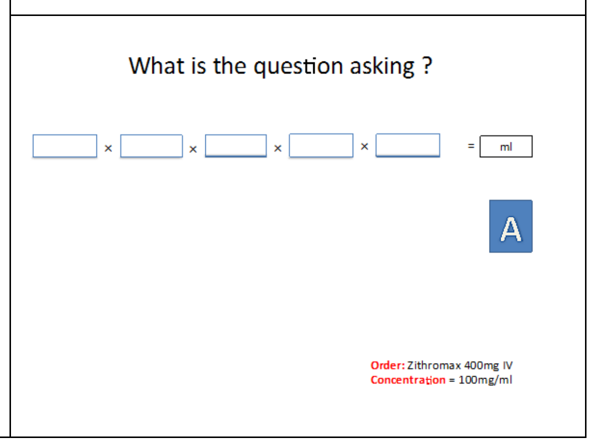
</td>
</tr>
</table>

To provide context for the following examples start with this order and a patient with an infection.	Your patient has an infection **Order:** Zithromax 400mg IV
Discuss how to read the label and ensure coverage of dose, dilution, and concentration.	Reading the label  **Package Insert** Dilute to 1-2 mg/ml Administer over 60 minutes
This slide reminds students of the questions they need to figure out before administering and intravenous medication. Explain the significance of each and explain that each will be presented one by one.	Questions • How much diluent to add • What is the concentration • How much medication to pull out • How much fluid to dilute the medication in • What rate of administration 
For this slide, show the students how to read the label and determine how much diluent they need to reconstitute the medication.	How Much Diluent ?  Notice no order here...Why?

<table>
<tr>
<td>Show the students where to find the medication concentration on the label. Discuss the importance of concentration.</td>
<td>


</td>
</tr>
<tr>
<td rowspan="3">Next, present students with a math question. Show them the order again and then ask them to solve the problem using dimensional analysis and the worksheet. While they are working, roam the room and provide assistance with problem set up and ensure students are using dimensional analysis. Once they are finished go through the following several slides that depict how to set up and solve this calculation.</td>
<td>


</td>
</tr>
<tr>
<td>


</td>
</tr>
<tr>
<td>


</td>
</tr>
</table>

What is the order?

400mg / 1 Dose × [ ] × [ ] × [ ] × [ ] = ml

B

Order: Zithromax 400mg IV
Concentration = 100mg/ml

What do you have on hand ?

400mg / 1 dose × 1ml / 100mg × [ ] × [ ] × [ ] = ml

C

Order: Zithromax 400mg IV
Concentration = 100mg/ml

Fill in the units left to right ensuring you can cancel them out

400mg / 1 dose × 1ml / 100mg × [ ] × [ ] × [ ] = ml

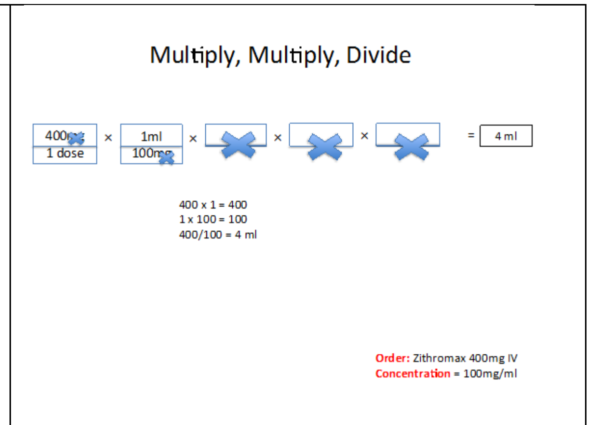
D

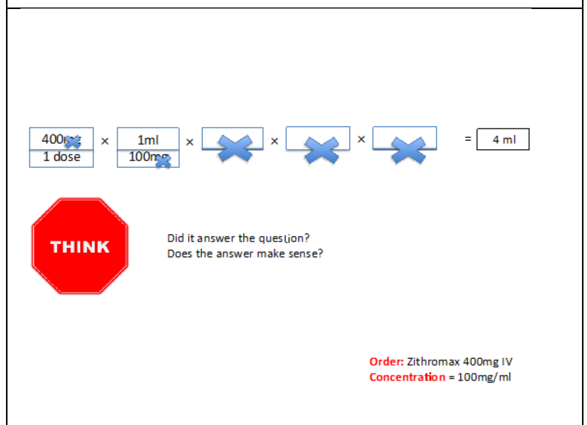
Order: Zithromax 400mg IV
Concentration = 100mg/ml

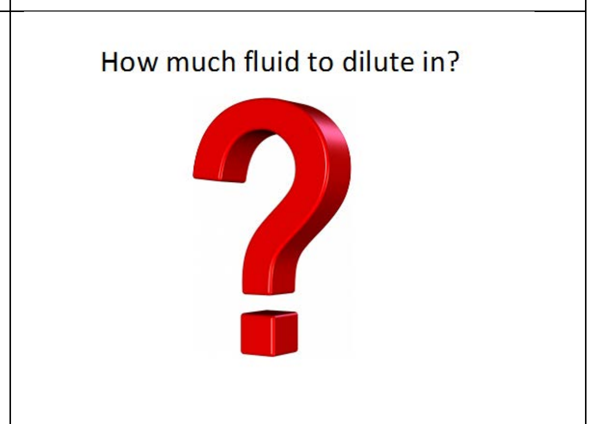
Cancel Units and Cells

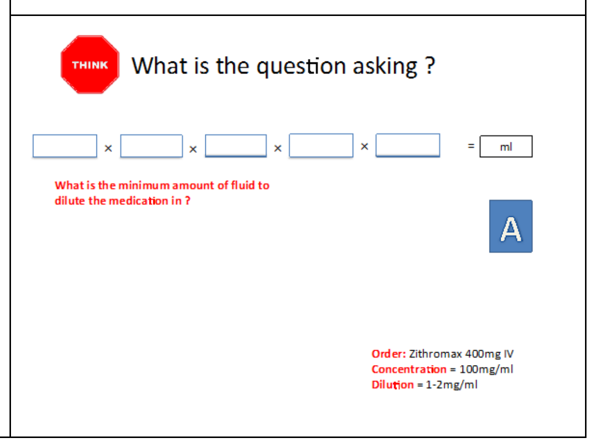
400~~mg~~ / 1 dose × 1ml / 100~~mg~~ × ~~[ ]~~ × ~~[ ]~~ × ~~[ ]~~ = ml

Order: Zithromax 400mg IV
Concentration = 100mg/ml

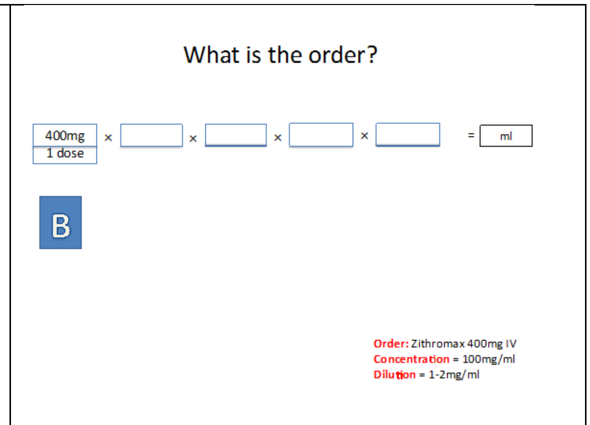
<table>
<tr>
<td></td>
<td>


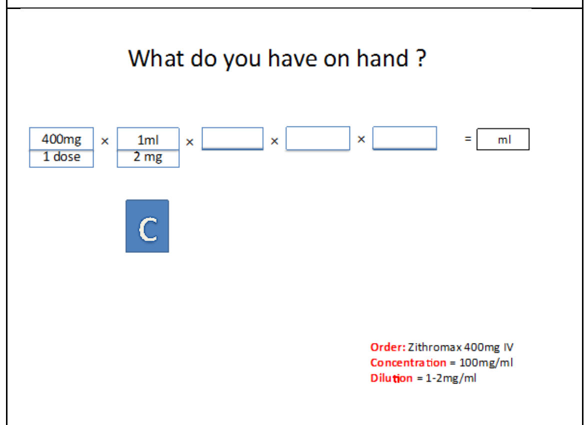


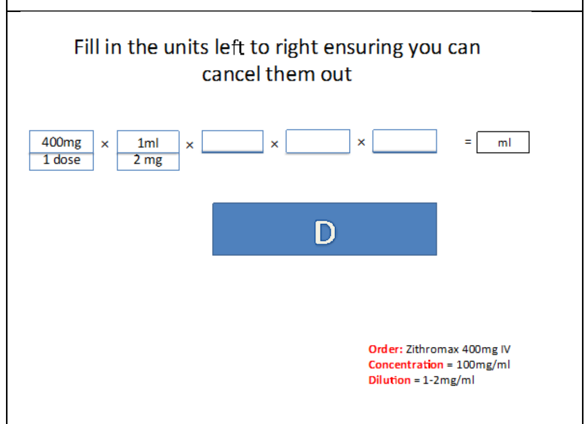
</td>
</tr>
<tr>
<td>For this next concept, explain dilution and its significance in pediatrics. Then ask students to solve the next part of the problem on their own. As before, wander the room and aid with set up while they work through the problem. Once they have finished, go through the following slides to demonstrate the setup and problem solution.</td>
<td>


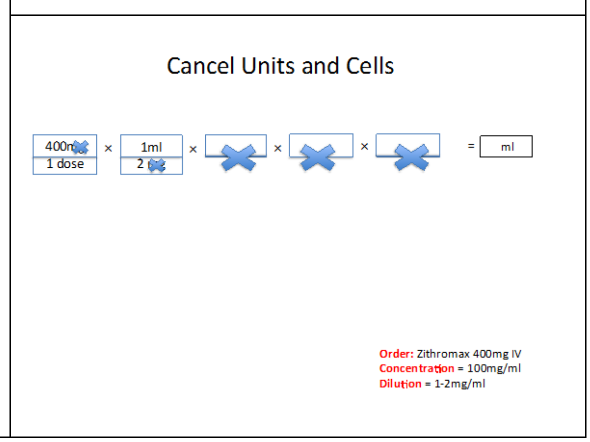


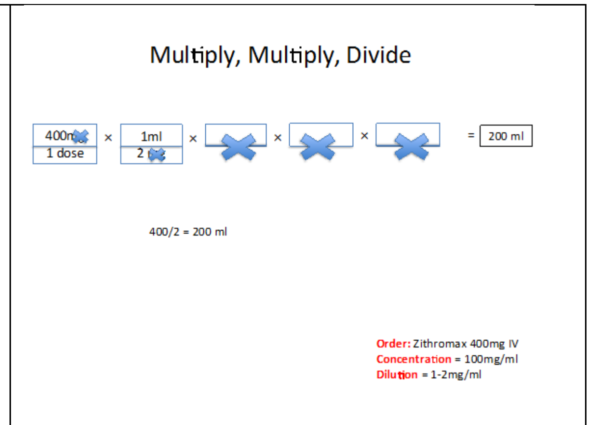
</td>
</tr>
</table>

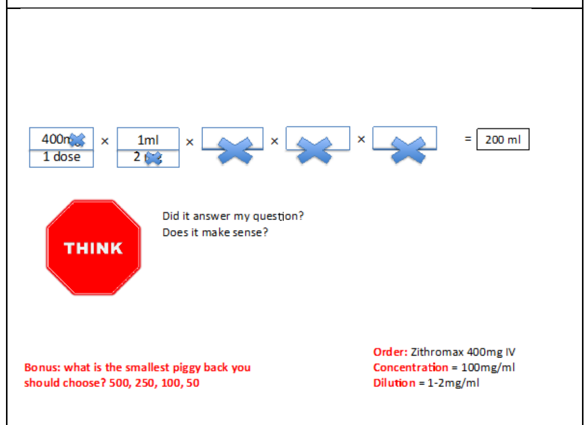

What is the order?
400mg
1 dose
×
×
×
×
= ml
B
Order: Zithromax 400mg IV
Concentration = 100mg/ml
Dilution = 1-2mg/ml


What do you have on hand ?
400mg
1 dose
×
1ml
2 mg
×
×
×
= ml
C
Order: Zithromax 400mg IV
Concentration = 100mg/ml
Dilution = 1-2mg/ml

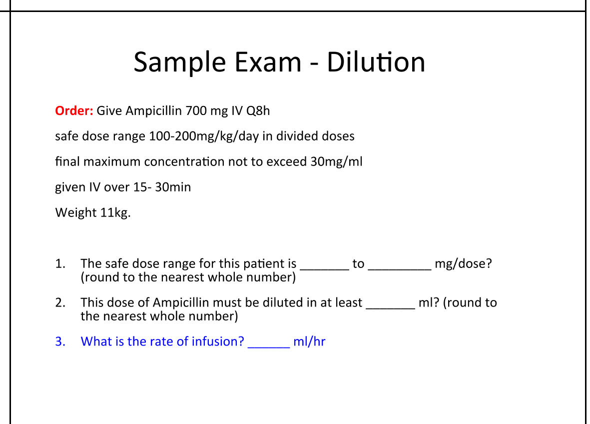

Fill in the units left to right ensuring you can cancel them out
400mg
1 dose
×
1ml
2 mg
×
×
×
= ml
D
Order: Zithromax 400mg IV
Concentration = 100mg/ml
Dilution = 1-2mg/ml

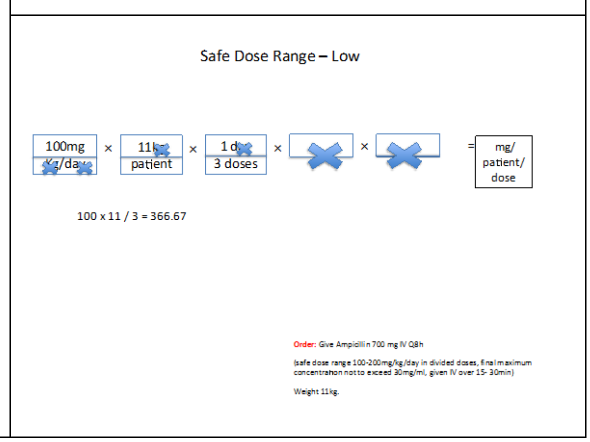

Cancel Units and Cells
400mg
1 dose
×
1ml
2 mg
×
×
×
= ml
Order: Zithromax 400mg IV
Concentration = 100mg/ml
Dilution = 1-2mg/ml





Now give the students a multi-step question and ask them to solve using dimensional analysis. At this point, you have not specifically gone over rate of infusion but they should be able to answer the question. If they can, this will demonstrate transfer to differing question types and help solidify the student medication calculation schema.





Safe Dose Range – High

$$\frac{200\text{mg}}{\cancel{\text{kg}}/\cancel{\text{day}}} \times \frac{11\cancel{\text{kg}}}{\text{patient}} \times \frac{1\ \cancel{\text{day}}}{3\ \text{doses}} = \frac{\text{mg}/}{\text{patient}/\text{dose}}$$

100 x 11 / 3 = 366.67 mg/pt/dose
200 x 11/3 = 733.3 mg/pt/dose

Order: Give Ampicillin 700 mg IV Q8h

(safe dose range 100-200mg/kg/day in divided doses, final maximum concentration not to exceed 30mg/ml, given IV over 15- 30min)

Weight 11kg.

$$\frac{200\text{mg}}{\cancel{\text{kg}}/\cancel{\text{day}}} \times \frac{11\cancel{\text{kg}}}{\text{patient}} \times \frac{1\ \cancel{\text{day}}}{3\ \text{doses}} = \frac{\text{mg}/}{\text{Patient}/\text{dose}}$$

Does it answer the question?
Does it make sense?

Low = 366.67 mg/pt/dose
High = 733.3 mg/pt/dose

Order: Give Ampicillin 700 mg IV Q8h

(safe dose range 100-200mg/kg/day in divided doses, final maximum concentration not to exceed 30mg/ml, given IV over 15- 30min)

Weight 11kg.

Dilution

This dose of Ampicillin must be diluted in at least _______ ml?
(round to the nearest whole number)

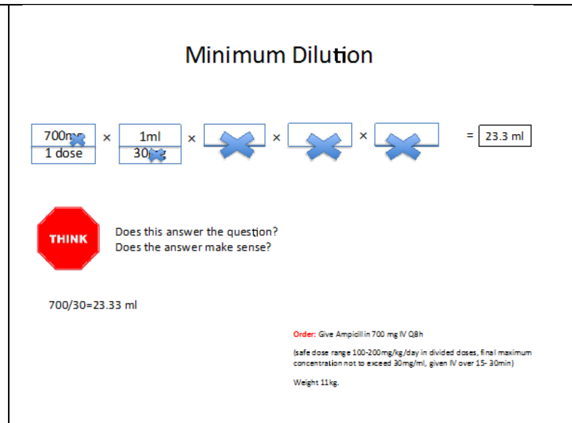
Minimum Dilution

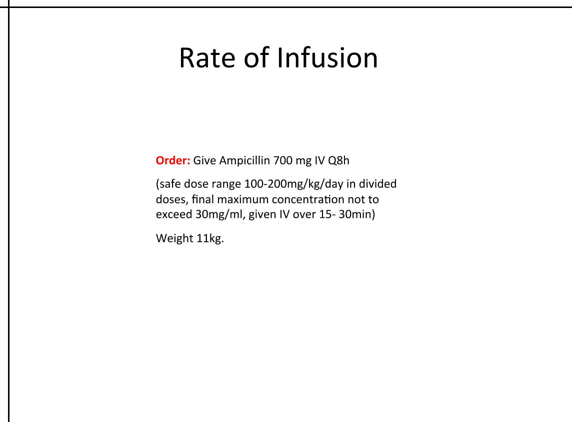
$$\frac{700\text{mg}}{1\ \text{dose}} \times \frac{1\text{ml}}{30\text{mg}} = \text{ml}$$

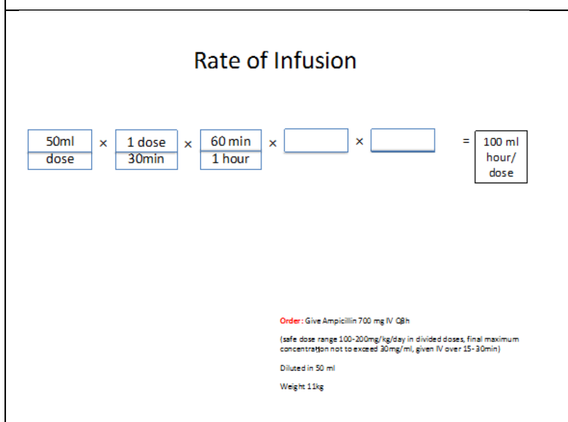
Order: Give Ampicillin 700 mg IV Q8h

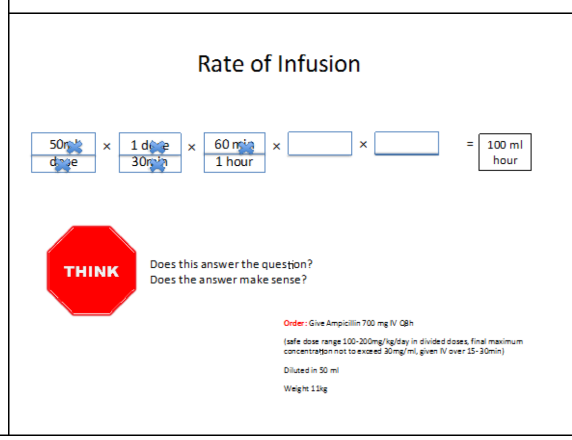
(safe dose range 100-200mg/kg/day in divided doses, final maximum concentration not to exceed 30mg/ml, given IV over 15- 30min)

Weight 11kg.

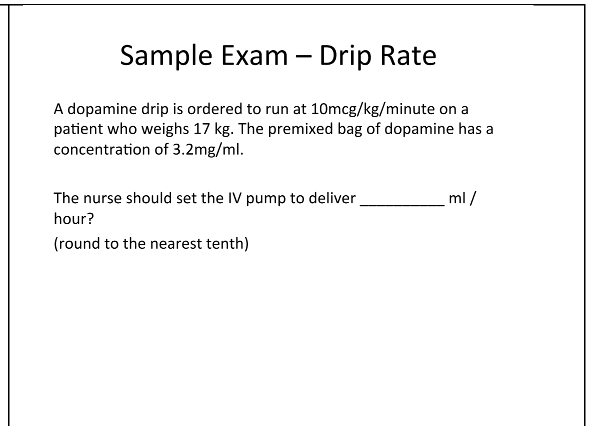
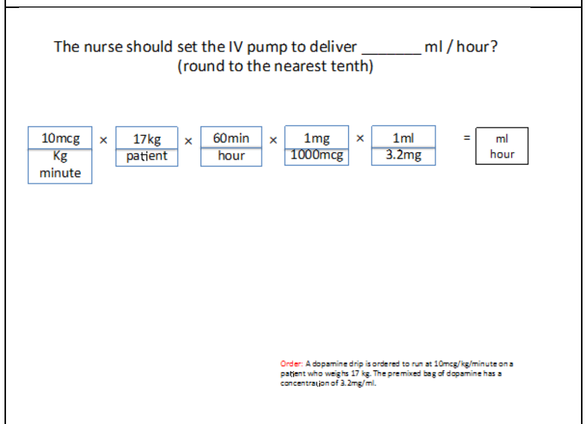
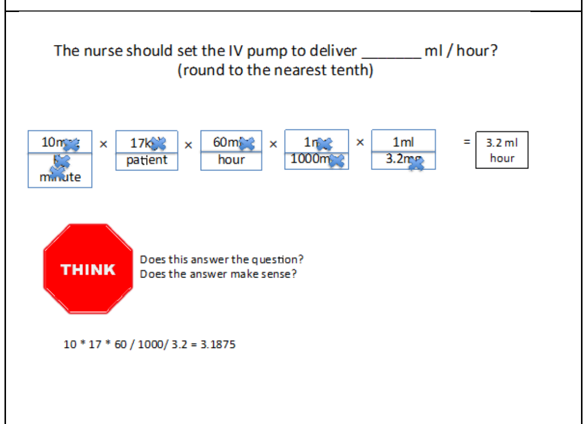
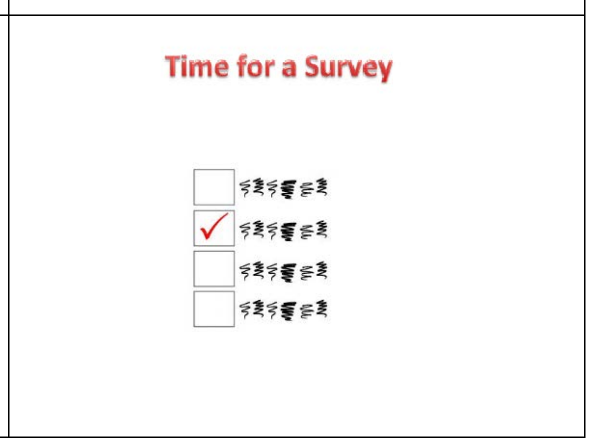
<table>
<tr>
<td></td>
<td>


</td>
</tr>
<tr>
<td rowspan="3">Now discuss the concept of infusion rate and remind the students they have already solved for infusion rate. Provide the students with the example and ask them to solve the questions on their own using dimensional analysis and the provided worksheets. While they work, roam the room and ensure students are using dimensional analysis, aid them with problem set up, and answer questions. When they are finished, show the following slides on the screen to ensure they have all set up and solved the problem correctly. Take care to ensure accuracy with the students as their schemas are developing.</td>
<td>


</td>
</tr>
<tr>
<td>


</td>
</tr>
<tr>
<td>


</td>
</tr>
</table>

<table>
<tr>
<td rowspan="3">Now discuss the concept of drip rate. Provide the students with the example and ask them to solve the questions on their own using dimensional analysis and the provided worksheets. While they work, roam the room and ensure students are using dimensional analysis, aid them with problem setup and answer questions. When they are finished, show the following slides on the screen to ensure they have all set up and solved the problem correctly.</td>
<td>
</td>
</tr>
<tr>
<td>
</td>
</tr>
<tr>
<td>
</td>
</tr>
<tr>
<td>At this point, the instructional portion of the workshop is complete. Hand out the student satisfaction survey and the practice exam. Ask students to complete both before leaving and ask questions as needed. Ask students to turn</td>
<td>
</td>
</tr>
</table>

in the survey on exit and let them know that you have the key for the exam.	
Students should have 1 hour to complete the practice exam. Roam the room, help with set up, and answer questions.	PRACTICE PRACTICE PRACTICE PRACTICE

Appendix G

Workshop Handout

Medication Calculation Dimensional Analysis
1/23/17 Workshop for Senior 1 students
Professor Laureen Turner

1. **THINK: What is the question asking?**

2. **What is the order?**

3. **What do you have on hand? OR what is the "known?"**

4. **Find the units (left to right)**

	×		×		×		×		=	

5. **Cancel the units and empty cells**

6. **Multiply, Multiply, Divide**

7. THINK

- **Did this answer the question? ☐ yes ☐ no**
- **Does the answer make sense? ☐ yes ☐ no**