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The Effect of a Contextualized Dosage Calculation Learning Intervention on Pre-Nursing Students’ Math Self-Efficacy and Ability to Pass High Stakes Dosage Calculation Examination On First Attempt

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THE EFFECT OF A CONTEXTUALIZED DOSAGE CALCULATION LEARNING INTERVENTION ON PRE-NURSING STUDENTS' MATH SELF-EFFICACY AND ABILITY TO PASS HIGH STAKES DOSAGE CALCULATION EXAMINATION ON FIRST ATTEMPT

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ABSTRACT

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Many students in pre-licensure nursing programs struggle with calculating accurate medication dosages even though they meet the numeracy requirements for application to the nursing programs. Most pre-licensure programs require that nursing students pass dosage calculation exams at a specified level of accuracy before progressing to the next term. Students typically have three tries to pass at the specified level and should they not succeed, they must withdraw. If they wish to continue in the program, they must complete the requirements for re-entry which may include space availability restrictions.

Factors influencing dosage calculation performance include fear of mathematics, low math self-efficacy, lack of practice, perception of unimportance, and decontextualization of dosage calculation problems which contributes to conceptual errors. High stakes testing environments described above exacerbate student anxiety which may hinder success.

This exploratory field study sought to examine the effects of a contextualized learning intervention on dosage calculation accuracy and math self-efficacy. In addition, it examined the relationships between the students' Test of Essential Academic Skills (TEAS; Assessment Technologies Institute, 2020) scores, their math self-efficacy, and their ability to pass a dosage calculation exam on the first attempt. The learning intervention incorporated activities to engage

the affective domain with the intent of internalizing a value for accurate dosage calculation skills.

Two unique features of this learning intervention were that it occurred before students began their nursing courses and used interactive video conferencing due to Covid-19 restrictions. Thirty-six of 47 newly accepted nursing students participated in the intervention and were given kits consisting of basic medication administration accoutrements such as syringes, graduated medicine cups, vials, and pills, which added context to drug dosages. Students collaborated with peers in small virtual groups to solve rudimentary dosage calculation problems using Polýa's (as cited in Pyo, 2011) problem-solving framework. Student math self-efficacy surveys (Nursing Student's Self-Efficacy for Mathematics [NSE-Math]; Andrew et al., 2009) were administered before the intervention and again five to seven days after the intervention. A Wilcoxon matched-pairs analysis revealed a statistically significant increase between the pre- and post-intervention NSE-Math survey means, $n = 25$, $Z = 3.786$, $p < .001$, with a moderate effect size, $r = 0.54$.

All nursing students ($N = 47$) took the initial dosage calculation exam six weeks after the start of their first semester of nursing courses with 41 (87%) passing. A 2 x 2 cross-tabulation table was used to compute the probability of passing the exam if students attended the learning intervention and compared it to the probability of passing if the intervention was not attended. The difference was statistically significant, X^2 (1, $N = 47$) = 4.68, $p = .021$ (*OR* = 9.71, 95% *CI*: 1.48, 63.81), using the continuity correction and Fisher's exact test. The positive relationship between the learning intervention attendance and passing the exam was low (*phi* = .391).

The predictive relationship of the TEAS and NSE-Math scores to passing the dosage calculation exam was not amenable to logistic regression analysis due to the small sample size. The relationships among the TEAS and NSE-Math scores were examined using the Spearman test of correlation. A statistically significant positive relationship was found between the NSE-Math scores and the TEAS Math scores, $r_s = .360$, $p = .047$.

Overall, the study suggested that a rudimentary contextualized learning intervention might help increase pre-nursing students' math self-efficacy and enhance their chances of passing a dosage calculation exam on the first attempt.

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I am grateful that the University of Northern Colorado provides such a high-quality Doctor of Philosophy in Nursing Education track and feel honored to be an alumnus.

I thank the nursing students from past and present with whom I have had the privilege of interacting. You are the reason I tell people that I have the best job in the world. Your passion for wanting to make the world a better place rings loud and true.

And finally, I thank my God, my higher power, for your continued presence. You lifted me during times of despair and provided a path for goodness and happiness.

DEDICATION

I dedicate this dissertation to my daughter, Tara, who exemplifies what it means to be a nurse, and to my grandchildren, Darwin and Basil. You are the loves of my life.

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CHAPTER I

INTRODUCTION

This research employed an exploratory field study design to examine the effect of a contextualized dosage calculation learning intervention on nursing students' math self-efficacy and the ability to pass a high stakes dosage calculation exam on the first attempt. In addition, the relationship between student Test of Essential Academic Skills (TEAS) scores (Assessment Technology Institute [ATI], 2020), math self-efficacy, and dosage calculation exam pass rates were examined. Performance of students who participated in the learning intervention were compared with the aggregated performance from contemporary student cohorts who did not receive the intervention. This chapter describes the background that inspired the research, presents the conceptual framework for the study, provides a statement of the problem, the purpose and professional significance of the study, and lists the research questions, hypotheses, and definitions of terms.

Background

A recent estimate of annual number of deaths due to medical error exceeds 250,000, supplanting the landmark 1999 Institute of Medicine's estimate of 98,000 (cited in Makary & Daniel, 2016). In addition, Makary and Daniel (2016) contended that medical error comprised the third leading cause of death in the United States. Examples of medical error included internal injuries incurred during invasive procedures, wrong site surgeries, and failure to recognize signs of patient deterioration. A substantial portion of medical errors occurred within the medication administration process. The Institute for Safe Medication Practices (2017) implied some 25,000 reported medication errors were responsible for death or significant harm for the year 2016. Nurses were often partly responsible for the errors due to their medication administration role while contending with mitigating factors such as distractions and staffing shortages (Treiber & Jones, 2018).

Medication administration is a highly complex skill, demanding up to 40% of a nurse's time in the work setting (Coben & Weeks, 2014; Wright, 2012). All pre-licensure nursing programs teach medication administration and inculcate a process that determines the correct drug and dose via the correct route at the right time for the correct reason to the right patient (Schneidereith, 2017). A medication error occurring under nursing purview could happen at any step in the administration process. Approximately 17% of medication errors result from dosage miscalculation (Williams & Davis, 2016)—the focus of this research. Miscalculations that lead to dosage error could result in patient harm or death. Clinicians who inadvertently commit serious errors experience significant distress, sometimes resulting in the taking of their own lives (Cadwell & Hohenhaus, 2011).

Although current research indicated mathematics mastery did not necessarily equate to nursing school success (Maley & Rafferty, 2019), numeracy skills of nursing students and practicing nurses have been questioned for several decades. As far back as 1939, Faddis declared that converting between apothecary and metric systems comprised the greatest number of medication administration errors. Concern regarding the numeracy skills of nurses and nursing students spans the globe as explicated in research originating from countries such as Australia (Sherriff et al., 2011; Stolic, 2014; Williams & Davis, 2016), Canada (Geist et al., 2018), Finland (Härkänen et al., 2016), Italy (Bagnasco et al., 2016), Mozambique (Bull et al., 2017), Turkey (Aydin & Dinç, 2017; Özyazicioğlu et al., 2018), and the constituent parts comprising the United

Kingdom (UK; Young et al., 2013). In 2007, the Nursing and Midwifery Council (NMC, 2019) of the UK implemented standards for medicines management that specifically delineated numeracy skill proficiency for nurses. United Kingdom nursing students were required to "correctly and safely undertake medicines calculations" as new graduates (NMC, 2010, p. 134). Such prescriptive requirements for nursing registry [licensure] in the UK likely spawned the cornucopia of literature originating from the UK since 2007 that addresses dosage calculation pedagogy. Curiously, the NMC standards were rewritten in 2019 and eliminated the prescriptive component with the explanation: "The Standards for medicines management (2007) and underpinning NMC Circulars 16/2008 and 05/2009 were withdrawn on 28 January 2019. We did this because it's not within our remit as a regulator to provide this type of clinical practice guidance" (p. 1).

In the United States, pre-licensure nursing graduates are expected to have the ability to meet practice standards for dosage calculations as described in the National Council Licensure Examination-Registered Nurse (NCLEX-RN, 2019) test blueprint. Reference to dosage calculation ability occurs within the client needs category of Pharmacological and Parenteral Therapies and states simply that [nurses] "perform calculations needed for medication administration" and "use clinical decision making/critical thinking when calculating dosages" (NCLEX-RN, 2019, p. 31).

Most nursing programs require that students pass medication calculation exams at a specified level of accuracy, usually between 80 to 100%, before progressing to the next term (Sherriff et al., 2011). Typically, students have three opportunities to pass the exam. Should students not be successful after the third try, they must withdraw from the term. If they wish to continue in the nursing program, they must complete the requirements for re-entry that might include space availability restrictions. High stakes test environments of this nature accentuate already existing stress and anxiety in nursing students and might further impair exam performance (Røykenes et al., 2014).

Identification of weak numeracy skills among other health-related professions existed in the literature as well, illustrating a ubiquitous concern regarding medication errors due to inaccurate calculations (Wallace et al., 2016). Several authors revealed the paradox regarding poor performance with medication calculations even though the students met the mathematics requirement for nursing program admission (Aydin & Dinç, 2017; Harris et al., 2014). Mathematics skills deemed adequate for most medication calculations were seventh-grade level or below, encompassing basic arithmetic operations (Melius, 2012).

Most prelicensure nursing programs require prospective students to achieve a predetermined minimum score on a proprietary entrance examination, which includes math skills, to be eligible for admission (Manieri et al., 2015). The vendors for the exams offer rigorous statistical analyses that support the exams' ability to predict nursing school success. Besides mathematics, entrance examinations typically cover language use and general science knowledge with some schools using the results to identify students who might require additional resources to ensure nursing school success (Van Hofwegen et al., 2019). For this research study, TEAS scores were used to explore relationships between the scores and students' ability to pass the dosage calculation exam. Scant literature was available that described such a relationship. The utility of nursing entrance exams focused more on predicting overall potential success in nursing programs and NCLEX pass rates (Manieri et al., 2015). A deeper understanding of the TEAS score relationship to dosage calculation exam performance might support a targeted intervention that facilitates student success early in the nursing curriculum.

Factors influencing nursing student numeracy skills included fear of mathematics with concomitant low math self-efficacy (Andrew et al., 2009; Røykenes et al., 2014), insufficient numeracy skill development in middle school (Mackie & Bruce, 2016; Røykenes, 2016), decontextualization of dosage calculation problems that contribute to conceptual errors (Ramjan et al., 2014; Weeks et al., 2019), lack of practice (Bagnasco et al., 2016; McGuire, 2015; Shanks & Enlow, 2011), and apathy or perception of unimportance (Baginski, 2017; Wallace et al., 2016).

The validity of traditional methods for teaching drug calculations and testing mastery, such as working through a series of word problems on paper, has been harshly criticized (Geist et al., 2018; Wright, 2007, 2010). Teaching medication calculations in a decontextualized learning environment was the very practice strongly discouraged by Benner et al. (2010) in their seminal book, *Educating Nurses: A Call for Radical Transformation*. Benner et al. proposed that transforming nursing education necessitated provision of contextualized learning experiences.

Since the release of the Benner et al. (2010) book, research concerning effective pedagogy for dosage calculation increased exponentially as nurse educators strove to flesh out the most salient practices. The contributions to nursing knowledge included examples of how to contextualize dosage calculations and descriptions of success to varying degrees with supplemental activities, which are further explicated in the literature review. In addition, a recent organizational coalition composed of Quality and Safety Education for Nurses, Mathematical Association of America, and The Charles A. Dana Center drafted a document that proposed solutions for addressing math skill deficiencies in nursing education, a movement anticipated to gain momentum (Ellis et al., 2019). The coalition endorsed a starting point that defined math skills essential for nursing practice and teaching in ways that supported and facilitated conceptualizing drug dosages.

A gap in the literature existed regarding strategies for addressing nursing students' attitudes toward the importance of accurate dosage calculation. Such an inquiry examined affective domain learning for which "there is limited literature…and its assessment in nursing students" (Oermann & Gaberson, 2017, p. 16). This research study included activities designed to evoke emotions that facilitated student recognition of math skill importance in nursing practice. This recognition served as the foundation for valuing math skills as a requisite for affective domain maturity (Beltrán-Pellicer & Godino, 2019).

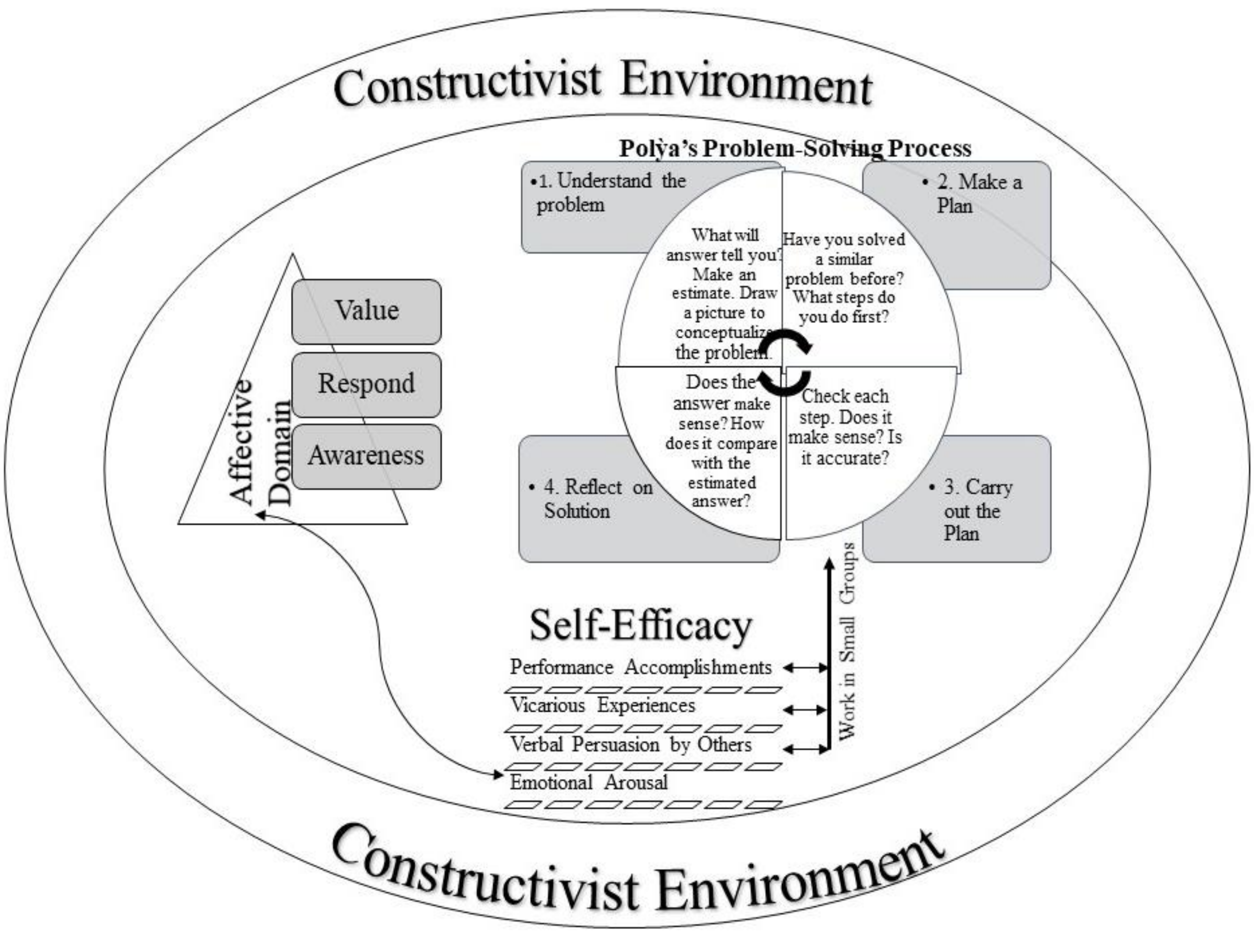
Virtually all the research regarding dosage calculation competency was conducted with nursing students who were presently enrolled in nursing courses or who had graduated and were employed as registered nurses. A search of current literature did not yield studies examining preemptive interventions—those targeted for students who have not yet begun nursing courses—which presented an additional gap in the literature. This research study facilitated closure of these gaps.

Conceptual Framework

Constructivist learning theory served as the overarching framework for this research study. Constructivism as a learning theory extrudes from the amalgamation of works by Piaget, Vygotsky, Bandura, Bruner, and von Glaserfeld (Candela, 2016; Weimer, 2013). Teachers who embrace constructivist philosophy provide an active learning milieu in which students construct new knowledge by building on existing knowledge. Constructivist teachers "*support* learning rather than *direct* it" (Weimer, 2013, p. 23). Constructivists embrace collaborative learning environments in which students have opportunity to observe and model behaviors that contribute to their sense of self-efficacy (Candela, 2016). Tenets from Bloom's taxonomy (1956, as cited in Anderson et al., 2001) of learning domains, Bandura's (1997) theory of self-efficacy, and Polẏa's (1957, as cited in Pyo, 2011) four phases of problem-solving were interwoven to provide the foundation and strategic pathway for this research study. Figure 1 represents a model illustrating the relationships among the theories and tenets that guided the study.

Figure 1

Weatherby Framework for Contextualized Learning of Dosage Calculations



(Adapted from Bandura, 1997; Oermann & Gaberson, 2017; Polẏa [1957 as cited in Pyo, 2011]; Wilmes et al., 2018; Wright, 2009).

Bloom's taxonomy (1956, as cited in Anderson et al., 2001) is the culmination of effort from several education scholars who desired a standard basis for student learning assessment and curriculum design (Anderson et al., 2001). Bloom's three learning domains are cognitive—which deals with multi-level thinking skills, affective—which encompasses attitudes and values, and psychomotor—in which motor skills are developed (Oermann & Gaberson, 2017). This study tapped into the affective domain to address nursing student attitudes regarding the importance of accurately calculating drug dosages. The learning intervention bridged the cognitive domain because of the knowledge acquisition required for building values (Anderson et al., 2001).

The affective domain taxonomy consists of five levels, each representing the extent of involvement and internalization of the value. Oermann and Gaberson (2017) offered the following descriptions within the context of nursing education:

> *Level One-Receiving*: Awareness of values, attitudes, and beliefs important in nursing practice.
>
> *Level Two-Responding*: Learner's reaction to a situation. Responding voluntarily to a given situation reflecting a choice made by the learner.
>
> *Level Three-Valuing*: Internalization of a value. Acceptance of a value and the commitment to using that value as a basis for behavior.
>
> *Level Four-Organization*: Development of a complex system of values. Creation of a value system.
>
> *Level Five-Characterization by a value*: Internalization of a value system providing a philosophy for practice. (pp. 16-17)

The study's learning intervention addressed the lower three levels of the affective domain. First was by evoking emotion when participants heard a nurse describe the devastating event of administering a miscalculated dose to a patient (Cox, 2017). Establishing an emotional connection with the topic enhanced long-term learning (Beltrán-Pellicer & Godino, 2019; Giddens et al., 2020; Wilson, 2019). Second, the learning intervention promoted student awareness of the importance of accurate calculations and provided the opportunity to react by improving their calculation skills. Third was begin internalizing the value of solid calculation skills. The remaining upper two domain levels required a longitudinal research design to evaluate effectiveness of lasting internalization of values.

Bandura (as cited in Wafer, 2019) developed the self-efficacy theory to predict the likelihood of accomplishing a specific action contingent upon one's belief that they are capable of doing so. Specifically, "perceived self-efficacy is not a measure of the skills one has but a belief about what one can do under different sets of conditions with whatever skills one possesses" (Bandura, 1997, p. 37). One's sense of self-efficacy influences the amount of energy to expend on a task, how to cope with one's abilities, and how long to persist in achieving the goal (Veldman, 2016). Self-efficacy is a component of the social learning element of constructivist philosophy (Candela, 2016).

Students' sense of self-efficacy evolved from four main sources: performance accomplishments, vicarious experiences, verbal persuasion by others, and emotional arousal (Bandura, 1997). This study was designed to increase nursing student dosage calculation self-efficacy using an intervention that incorporated the four sources in affirmative ways. Participants experienced performance accomplishment when calculating the correct medication dosages during the small group activities. Vicarious experiences occurred while participants observed their more confident peers actively solving dosage problems. Those with lower math self-efficacy benefitted from the verbal persuasion their peers bestowed upon each other, instilling confidence that all could successfully solve the dosage problems. And lastly, the emotional arousal initially felt from learning about a nurse's specific experience with a serious medication error (Cox, 2017) strengthened from group interaction and individual successes with practice problems. In summary, the study provided for a low-stakes social learning environment in which small groups of students solved dosage calculation problems with opportunities to practice, observe, encourage, and model successful strategies for doing so.

George Polýa (1945, as cited in Chadli et al., 2018), an early 20th century professor of mathematics, developed a four-step problem-solving process to serve as a model for mathematics teaching and assessment. The model has withstood seven decades of implementation and assessment by several professional disciplines including nursing (Huse, 2010; Pyo, 2011; Wright, 2009). The four steps follow with qualifiers to ponder for further meaning:

1. Understand the problem. Nursing students who have no prior experience with medication administration would encounter the most difficulty with this step. They have not yet developed the mental representations formulated from experiential learning that facilitate recognition of similar problems (Wright, 2009). This study provided students with a contextualized learning environment in which the typical vessels used for medication administration facilitated conceptualization of the problem. Accoutrements such as syringes, graduated measuring cups, vials, tablets, and intravenous fluid bags all contributed to contextualizing the environment. Students looked these over, held them, operated the plungers, and examined the increments to develop a sense for volume and measurement.
2. Devise a plan. Students decide how to solve the problem. They would look for similarities to previous problems they had solved and decide which steps to take

first. Drawing a picture might be helpful (Melvin, n.d.). The research study provided opportunities for students to discuss possible solutions with peers, consistent with the social learning component of constructivist philosophy (Candela, 2016).

3. Carry out the plan. Students carefully implement each step and monitor for accuracy (Pyo, 2011). Polýa (1957, as cited in Pyo, 2011) asserted that for learning to occur, each student must devise and carry out the plan rather than merely receiving the information. Some assistance is acceptable to achieve success, which enhances student confidence and knowledge retention (Pyo, 2011). In this study, students were provided with dosage calculation problems to work out on their own before conferring with peers.

4. Look back. During this phase, students evaluate their solutions and ponder whether the answers make sense and seem logical and reasonable. If students estimated the answer earlier in the process, they should compare the actual results to the estimate (Wright, 2009). The final phase of Polýa's (1957, as cited in Pyo, 2011) problem solving process resembled reflection-on-action that Tanner (2006) identified as a necessary component for developing sound clinical reasoning. In this study, students were strongly encouraged to reflect on their answers and encouraged to contemplate the congruence to nursing practice.

Problem Statement

Medication dosage errors have the potential to harm the healthcare consumer, even causing death. Although students met the math requirements when accepted into nursing programs, many struggled with performing accurate dosage calculations for medication administration. Decontextualized learning environments, low math self-efficacy, and failure to conceptualize problems were some of the factors implicated in dosage calculation errors. Nursing faculty could mitigate these factors by providing a contextualized milieu for students to better conceptualize dosages.

Purpose of the Study

The purpose of this exploratory field study was to examine the effect of a contextualized dosage calculation learning intervention on pre-nursing students' math self-efficacy before beginning their nursing courses. After students begin their nursing courses, the effect of the learning intervention on the ability to pass a high stakes dosage calculation exam on the first attempt was examined. In addition, the relationships among student TEAS scores, math self-efficacy, and dosage calculation exam performance were examined.

Research Questions and Hypotheses

Q1 What effect does a contextualized learning intervention have on pre-nursing student math self-efficacy?

$H_0$1 A contextualized learning intervention has no effect on pre-nursing student math self-efficacy.

H_A1 A contextualized learning intervention does have an effect on pre-nursing student math self-efficacy.

Q2 What effect does a contextualized learning intervention have on pre-nursing student ability to pass a high stakes dosage calculation exam on the first attempt?

$H_0$2 A contextualized learning intervention has no effect on pre-nursing student ability to pass a high stakes dosage calculation exam on the first attempt

H_A2 A contextualized learning intervention does have an effect on pre-nursing student ability to pass a high stakes dosage calculation exam on the first attempt.

Q3 What is the relationship between math self-efficacy, TEAS scores, and dosage calculation exam performance?

$H_0 3$ There is no relationship between math self-efficacy, TEAS scores, and dosage calculation exam performance.

$H_A 3$ There is relationship between math self-efficacy, TEAS scores, and dosage calculation exam performance.

Significance of the Study

If pre-nursing students can begin their nursing courses with contextual knowledge of medication dosages and internalize the value of dosage calculation competency, the potential exists for averting client harm when nursing students become practicing nurses. In addition, confidence and competence with dosage calculations could enhance success with high stakes dosage calculation exams.

Definition of Terms

The contextualized learning environment served as an explanatory (independent) variable. When examining the relationship among math self-efficacy, TEAS scores, and dosage calculation exam performance, math self-efficacy and TEAS scores served as explanatory variables for dosage calculation exam performance. When examining the effects of a contextualized learning environment on math self-efficacy, math self-efficacy served as a dependent variable.

Variables

Contextualized Learning Environment

Conceptual Definition. The contextualized learning environment exposes students to authentic tasks that are meaningful and relevant and reflect what would be expected in the real practice setting. The learning occurs in a physical area that resembles the real practice setting and includes the commonly used tools. The expected learning outcomes should be realistic and resemble professional practice criteria (Coben & Weeks, 2014).

Operational Definition. The contextualized learning environment for this study was to be a large classroom containing multiple round tables that accommodated small groups. Each table was to display the typical vessels used for medication administration that facilitated conceptualization of the problem. Due to Covid-19 restrictions, the learning intervention was transformed to a synchronous video conferencing format. Accoutrements such as syringes, graduated measuring cups, tablets, vials, medication concentration labels, which contributed to contextualizing the environment, were distributed to students individually prior to the learning intervention. Students could look them over, hold them, operate the plungers, and examine the increments to develop a sense for volume and measurement. They calculated dosages of commonly used medications and conferred with peers via videoconferencing, replicating the authentic environment where nurses conferred with other nurses.

Affective Learning Domain (Importance of Dosage Calculation Competency)

Conceptual Definition. The development of attitudes, beliefs, and values "consistent with standards of professional nursing practice" (Oermann & Gaberson, 2017, p. 16).

Math Self-Efficacy

Conceptual Definition. The degree of confidence one has "in successfully performing various mathematics skills related to medication calculations" (Andrew et al., 2009, p. 219).

Operational Definition. Nursing student math self-efficacy as measured by nursing students' self-efficacy for mathematics (NSE-Math) instrument developed by Andrew et al. (2009). The instrument consists of various mathematical operations for which students rate their confidence in performing using a 10-point Likert scale. A rating of 1 indicates no confidence at all and a rating of 10 indicates complete confidence. The ratings for all questions were averaged for a final overall rating of self-efficacy.

Passing Dosage Calculation Exam

Conceptual Definition. Correctly answering a specified number of medication dosage calculations on a paper-pencil or computerized medication dosage calculation examination. Typically, among nursing programs, 80 to 100% of the questions need to be answered correctly to achieve a passing score (Sherriff et al., 2011).

Operational Definition. The medication dosage calculation exam requires 90% of questions to be answered correctly to be considered a passing grade. The exam is considered a dichotomous variable: pass or no pass.

Test of Essential Academic Skills Score

Conceptual Definition. The TEAS (ATI, 2020) evaluates basic academic knowledge in reading, English, language usage, math, and science. The test results are reported as a composite score that encompasses all subject areas and the score achieved for each of the subsections (ATI, 2020).

Operational Definition. The TEAS (ATI, 2020) composite score and each score of the subsets are examined in the relationship analysis.

General Terms

Dosage Calculation Competency

Dosage calculation competency is an integration of "conceptual competence (understanding the medication dosage problem to be solved); calculation competence (computation of an accurate numerical value for the dose to be administered); technical measurement competence (accurate measurement of the medication dose and/or rate of administration)" (Young et al., 2013, p. e11); and "personal and meta competence (demonstration of patient-safety…; reflection on dose calculation practice and correction of diagnosed errors; understanding personal limitations; managing uncertainty and the ability to learn from experience)" (Weeks et al., 2019, pp. 31-32).

Prelicensure Nursing Student

For this study, a prelicensure nursing student is defined as a student who is currently enrolled in an associate degree entry-level nursing program who has not yet begun nursing courses and is not nor has ever been licensed as a professional registered nurse (RN) in the United States.

High Stakes Exam

A high stakes exam is "any examination used for tracking or determining promotion or graduation" (Tagher & Robinson, 2016, p. 160).

Summary

This chapter highlighted the difficulties prelicensure nursing students experience when calculating drug doses despite fulfilling prerequisite math requirements. Several mitigating factors were discussed such as low math self-efficacy, decontextualized learning environments, lack of math problem practice, weak math skill development, and possible apathy toward math competency importance. Chapter II illuminates research that describes pedagogical approaches to teaching dosage calculations, demonstrating variable effectiveness.

CHAPTER II

REVIEW OF THE LITERATURE

Overview

This study examined the effect of a contextualized dosage calculation learning intervention on pre-nursing student math self-efficacy and ability to pass a dosage calculation exam on the first attempt. In addition, the relationships among student TEAS scores (ATI, 2020), math self-efficacy, and dosage calculation exam performance were examined.

The following databases were used for performing the literature review: Cumulative Index of Nursing and Allied Health Literature, Cochrane Central Register, PubMed, Journal Storage, Education Resources Information Center, PsychINFO, and Google Scholar. Searches using the terms nursing education, nursing students, medication calculation, numeracy skills, drug calculations, metrology, math, self-efficacy, and constructivism were entered separately and in combination. Searches were limited to peer-reviewed articles in English and gray literature comprised of dissertations and theses that were published in the last 10 years. The recommendation of publication within five years (Roush, 2018) was expanded to capture the marked evolution of dosage calculation pedagogy spanning approximately the past 10 years. Manual searches of article reference lists augmented the revelation of additional evidence. The literature review is organized into the following sections: theoretical review of constructivism and self-efficacy; overview of Polỳa's process (as cited in Pyo, 2011); the manners in which TEAS scores are applied; and teaching strategies for dosage calculation that include arithmetic approach, contextualizing the dosage calculation process using varying levels of fidelity, and web-based/computerized instruction.

Theoretical Review of Constructivism

Crotty (1998/2015) differentiated constructivism from constructionism by emphasizing the individual's unique experience in building knowledge versus society's collective production of knowledge in constructionism. Crotty further asserted that constructivists tend to hold their personal views as truths whereas constructionists question and challenge the status quo. This research study used constructivism as the guiding framework through the lens described by Weimer (2013):

> The approaches associated with constructivism often involve group work, although those writing about the theory more regularly refer to the act of individual learners connecting new information to what they currently know in ways meaningful to them. The distinction is something of a moot point, because when students work together in groups, each group member still deals with content individually, relying on his or her own experiences and understandings. (p. 21)

A component of constructivism, social learning theory, encompasses learning that occurs through observation and modeling of behaviors with a goal of self-efficacy development (Bandura, 1997). Learners with high self-efficacy embrace complex tasks, confident they will be successful. The constructivist learning environment is, by definition, a learner-centered environment in which students actively build their knowledge rather than passively receiving knowledge from teachers (Weeks et al., 2019). Providing authentic experiences when teaching dosage calculations takes advantage of situated cognition theory in which knowledge is a product of the learning context. Situated learning experiences facilitate students' transfer of new skills to the professional setting (Driscoll, 2005). The reviewed literature pieces that describe dosage calculation interventions using simulation and/or contextualized environments used pedagogical practices consistent with constructivist philosophy whether stated or not within the articles.

Self-Efficacy

Student self-efficacy in mathematics has been studied for decades and influences motivation, academic performance, and career choices (Andrew et al., 2009). Nursing students with low math self-efficacy lack confidence in their ability to accurately perform the mathematical operations involved with calculating medication dosages (Melius, 2012). The focus of this section is literature that explicates the relationships among math self-efficacy, various teaching interventions, and dosage calculation exam performance. Three of the studies measured nursing student math self-efficacy using the instrument designed and tested by Andrew et al. (2009): Nursing Student's Self-Efficacy for Mathematics (NSE-Math). The instrument specifically addressed mathematic operations used for calculating dosages and was the instrument used in this research study.

Andrew et al. (2009) administered the NSE-Math instrument to 112 second-year baccalaureate students who had also completed a compulsory dosage calculation exam. The full instrument achieved a Cronbach's alpha of 0.88. The authors compared the differences between low and high NSE-Math scores demarcated by the NSE-Math median score with dosage calculation exam performance using the independent *t*-test. The NSE-Math instrument performed as hypothesized—students with low math self-efficacy performed worse on the dosage calculation exam (M = 81.3, SD = 15.0) compared to those with higher math self-efficacy (M = 88.2, SD = 12.6) (t (110) = 2.65, p = 0.009). The results echoed the findings of previous research studies that predicted lower math exam performance when student math self-efficacy was low (Andrew et al., 2009). The authors emphasized the need for implementing strategies that enhanced student math self-efficacy with the tacit understanding that more accurate calculation of medication doses would follow. Specific pedagogies to accomplish the recommendation were not provided. This research study provided for a learning intervention intended to enhance self-efficacy with performing accurate dosage calculations.

Veldman (2016) compared the effects of two teaching strategies on nursing student math self-efficacy measured by the NSE-Math instrument (Andrew et al., 2009). In the quasi-experimental design, 147 total second-year nursing students in two different programs completed the instrument. Program A, the experimental group, used dimensional analysis to teach dosage calculations while Program B, the control group, used the formulaic method. Dimensional analysis was taught using traditional teaching practices, i.e., teacher-delivered lecture with a textbook, and was used consistently in the clinical setting guided by well-versed faculty. The formulaic method was taught using textbook and online resources with application in the clinical setting. There was no statistically significant difference in NSE-Math scores between the groups after the learning intervention. However, three other factors influenced the NSE-Math scores for both groups: gender (F (1, 140) = 6.08, p = .015, partial n^2 = .042), high school mathematics grades (F (1, 140) = 8.42, p = .004, partial n^2 = .057), and age (F (1, 140) = 7.32, p = .008, partial n^2 = .050). The full NSE-Math instrument achieved a Cronbach's alpha of 0.88. To summarize for both groups, males, those who performed well in high school mathematics, and older-aged students tended to score higher on the NSE-Math. In addition, the NSE-Math scores improved across all students over time. Both learning interventions provided essentially equal influence on nursing student math self-efficacy, which was statistically insignificant.

A sample of 84 nurses, of which 92% were RNs, participated in a study by Melius (2012) who investigated the relationships among math anxiety, math self-efficacy, and performance with medication dosage calculations. The initial invitation extended to the approximately 270 RNs and licensed vocational nurses employed at a single acute care facility in Texas. The nurses completed three documents: Mathematics Anxiety Scale (MAS; Bai et al., 2009, as cited in Melius, 2012), the NSE-Math (Andrew et al., 2009), and the Bayne-Bindler Medication Calculation Test (BB; Bayne & Bindler, 1984, as cited in Melius, 2012). The MAS is a 14-item Likert style questionnaire in which participants rate their perceived apprehension regarding certain mathematics operations. The BB is a fill-in-the-blank medication calculation test that contains 20 items ranging from simple to complex. The items reflected calculations common in nursing practice, aligned with the metric system, and were updated with current abbreviations by Melius (2012). The full NSE-Math instrument achieved a Cronbach's alpha of .83. Results from the study demonstrated a statistically significant relationship between the MAS and NSE-Math scores—as anxiety increased, self-efficacy decreased (r = -0.506, p < 0.001). In addition, the NSE-Math score was positively related to medication exam performance—the higher the self-efficacy, the better the performance (r = .225, p = 0.02). However, the commonality variance coefficient matrix revealed the effect NSE-Math scores exerted on the BB medication calculation exam overlapped with other explanatory variables. The matrix demonstrated the NSE-Math score accounted for only 2.85% of the variance, prompting the author to urge more research be completed to gain deeper understanding of factors influencing medication calculation exam performance. An additional, serendipitous finding revealed the number of hours worked explained 37% of the medication calculation exam performance. Although this study focused on licensed nurses rather than nursing students, it provided additional evidence for early intervention in facilitating the development of math self-efficacy for clinical practice.

The variables of math anxiety and self-efficacy were examined by McMullan et al. (2012) in conjunction with numerical ability and the influence on nursing student drug calculation ability. A convenience sample of 229 second year nursing students were recruited for the study. The MAS (Bai et al., 2009, as cited in Melius, 2012) was administered as well as the numerical ability test and math self-efficacy scale (MSES; Betz & Hackett, 1983, as cited in McMullan, 2012). Two additional instruments created and validated by the principal author were administered: the drug calculations self-efficacy scale and the drug calculation ability test (DCAT). The numerical ability test is a 15-item exam covering basic math skills such as addition, subtraction, multiplication, decimals, and conversions; it is used as an entrance test for specific-level nurses in the Australian health facilities. The MSES consists of 18 items, each rated on a scale from 1 to 10 with 1 indicating *no confidence at all* and 10 indicating *complete confidence* in performing a math operation. The drug calculations self-efficacy scale consists of six items pertaining to the most salient drug dosage calculations encountered in nursing practice. Nursing students rank each item on a scale of 1 to 10 with 1 indicating *no confidence at all* and 10 indicating *complete confidence* in performing the dosage calculation. The instrument achieved a Cronbach's alpha of 0.90 in the pilot study and 0.93 in the published study. The DCAT served as the dependent variable. The DCAT instrument is comprised of 20 dosage calculation problems that reflect the most common types of calculations encountered in nursing practice. Face validity was established by independent medication calculation experts in nursing education.

Students completed all five instruments and data were analyzed using independent *t*-tests to compare the group that achieved > 60%, the passing score, on the DCAT with the group that failed the DCAT (McMullan et al., 2012). Students who failed had lower levels of self-efficacy in performing numerical calculations (t (224) = -3.18, p = .002) as well as drug calculations (t (223) = -.2.48, p = .014). In addition, higher levels of anxiety were experienced by the students who failed (t (226) = 4.43, p < .001). Multiple regression analysis revealed that the strongest unique contributions to DCAT performance were numerical ability (B = 0.500, p < .001) and drug calculation self-efficacy (B = 0.162, p = .036). The model demonstrated a good fit (R^2 = 36.5%) with an overall significant relationship (F (4,217) = 31.2, p < .001).

Literature that specifically examined nursing student math self-efficacy as a variable to be measured was reviewed and summarized. Studies treating math self-efficacy as an independent variable demonstrated a statistically significant influence on dosage calculation exam performance, i.e., nursing students with low math self-efficacy scored lower on dosage calculation exams. Similar results have been reported in the non-nursing student population who take mathematics courses (McMullan et al., 2012). A natural conclusion nursing faculty drew from the results was the importance of identifying students with low levels of math self-efficacy early in their programs and implementing learning activities that increase math self-efficacy. What was not so clear was which interventions were the most effective. The single study (Veldman, 2016) that treated nursing student math self-efficacy as a dependent variable subjected to two different learning interventions did not elucidate the solution. The learning interventions consisted of methods for calculating dosages: one strictly using dimensional analysis (the experimental variable) and the other using formulaic methods (the control group). There was no statistically significant difference between the groups for nursing student math self-efficacy. This research study measured the effects of a contextualized learning intervention on nursing student math self-efficacy.

Polýa's Problem Solving Process

The use of Polýa's (1957, as cited in Pyo, 2011) four-step problem-solving process as a model for mathematics teaching and assessment was well documented in the literature (Chadli et al., 2018). Application of the model in nursing practice was encouraged as a framework for increasing accuracy of medication dosage calculations (Wilmes et al., 2018). The model was especially useful for nursing students who typically did not have prior experience with medication administration and therefore lacked the context for solving the problem (Wright, 2009). Step one, *understanding the problem*, provided for pause in which nursing students pondered what the question was asking them to do. It was during this phase that nursing students began to conceptualize the problem—understanding its meaning (Mackie & Bruce, 2016). In meeting the full intent of step one, students should be able to make accurate estimates of the solution (Pyo, 2011). Providing contextual clues such as syringes and graduated medication cups facilitated students' ability to conceptualize the problem. In step two, *devise a plan,* dosage calculation-naïve students were encouraged to think about similar problems they encountered in their chemistry or math courses (Huse, 2010). In step three, *carry out the plan,* students implemented their plan and were held responsible for doing so to internalize the learning (Mills, 2012, 2016). In step four, *looking back*, students reflected on the answer and asked if it made sense. If they estimated the answer in step one, a comparison should be made. Step four facilitated the development of clinical judgment (Wright, 2009).

In summary, Polýa's (1957, as cited in Pyo, 2011) four-step problem-solving process has not been subjected to testing and analysis per se in the nursing education literature; instead, it has been used as a guiding framework for students and nurses in solving medication dosage problems (Huse, 2010; Mills, 2012; Pyo, 2011; Wilmes et al., 2018). It served as a framework for problem solving in this research study as well.

Test of Essential Academic Skills

Most pre-licensure nursing programs require prospective students to achieve a specified threshold score on a proprietary entrance examination as one of the criteria that determine admission eligibility. These entrance exams are valued for their potential to predict student success in a rigorous nursing curriculum. The exams typically assess student proficiency with reading and language use, mathematical operations, and science topics (Manieri et al., 2015). Entrance exam vendors readily provide research literature that supports the validity and reliability of their product. This research study focused on the TEAS (ATI, 2020) exam as it was used by the nursing program from which participants were recruited. The TEAS scores were used for ranking, admission, and identifying those who might benefit from remediation and early intervention to ensure success in the nursing program. The correlation among TEAS scores, nursing program success, and ultimate first time passing of the NCLEX-RN (2019) was explicated in the literature. The next section provides a sampling of the results.

Van Hofwegen et al. (2019) used a logistic regression model to assess the predictive value of wo admission criteria, the TEAS performance and science grade point average (GPA), in predicting program completion, first-time NCLEX passing, and graduation GPA. The authors specifically examined students who were U.S. military veterans and enrolled in a highly competitive Bachelor of Science in Nursing (BSN) program in which all veterans who met basic requirements were admitted. The authors reviewed the data from 55 veteran students spanning five years of enrollment with 2016 as the final graduating year. There was no statistically significant correlation of TEAS scores and science GPA with program completion ($X^2 = 1.0357$;

df = 2; *p* = .5958) nor were the TEAS scores and science GPA statistically significant predictors of first-time NCLEX passing (X^2 = 2.77; *df* = 2; *p* = .25). The results contradicted findings from the authors' earlier research (Wambuguh et al., 2016) to be discussed later and the authors conceded the small sample size likely contributed to the lack of statistical significance. However, TEAS scores and science GPA did significantly predict graduation GPA (X^2 = 9.9265; *df* = 2; *p* = .007). Program completion (89.1%) and first time NCLEX-RN (2019) pass rates (85.4%) were similar when compared with the 584 non-veteran students during the same time frame (89.3% and 86.8%, respectively). Statistical analysis of group comparisons was not reported.

In their study from 2016, Wambuguh et al. sought to reveal predictors of pre-licensure BSN nursing program completion—first-time NCLEX-RN (2019) passing and GPA upon graduation—to provide evidence supporting admission requirements. The authors used a simultaneous logistic regression model to analyze data generated from five predictor variables for 523 students spanning five years. Two of the variables reached statistical significance: TEAS (ATI, 2020) scores and preadmission science GPA. The odds of graduating were increased by a factor of 2.14 for those students scoring > 81 on the TEAS (β = 0.76, *p* = .01), the only predictor variable reaching significance for this category. In addition, those scoring > 81 on the TEAS increased their odds of passing the NCLEX on the first attempt by a factor of 3.91 (β = 1.36, *p* = .02). Preadmission science GPA of ≥ 3.80 increased the odds of first time NCLEX passing by a factor of 6.99 (β = 1.94, *p* = .01). And finally, students scoring > 81 on the TEAS increased their odds of achieving a graduation GPA of 3.25 by a factor of 3.17 (β = 1.15, *p* = .00). The odds of achieving a graduation GPA of ≥ 3.25 were increased by a factor of 3.24 if preadmission science GPA was ≥ 3.80 (β = 1.17, *p* = .00). The three predictor variables not reaching significance for any of the categories were prior baccalaureate degree, prior healthcare experience, and university versus community college prerequisites.

In addition to TEAS scores, McCarthy et al. (2014) investigated the predictor performance of five ATI subject tests, pre-nursing GPA, and a communication course for NCLEX-RN (2019) success in a retrospective analysis involving 794 students from four BSN programs in a state university system. The logistic regression analysis using all predictor variables revealed a statistically significant model ($X^2 = 62.72$, df = 11, $p < .001$). Variables were subjected to canonical correlation analysis and iterations of multiple linear regression analyses to tease out the most salient predictors: ATI Medical-Surgical and Mental Health subject exams. Overall, McCarthy et al. concluded the analyses "revealed a significant correlation among prenursing, ATI scores, and NCLEX-RN first try pass rates" (p. 151).

Newton et al. (2009) researched the relationship between TEAS scores and students' ability to pass the dosage calculation exam. One-hundred and twenty-seven BSN students took the TEAS in the first semester of their sophomore year, followed by the dosage calculation exam in the first semester of their junior year. The authors found a positive relationship between the TEAS math aptitude score and the ability to pass the medication calculation exam on the first attempt ($r = .264$, $p < .003$). A more interesting finding was a stronger positive relationship between the TEAS composite score and the first time passing of the dosage calculation exam ($r = .336$, $p < .001$). Newton et al. surmised that reading ability facilitated passing of the dosage calculation exam. The hypothesis was further supported with a subsequent study that revealed a positive relationship between reading aptitude as measured by the TEAS and first time passing of the dosage calculation exam ($r = .351$, $p < .001$; Newton et al., 2010). The statistical analysis was generated from a sample of 126 junior-level BSN students.

A dearth of literature existed pertaining to associate degree pre-nursing programs exploring the relationships between TEAS scores and nursing student outcomes. Esper's (2009) research revealed a significant correlation between dosage calculation exam scores and the Science component of the TEAS ($r = .231$, $p = .05$). However, the correlation between the TEAS Math score and the dosage calculation exam was not significant ($r = .187$, $p = .054$). The results were generated from a sample of 107 nursing students in an associate degree program.

In a more recent study, Manieri et al. (2015) conducted a logistic regression analysis using data collected over five years to determine which pre-admission nursing exam best predicted success in an associate degree program. The authors compared the Pre-Admission Examination for Registered Nurses, Admission Assessment exam (A2), and the Test of Essential Academic Skills (TEAS) from two cohorts of students. The first cohort of 171 students took both the Pre-Admission Examination for Registered Nurses and the A2. The second cohort of 168 students took only the TEAS exam. Both the A2 and TEAS scores were significantly related to successful completion of an associate degree program ($\beta = 0.101$, $p = .000$; $\beta = 0.076$, $p = .004$, respectively). However, the A2 shone stronger, explaining 15.9% of the variance of success compared to the TEAS at 5.9%. The authors conceded a much larger portion of the variance was attributable to other untested factors.

In summary, research that explicated the relationship of TEAS scores to the probability of first-time dosage calculation exam pass rates was limited. The bulk of the literature focused on the predictive value of pre-admission exam performance toward nursing student success typically defined as program completion and NCLEX-RN (2019) pass rates. One of the foci of this research study was to explore the relationship between TEAS scores and new nursing students' first-time dosage calculation exam pass rates.

Teaching Strategies for Dosage Calculations

The following paragraphs highlight the various teaching methods gleaned from the literature review that were used to help nursing students learn dosage calculations. The methods included arithmetic strategies, contextualized environments from low to high fidelity, and web-based or computerized instruction. The research findings regarding the effectiveness of each method are included in the discussion.

Various Arithmetic Approaches

Nurse faculty who teach dosage calculations tend to do so through the lens of their personally preferred math operation strategy (Revell & McCurry, 2013). The most common approaches are dimensional analysis, formulaic, and ratio/proportion. Of the three, the formulaic approach is farthest removed from context and diminishes the student's ability to conceptualize the problem, yet tends to be the favorite (Rollings, 2019; Wright, 2008). Research that compared the efficacy of the different approaches yielded mixed results. A sampling of the studies follows.

In the Veldman (2016) study, two groups of nursing students were taught dosage calculations by two different methods. One group used dimensional analysis exclusively and the other group used the formulaic approach. The reported average dosage calculation exam scores were 94.46 (*SD* = 7.19, range = 70-100) for dimensional analysis group, and 94.33 (*SD* = 5.40, range = 77-100) for the formulaic approach. The exam means were not subjected to statistical analyses. Prima facie evidence suggested no difference between the methods in their effects on exam performance.

A twist on dimensional analysis was proposed by Pursell et al. (2017) in their suggestion for helping nursing students perform accurate dosage calculations. Pursell et al. encouraged students to try a "reverse" dimensional analysis by setting up the equation with the unknown item listed first rather than at the end as was traditionally done. Pursell et al. compared the results of using reverse dimensional analysis with traditional dimensional analysis from 73 beginning chemistry students who solved a 20-point titration problem. Those who used reverse dimensional analysis were far more likely to arrive at the correct solution than those who used traditional dimensional analysis (Welch *t* test: $p < .0001$). Results suggested the reverse dimensional analysis technique might be beneficial for computing accurate dosage calculations. The small sample size and the testing of chemistry rather than nursing students boded caution with generalizing results.

Contextualized Environments

Achieving a passing score on a written drug calculation test is not a valid measurement of computational skill fluency, although most nursing programs uphold this practice as a requirement for passing a course (Wright, 2008). However, more nursing programs are attempting to add context to dosage calculation pedagogy to help students conceptualize the problems, thus committing fewer calculation errors.

Anecdotal evidence supporting the use of contextualized dosage calculation exams was provided by Baginski (2017) who was concerned about student indifference toward dosage miscalculation. Baginski used low-fidelity simulation scenarios to provide an authentic environment that would encourage recognition of the importance of accurate calculations and enhance calculation accuracy. Students had one hour to complete 12 dosage calculation questions—each question was represented by 1 of 12 mannequins set up in a large simulation lab. The mannequins were set up with the equipment specific to the scenario including medication administration records, IV pumps, IV solutions, and other forms of medications. In addition, the mannequins were prepared to appear as lifelike as possible with personal possessions and common acute care therapy supplies such as supplemental oxygen and wound dressings. Students could work alone or with others as they moved from bed to bed to compute the dosage calculation. Students reported the realism of the activities facilitated a deeper understanding of the importance of accuracy with calculations. Baginski did not address whether the experience facilitated dosage calculation accuracy.

Harris et al. (2014) used a quasi-experimental design to examine the effects of two different teaching modalities on student medication administration and dosage calculation abilities. Two groups, each consisting of 79 junior-level BSN nursing students, were placed into two types of review sessions prior to taking the dosage calculation exam. The first group, the control, attended a review session consisting of the traditional didactic format. The second group, the intervention group, experienced simulation as the method for review. The control group listened to a slide presentation by the nursing faculty, watched demonstrations of calculations, and participated in class discussions. The intervention group was divided into groups of four and rotated through different simulation stations. At each station, students were exposed to the same types of calculation problems presented in the traditional classroom. Students in the simulation settings worked through the problems using the accoutrements necessary to carry out the dosage calculation and administration including syringes, medication vials, IV tubing, and IV fluids. All students sat for the same paper and pencil dosage calculation exam for which a simple calculator was allowed. A *t*-test was then conducted to determine whether a significant difference existed between the two groups. The dosage calculation scores for the intervention group were significantly higher than the scores for the control group ($t = 2.92$, df = 118, $p = .004$). Harris et al. concluded that contextualized experiences helped students successfully perform dosage calculations on the exam. Limitations included the small sample size and caution with generalizing results.

A pretest-posttest design with random assignment was used by Hurley (2017) to evaluate the effectiveness of a contextualized teaching strategy on dosage calculation accuracy. Hurley used a sample of 78 BSN nursing students in their sophomore nursing foundation course that included dosage calculation. Students were randomly assigned to two groups. The control group was taught dosage calculation by the traditional method of lecturing that covered dimensional analysis, ratio/proportion, and formulaic methods. The experiential group was taught using a student-centered approach that placed dosage calculations in context using authentic case studies. Students were supplied with the equipment and materials needed to prepare the medications. Both groups had taken the pretest with no significant differences in their scores (t = -1.106, df = 37, p = .276). A paired t-test on the posttest scores revealed a significant difference (t = -0.312, df = 37, p =.004) with the experimental group averaging 9.47 points higher. Although Hurley cautioned readers regarding generalizing results due to sample characteristics, the findings lent support to the body of evidence revealing the negative effects of separating math from the clinical context.

A convenience sample of 59 fundamentals level nursing students enrolled in an associate degree program were invited by Huse (2010) to participate in a dosage calculation education session. The students were assigned to one of two groups. The control group received dosage calculation instruction in a traditional classroom setting with the teacher providing the information. The experimental group participated in a low fidelity simulation in which the same drugs being tested in the control group were now being tested as actual medications to be administered complete with a medical record and the supplies needed to administer the drug.

During the last hour of the session, both groups were further subdivided into smaller groups where they could discuss problem-solving methods and solutions. Instructors provided guided reflection for both groups to ensure closure of the theory to practice gap. Both groups completed a dosage calculation exam after the learning interventions. A Mann-Whitney *U* test was used to analyze the difference between the control group mean score of 27.36 (SD = 3.915) and the experimental group mean score 28.23 (SD = 2.759). There was no statistically significant difference between the means (U = 254.000, p = .650). Both groups improved their performance when compared with their pretests. Interestingly, students in the experimental group reported significantly more confidence in their acquisition of skills and knowledge necessary to work in a clinical setting (U = 163.000, p = .005). In addition, students in the experimental group reported significantly more satisfaction with their learning experience than the students in the traditional classroom (U = 88.500, p = .000). Limitations of the study included small sample sizes and lack of randomization.

Nursing student preference for learning in a contextualized environment was further supported by a mixed methods study conducted by Ramjan et al. (2014). Ramjan et al. provided a variety of pedagogical strategies to nursing students in their final semester who had three opportunities to pass a pen-and-paper dosage calculation exam with 100% accuracy. A purposive sample yielded 390 participants who consented to having their test scores analyzed and surveys linked to their grades, representing 62% of the total cohort. Students were prepared for the dosage calculation exams according to an algorithm. Before the first exam, students were strongly encouraged to engage in online practice quizzes, which were readily accessible. Simulated medication calculation scenarios were also incorporated into the normally scheduled clinical practice units. Exam one was administered and those who did not achieve a satisfactory grade (*n* = 95) progressed to the next step of the algorithm—the visually enhanced didactic remediation workshop. Ninety students chose to attend the workshop, which was not mandatory. Concepts were visually enhanced using items such as dye to demonstrate solutions and volumes. Exam two was then administered of which 32 students did not achieve a satisfactory grade. The penultimate step of the algorithm, a "hands on" contextualized workshop, was offered to the students of which 31 attended. Students were able to use syringes and other accoutrements to prepare the correct doses. Ample teacher support was available as needed. Exam three was then administered and only one student did not achieve the required grade—the student who did not participate in the final intervention.

Ramjan et al. (2014) used a backward stepwise logistic regression to analyze the predictors of exam performance described in the previous paragraph. For passing exam one, achieving an overall practice quiz score of 59% or more was significant at $p = 0.001$ (OR: 2.55: 95% CI: 1.49, 4.38). For exam two, the five students who did not attend the visually enhanced didactic remediation workshop and failed the exam was statistically significant ($p = .001$). For exam three, one of the five who did not attend the final learning intervention did not pass the exam, which was also statistically significant ($p = .002$). Ramjan et al. suggested practice quizzes worked well for those students who function independently but not so well for students who require more face-to-face support. Qualitative results demonstrated that students who participated in the visual and "hands on" interventions provided exceptionally positive feedback and scored high in confidence on survey ratings. Ramjan et al. identified the survey instrument as a limitation due to lack of validation and having too many options (0-10). Additional limitations included cautious generalization to other nursing programs in other countries.

An integrative review conducted by Zahara-Such (2013) examined the use of simulation to improve dosage calculation skills of nursing students. Fifteen articles met the inclusion criteria spanning time up to October of 2011. The articles ranked from V to VII on the "Rating System for the Hierarchy of Evidence" by Melnyk and Fineout-Overholt (2010, as cited in Zahara-Such, 2013). Evidence supported four teaching strategies as identified in the literature:

- Teach math skills early and reinforce often throughout the nursing curriculum.
- Implement simulation with real, practical problems to solve.
- Develop the most accurate ways to assess math competency.
- Increase nursing students' confidence in order to improve math skills. (Zahara-Such, 2013, p. e382)

The learning interventions in this researcher's study addressed three of the four recommendations put forth by the integrative review described above. This study targeted newly accepted nursing students who had not yet begun their nursing courses. The participating students experienced hands-on dosage calculation scenarios wherein they could see the medications and the vessels used to measure correct doses such as syringes, tablets, and medicine cups with metric increments. Having the visual cues helped the participants to conceptualize the problem and set it up more accurately. As students gain proficiency with setting up and computing dosage calculations properly, their math self-efficacy should strengthen, which further enhances dosage calculation proficiency (Andrew et al., 2009).

Web-Based, Virtual, and/or Computerized Instruction

A large body of research and development of a proprietary web-based/computerized instruction module spanning nearly three decades was provided by United Kingdom (UK) scholar Keith Weeks and his associates. In 2013, an entire issue of *Nursing Education in Practice,* Safety in Numbers Special Issue, was devoted to dosage calculation pedagogy (Macdonald et al., 2013; Sabin et al., 2013; Weeks, Clochesy et al., 2013; Weeks, Higginson et al., 2013; Weeks, Sabin et al., 2013; Young et al., 2013). Weeks et al. (2019) initially identified three components of medication calculation competence, which was later expanded to four components. The four components—conceptual competence, calculation competence, technical measurement competence, and personal and meta competence—served as the definition for dosage calculation competence in Chapter I of this research study (Weeks et al., 2019; Young et al., 2013). Weeks et al. (2019) developed and tested "a virtual drug dosage calculation clinical learning and diagnostic assessment environment" that occupies the gap between theory and practice, which Weeks dubs "the liminal space" (p. 30). The following paragraphs describe the results of recent research that examined the effects of the proprietary virtual program on nursing students' drug calculation abilities.

In a longitudinal study of two nursing cohorts comprised of 210 students, Macdonald et al. (2013) examined the development of dosage calculation problem solving competence spanning three years of nursing education. The students were exposed to the virtual medication administration learning environment developed by Weeks et al. (2019) that was leveled for each progression point of the students. Macdonald et al. first conducted an internal consistency analysis, achieving a Cronbach's alpha of 0.891. Next, a *t*-test analysis was used to compare student medication calculation performance with their prerequisite mathematics grade, which revealed no statistically significant difference (t = 0.231, df = 208 [p level not provided]). The students needed to achieve 100% on their final medication calculation assessment, which was administered through the virtual medication administration learning environment. Although multiple attempts were allowed, 72% of the students achieved the 100% on the first attempt and by the second attempt, 96% had earned 100%. Macdonald et al. compared the performance in a qualitative assessment with two other studies that used traditional paper-pencil exams. In the first comparison, 229 students achieved an average score of 35% (McMullan, 2010, as cited in Macdonald et al., 2013) and in the second comparison, only 17% of registered nurses (RNs) scored 100% on a calculation test (Grandell-Niemi et al., 2003, as cited in Macdonald et al., 2013). Macdonald et al. attributed the superior performance to student exposure to authentic clinical environments the virtual medication administration learning software provided. This assertion would have been more compelling if the participants were compared to like participants, i.e., nursing students enrolled in concurrent courses or recent nursing curriculum enrolment. In addition, it was not stated how similar or different the dosage calculation exams were with the comparison groups.

Sabin et al. (2013) recruited 63 third-year nursing students to participate in both the virtual medication administration learning environment and an objective structured clinical experience occurring in a high fidelity simulated clinical environment. The purpose was to compare outcomes, reliability, and validity of the two assessment environments. The testing occurred in a single day with half the students participating in virtual environment while the remaining half participated in the simulated clinical setting in the morning. The roles were reversed for the afternoon to allow all students to experience both environments. Dosage calculation problems completed in the virtual environment achieved a Cronbach's $\alpha = .89$ compared to the high-fidelity simulated environment, $\alpha = .85$. The correlation between the virtual environment assessment and the high-fidelity simulation environment assessment was statistically significant (r = .77, p < .01), supporting the use of virtual environments for dosage calculation skill development and assessments.

In the development stages of the proprietary virtual dosage calculation module, Weeks, Clochesy, et al. (2013) in the United States teamed up to evaluate the effects of an authentic education environment on students' conceptual and calculation competency development. The authors used a crossover experiment design wherein students were exposed to two learning environments: the virtual prototype authentic environment and the traditional didactic classroom in which teachers lectured for 90 minutes followed by 90 minutes of practice and formative assessment with teachers offering tutorial support. The UK participants consisted of 44 randomly chosen students from a class of 110 who possessed characteristics representative of the whole. The sample size was dictated by the number of computers available at the time, which was 22. The groups were similar in their cognitive learning styles (X^2 = 1.40, df = 2, p = .496). After a three-week instruction period, all students completed a 30-item written dosage calculation exam and the didactic classroom results were compared with the virtual authentic environment results. Students in the virtual authentic environment committed significantly fewer total errors than the students in the traditional classroom (X^2 = 14.03, df = 1, p < .001). In addition, the students in the virtual authentic environment committed no conceptual errors, indicating successful movement from concrete thinking to symbolic knowledge construction. In the second stage of the experiment, students crossed over to the opposite learning environment and were tested again after three weeks of instruction. The error rate for the students who crossed over from the traditional classroom to the virtual learning environment was statistically significantly reduced when compared with the error rate reduction of the students who crossed over from the virtual to the traditional classroom environment (X^2 = 10.38, df = 1, p = .001), essentially leveling the error occurrence for the two groups.

The United States study used a convenience sample of 72 nursing students who were randomized to either the virtual authentic learning environment or the traditional didactic classroom (Weeks, Clochesy, et al., 2013). After three weeks of instruction, students took a 100-item dosage calculation written exam. A significant difference was detected between the two groups with the virtual authentic environment group scoring higher on the exam (t = -4.428, df = 68, p < .001), again lending support for successful learning in a virtual, authentic environment. A crossover follow-up was not discussed.

Qualitative inquiry was used to create a grounded theory to describe the learning process that entails dosage calculation cognitive and functional competence (Weeks, Higginson, et al., 2013). A total of 23 nursing students were interviewed regarding their perceptions and experiences with both the traditional lecture-based didactic classroom and the virtual dosage calculation learning environment. One theme that emerged highlighted that students felt the traditional didactic environment created a barrier to truly understanding dosage calculations because the numbers had no meaning. Another theme suggested the virtual environment provided a realistic depiction of calculating dosages in an authentic situation. Students stated the virtual environment helped them visualize proper measurement and delivery of medications. Weeks, Higginson, et al. (2013) provided numerous quotes from students that showcased students' evolution with mental framework construction and competence development with conceptualizing and accurately calculating drug dosages using the virtual environment.

Aydin and Dinç (2017) demonstrated another method for using online technology. Aydin and Dinç used a pretest-posttest design to evaluate the effects of an eight-week web-based course designed to improve arithmetical and drug calculation skills. The course employed audio presentations of lectures and quizzes and provided online posttests. Sixty-three students from a voluntary, convenience starting sample of 120 second-, third-, and fourth-year nursing students completed the pretest, eight-week course, and posttest. The Wilcoxon signed-rank test was used to compare the students' pretest and posttest scores. The mean score of 74.98 on the arithmetic skill pretest increased to 82.03 on the posttest (p = .000) and the mean score of 71.55 on the dosage calculation pretest increased to 82.03 on the posttest (p = .000). Aydin and Dinç concluded a web-based course could be effective for improving arithmetic and dosage calculation skills and had the advantage of being available when convenient for students. Limitations identified by the authors included no supervision with the posttests, suboptimal reliability scores for the arithmetic and dosage calculation instruments (0.64 and 0.66, respectively), and the possibility that students might have used other preparatory resources during the eight-week period.

Mackie and Bruce (2016) recruited three teacher candidates about to graduate to assist with creating online resources addressing dosage calculations to benefit nursing students. Fifty-seven dosage calculation exam results were reviewed for academic year 2012 with the type of errors categorized in one of the following groups: conceptual errors, procedural errors, unit errors, and implausible errors. Students were then exposed to the online resources throughout the following year. The online resources were developed to address the types of identified errors from the exams. The resources built on basic arithmetic operations that increased in complexity, culminating in contextualized practice questions. Test results were collected again for academic year 2013 to determine if the online resources were effective in reducing the errors. Using chi-square goodness-of-fit for the distribution of errors, a significant difference was detected between the two years (X^2 = 97.51, p < .001) with a moderate effect size (w = .33). Students taking the dosage calculation tests in 2013 performed significantly better than in 2012.

In summary, although dated, Zahara-Such's (2013) integrated review lent support for the contextualized environment offered by simulation defined as inclusion of mannequins and/or actors to serve as patients. However, contextualized environments that simply include the accoutrements needed to administer the medication such as syringes, vials, IV solutions and the like are also effective with facilitating student ability to conceptualize the problem. Evidence supporting one method of calculation over another, e. g., dimensional analysis versus ratio-proportion, was not compelling enough to mandate a single approach. The effectiveness of computerized dosage calculation modules in facilitating student mastery of accurate dosage calculations was supported. Virtual authentic environments offered convenience to both students and faculty. The virtual environment was accessible at any time and faculty were not burdened with assembling an equivalent low- to moderate-fidelity simulation for which time and space must be included. However, the research cited focused on a sampling of proprietary virtual environment products and similar results could not be assumed for other virtual environment products. The research was conducted with convenience samples within single nursing programs, thus generalizing results should be done with caution. In addition, the mere opportunity to practice dosage calculation questions as often as desired might have confounded the effects of the virtual program as practicing dosage calculations enhanced accuracy (Bagnasco et al., 2016; McCollum & Rogers, 2013; McGuire, 2015; Stolic, 2014; Wilmes et al., 2018). The Weeks, Clochesy, et al. (2013) research supported the observation that high grades in prerequisite math courses did not necessarily equate to dosage calculation acumen.

Instruments

The survey instrument used in this research study was the Nursing Self-Efficacy-Math (NSE-Math, Andrew et al., 2009). The NSE-Math instrument was evaluated by the researcher according to the criteria identified by Dunemn et al. (2017) for appraisal of instruments.

The NSE-Math instrument was developed in 2008 and copyrighted in 2009 by Andrew et al. to measure nursing students' confidence "in performing various mathematical skills related to medication calculations" (p. 219). The conceptual basis underpinning the instrument was Bandura's (1997) self-efficacy theory in which a person's sense of self-efficacy was a consistent indicator of whether that person would attempt a task, the amount of effort exerted, and whether the person would persist if unsuccessful (Andrew et al., 2009). The conceptual basis was consistent with this research study's theme. The instrument measures mathematics self-efficacy of nursing students in their second year (Andrew et al., 2009) and aligned well with this study's variables. The instrument was based on previously developed information in many other contexts other than nursing education. The instrument only has 12 questions, all of which pertain to the overall purpose specific to nursing students. Each question is rated on a Likert scale from 1 to 10 with 1 *indicating no confidence* at all and 10 indicating *complete confidence*. The question scores are added together and the mean of all the scores is compared. The instrument's data were treated as an ordinal level measurement although disagreement exists among scholars regarding the treatment of survey data at this level (Grove et al., 2013). The instrument could be used to measure the same variable again across a time continuum. The authors have granted the researcher permission for its use and do not require data to be sent to them (see Appendix A).

When Andrew et al. (2009) developed the instrument, 112 second-year nursing students completed all the requirements of the activity. Ninety one percent were female and the average

age was 25.22 years. The instrument achieved a Cronbach α of 0.88 in the original study (Andrew et al., 2009). A principal components analysis with iteration, oblique rotation, and pairwise deletion of missing data produced two factors, achieving Cronbach α of 0.90 and 0.87. The two factors were "Confidence in arithmetic concepts" and "Confidence in application of mathematic concepts to nursing practice." The factor analysis was deemed adequate by achieving a Kaiser-Meyer-Olkin adequacy score of 0.82. Face validity was achieved by consulting a panel of experienced nurse educators who taught medication calculations.

The instrument was subsequently used in two studies and the researcher's pilot project. Melius (2012) recruited a sample of 84 nurses, of which 92% were RNs and the remainder licensed practical nurses (LPNs), for a study that explored the relationships among math anxiety, math self-efficacy, and performance with medication dosage calculations. The a priori power analysis called for a minimum sample size of 51 using a medium effect size of 0.3, α of 0.05, and power of 0.95. The full NSE-Math (Andrew et al., 2009) instrument achieved a Cronbach's alpha of 0.83. The factor *Confidence in arithmetic concepts* achieved 0.90 and the factor *Confidence in application of mathematics to nursing practice* achieved 0.83. Results from the study demonstrated a statistically significant relationship between math anxiety and self-efficacy—as anxiety increased, self-efficacy decreased (r = -0.506, p < .001). In addition, the NSE-Math score was positively related to medication exam performance—the higher the self-efficacy, the better the performance (r = .225, p = .02). However, the commonality variance coefficient matrix revealed the effect NSE-Math scores exerted on the medication calculation exam overlapped with other explanatory variables. The matrix demonstrated the NSE-Math score accounted for only 2.85% of the variance, prompting Melius to urge more research be completed to gain deeper understanding of factors influencing medication calculation exam performance.

Veldman (2016) conducted a power analysis prior to implementing research in which the independent variable was the use of dimensional analysis as a teaching strategy and the dependent variable was student self-efficacy as measured by the NSE-Math instrument. Veldman used an alpha level of .05, level of acceptable error of 5%, effect size of moderate at 0.5, and power rating set at 0.90 to generate the recommended sample size of 140. Veldman recruited a total of 147 nursing students in their second year of a BSN program. Eighty nine percent were female and the mean age was 21.5 for one group and 23.2 for the second group. Veldman reported the Cronbach's alpha score for the full instrument was 0.88, while the result for the *Confidence in application of mathematic concepts to nursing practice* factor was 0.90 and for the *Confidence in arithmetic concepts* factor, the resulting score was 0.87. There was no statistically significant difference in NSE-Math scores between the groups after the learning intervention. However, three other factors influenced the NSE-Math scores for both groups: gender (F (1, 140) = 6.08, p = .015, partial n^2 = .042), high school mathematics grades (F (1, 140) = 8.42, p = .004, partial n^2 = .057), and age (F (1, 140) = 7.32, p = .008, partial n^2 = .050).

Although the NSE-Math instrument was not extensively tested, it was the instrument of choice for this research study. Unlike prominent math self-efficacy instruments in the literature, the NSE-Math pertained specifically to nursing students and dosage calculation problems common in nursing practice.

Chapter Summary

The chapter provided the rationale for using constructivism to frame the research. Literature that described the association between nursing student self-efficacy and dosage calculation performance demonstrated a positive relationship in that the higher the sense of self-efficacy with math, the better the performance with dosage calculations. This research study added to the body of evidence by increasing nursing student math self-efficacy with an intervention targeting dosage calculation-naïve students. Literature elucidating the use of TEAS scores with regard to dosage calculation competence was discussed and gaps were identified. Scant literature existed that examined the relationship of TEAS scores to dosage calculation exam performance, particularly as it pertained to pre-nursing students starting their associate degree nursing courses. This research study examined this relationship and discussed targeted intervention based on the results. The literature pertinent to a comprehensive examination of dosage calculation pedagogy was examined and critiqued. Quantitative studies demonstrated mixed results with regard to the most effective mathematical approach. Using Polỳa's (1957, as cited in Pyo, 2011) problem solving process in this research study, nursing students had the opportunity to choose what they believed was the proper approach to solving the problem. Several articles were described that used Polỳa's method as a framework for solving dosage calculations. This research study added to the body of evidence indicating whether this was an effective strategy. Contextualized environments for teaching and learning dosage calculations were supported by the literature in two ways. Quantitative studies demonstrated effectiveness with student performance on dosage calculation exams. Qualitative evidence demonstrated exceptionally high student satisfaction with this type of authentic learning. Contextualized environments could be as simple as merely using a few typical "tools of the trade" such as syringes, IV solutions, and pills to demonstrate volume and amount to sophisticated simulation scenarios that included live actor-patients, beds, charts, and other equipment typical of the acute care setting. The gap in the literature targeted dosage-calculation naïve pre-nursing students using a simple contextualized environment to introduce medication calculations. This research study provided for basic accoutrements common to nursing practice for administering medications and offered the benefits of social learning in the constructivist environment. The web-based/virtual/computerized learning environments demonstrated effectiveness in helping students garner dosage calculation acumen. This type of environment could be considered contextualized when the modules displayed pictures of the accoutrements of dosage calculation and medication administrations. Many programs allow manipulation of the items displayed on the screen. For example, students could adjust syringes to the correct amounts, pour liquids into graduated medication cups to the correct mL marking, or select the correct number of tablets (Weeks, Higginson, et al., 2013). For this research study, the web-based/virtual programs were not defined as contextualized environments and were not used in the learning intervention. The final section of this chapter discussed the reliability and validity of the instrument used in this research study. The NSE-Math (Andrew et al., 2009) was evaluated according to the criteria put forth by Dunemn et al. (2017). Testing and validation of the instrument was described.

CHAPTER III

METHODOLOGY

The purpose of this research study was to examine the effects of a contextualized dosage calculation learning intervention on pre-nursing students' math self-efficacy and ability to pass a high stakes dosage calculation examination on the first attempt. In addition, the relationship between TEAS and Math-NSE scores and the ability to pass the dosage calculation exam on the first attempt were explored. This chapter describes the research design, the study's setting, sampling methods and recruitment of research participants including protection of human subjects, instruments, data collection, the learning intervention, data analysis, and limitations. This chapter also describes the modifications to the study that were required for adherence to Covid-19 safety standards. All modifications were approved by the University of Northern Colorado and the researcher's home campus Institutional Review Boards.

Research Design

This was an exploratory field study in a partially controlled setting that involved a small convenience sample. Exploratory field studies explore relationships among variables outside of a controlled laboratory setting (Remler & Van Ryzin, 2015). This type of approach was suitable for exploring relationships among student Math-NSE scores, TEAS scores, and passing the dosage calculation exam.

Setting

The learning intervention was implemented by recruiting newly accepted nursing students from a large community college in a midwestern state. About 15,000 part- and full-time students are enrolled in the college in any given year. Females comprise 56% of the student body and students of color make up 41%. Twenty-three percent of the students are 25 years of age or older. Nursing is one of the top five declared majors.

Covid-19 precautions necessitated the transformation of the learning intervention to a virtual format. Students attended from their homes or from locations within the state via Zoom® (2020) technology.

Sampling

Recruitment

The study employed a convenience sampling strategy from a pool of pre-nursing students. Approximately 48 newly accepted students in the associate degree nursing curriculum were invited to participate in the study during their inaugural welcome and information session. This event occurred several weeks prior to the start of their first semester in nursing courses. The invitation to participate was extended two more times via electronic notification (see Appendix B). Inclusion criteria extended to only those students who were newly accepted into the nursing program, were to begin their first semester in the nursing curriculum, and were 18 years of age or older. No exclusion criteria were declared.

Targeted Population

The target population for this research study was newly accepted students into an associate degree nursing program at a large midwestern community college. The nursing program admits 96 students annually from a pool of around 200 applicants who have successfully completed the prerequisites. Qualified applicants to the school of nursing must have at least a 2.75 GPA. No minimum composite TEAS score was required. However, because students were ranked using the composite TEAS score and GPA, the lowest TEAS scores of accepted applicants typically fell in the "proficient" category: 58.7% to 79%. The pool of students admitted to the nursing program have historically represented ages from 19 to 60 years, 15% to 20% are male, and 23% to 40% are students of color. Historic first-time pass rates for the dosage calculation examination in the first nursing semester have ranged from 51% to 70%. Unsuccessful students have two more tries to achieve 90% to remain in the program.

Protection of Human Subjects

Initial approvals from both the University of Northern Colorado and the affiliated community college Institutional Review Boards were obtained (see Appendix C). An amended proposal that described transforming the learning intervention to a virtual format was subsequently approved prior to the initiation of data collection (see Appendix C). Adherence to all guidelines and ethical principles outlined by the Collaborative Institutional Training Initiative program for research with human subjects was accomplished. Risk to participants was minimal and might have consisted of feelings of anxiety or frustration when completing the surveys or calculation problems. The benefits to participants were development of more confidence with dosage calculation and thinking skills, establishing personal connections with cohort peers, and contributing to the advancement of nursing science. Informed consent using paper format, which included authorization to access TEAS scores, was obtained during the week preceding the learning intervention (see Appendix D). Students could still participate in the learning intervention if they chose not to sign the consent. The researcher recognized potential conflict of interest due to the researcher's faculty position in the nursing program and intentionally refrained from placing undue pressure on students to participate. The researcher did not have a personal or professional relationship with the students and was not be the students' nursing instructor until their final semester of nursing school.

Data Security

Because data were analyzed according to individual performance, it was necessary to connect surveys with the student who completed the survey and to further connect the surveys and TEAS scores with the student's dosage calculation exam pass/fail status. The surveys identified students using a unique numerical identifier. If students completed the surveys but did not sign the informed consent, those survey data were discarded. The data (completed demographic and NSE-Math surveys) were compiled using the Qualtrics® survey platform provided by the University of Northern Colorado and collected by the researcher. The data were entered on the researcher's computer that was password protected and situated in a locked area only accessible by the researcher. The computer was not left unattended. The data were entered into the statistical program SPSS v.26 using the unique numeric identifier associated with each case. The researcher recognized her dual role as researcher and faculty and did not share identifiable information with anyone specifically and especially those in the college setting. The aggregated data with only the unique numeric identifier will be stored electronically for a period of three years. The signed consent forms are maintained in a locked desk drawer in the researcher's locked office where they will remain for a period of five years. The volunteer course instructor had access to the students' dosage calculation exam results by virtue of her teaching position. The volunteer course instructor had no access to the remaining data—the TEAS scores, the Math-NSE scores, and the demographic information.

Instrument Analysis

The researcher used the Nursing Self-Efficacy for Mathematics (NSE-Math; Andrew et al., 2009) instrument for a pilot project prior to the commencement of this research study. After obtaining approval through the community college Institutional Review Board (see Appendix C), the researcher administered the NSE-Math instrument to 34 volunteer pre-nursing students newly accepted into the nursing program. Using SPSS v25, a Cronbach's alpha of 0.84 was computed for the full instrument derived from 26 complete surveys. A principal components analysis was conducted to compare the underlying constructs with the original findings. Bartlett's test of sphericity, which tests the overall significance of all the correlations within the correlation matrix, was significant ($\chi^2 = 281.195$, $p < .001$), indicating the data were suitable for factor analysis. The Kaiser-Meyer-Olkin measure of sampling adequacy was 0.589, less than the recommended 0.80, and not unexpected given the small sample size. The recommended sample size for conducting factor analyses was 10 respondents for each variable (Kellar & Kelvin, 2013). For the NSE-Math instrument, the 26 completed surveys should have been adequate as previous factor analyses yielded two main constructs. Regardless, results yielded a solution of three factors with eigenvalues ranging from 2.054 to 4.583. The three-factor solution accounted for 78.76% of the variance in the correlation matrix. Two of the three factors appeared generally consistent with the dimensions specified: (a) confidence in arithmetic concepts and (b) confidence in application of mathematic concepts to nursing practice. The third factor that emerged was what the researcher labeled as (c) confidence with conversions. Alpha reliabilities for each of the subscales were (a) confidence in arithmetic concepts ($\alpha = .809$), (b) confidence in application of mathematic concepts to nursing practice ($\alpha = .928$), and (c) confidence with conversions ($\alpha = .889$).

For this study, the NSE-Math instrument was combined with the demographic tool and transformed to a Qualtrics survey format for electronic distribution (see Appendix E). The researcher designed a demographic survey that consisted of questions about age (numeric value), gender (fill in blank, categorical value), ethnicity (categorical value), prior health care experience (categorical value), experience with administering medications (categorical data), and prior degree (categorical value). The NSE-Math questions were designed such that respondents could use a slider bar to indicate a discrete number between 0 and 10, indicating level of confidence for each item where 0 = *No confidence at all*, 5 = *Some confidence*, and 10 = *Complete confidence*. This replicated the copyrighted paper version upon which students would place an ‘X’ in the box corresponding to a number from 0 to 10 to indicate level of confidence with each item (Andrew et al., 2009). The survey link was emailed to all 32 participants three days before the scheduled learning intervention. One reminder was emailed the evening before. All 32 participants completed the pre-intervention survey for a 100% return rate.

Eleven (34%) surveys were eliminated from reliability analysis due to one or more missing data points. Using SPSS v26, a Cronbach’s alpha of 0.89 was computed for the full instrument derived from 21 complete surveys.

To determine the effectiveness of the learning intervention on nursing student self-efficacy with performing mathematics, participants were asked to complete the NSE-Math survey again. Five days after the learning intervention, a post intervention survey link was emailed to all 32 participants. The survey remained open for one week and a reminder email was sent the evening before closing the survey. Twenty-five participants completed the post intervention survey for a 78% return rate. Of the 25 completed surveys, 23 (92%) contained complete data sets for reliability analysis. Using SPSS v26, a Cronbach's alpha of 0.85 was computed for the full instrument derived from 23 complete surveys.

Procedure

The study consisted of multiple steps that unfolded after all students applying for Fall 2020 nursing program admission fulfilled the necessary requirements that included taking the TEAS exam. The TEAS exam scores were used in the ranking of applicants, which occurred during March 2020, for the Fall start of nursing courses. The exploratory field study commenced in the following manner:

Phase 1

All newly accepted students into the nursing program received an invitation to participate in the learning intervention during their inaugural information session that occurred during May 2020 (see Appendix B).

Phase 2

Invitation reminder emailed to all students two weeks and again one week before the scheduled intervention. The email included information regarding pick-up of the intervention kit and signing the consent form.

Phase 3

Four days before the learning intervention, August 14th, consenting students completed the demographic and Math-NSE surveys.

Phase 4

Students attended the learning intervention on August 17th, 2020.

Phase 5

From August 22 to August 24, 2020, students again completed the Math-NSE survey. Data collected from the pre- and post-intervention Math-NSE surveys were used to answer Research Question 1 as well the hypotheses:

Q1 What effect does a contextualized learning intervention have on pre-nursing student math self-efficacy?

The null and alternative hypotheses for this question were as follows:

$H_0$1 A contextualized learning intervention has no effect on pre-nursing student math self-efficacy.

H_A1 A contextualized learning intervention does have an effect on pre-nursing student math self-efficacy.

Phase 6

Nursing courses started August 24th and students took their first dosage calculation exam on September 30. The aggregated data regarding pass/no pass and learning intervention attendance were provided by the volunteer course instructor. The aggregated categorical data from the dosage calculation exam were used to answer Research Question 2,

Q2 What effect does a contextualized learning intervention have on pre-nursing student ability to pass a high stakes dosage calculation exam on the first attempt?

The null hypothesis and alternative hypotheses for this question were as follows:

$H_0$2 A contextualized learning intervention has no effect on pre-nursing student ability to pass a high stakes dosage calculation exam on the first attempt.

H_A2 A contextualized learning intervention has an effect on pre-nursing student ability to pass a high stakes dosage calculation exam on the first attempt.

Phase 7

The dosage calculation exam categorical data, the TEAS, and pre-intervention Math-NSE scores were used to answer Research Question 3:

Q3 What is the relationship between math self-efficacy, TEAS scores, and dosage calculation exam performance?

The null and alternative hypotheses for this question were as follows:

H_03 There is no relationship between math self-efficacy, TEAS scores, and dosage calculation exam performance.

H_A3 There is a relationship between math self-efficacy, TEAS scores, and dosage calculation exam performance.

Data Collection

The volunteer course instructor distributed the Qualtrics survey link by email to consenting students during the five days prior to the learning intervention. A reminder email was sent the night before the learning intervention. The survey consisted of the researcher-designed demographic questionnaire and the NSE-Math instrument. The NSE-Math instrument was completed before and after the learning intervention, again using a Qualtrics link distributed by the volunteer course instructor. The TEAS scores were compiled by the nursing department administrative staff and given to the researcher after the researcher had determined student consent for this data. Pass/fail statistics were compiled by the volunteer course instructor administering the first dosage calculation exam that occurred approximately six weeks after the learning intervention. The results were then given to the researcher electronically.

Modality

Due to Covid-19 precautions, in-person attendance on the college campus was prohibited; thus, the learning intervention was implemented using Zoom (2020) technology, which provided synchronous, online videoconferencing opportunities among other features. The technology allowed for chat rooms and virtual breakout rooms where students could be placed in small groups to complete activities, then returned to the main virtual room where results could be shared. The person, or host, who arranged the Zoom conference had the ability to join each breakout room to monitor progress and address any questions. In addition, document cameras interfaced with Zoom, which allowed for display of physical items and replication of a chalk board for real-time handwriting. The volunteer course instructor attended the entire Zoom session where she noted attendance, assisted with monitoring the chat room, and fielded questions concerning the first semester nursing courses.

Consent and Distribution of Learning Kits

All newly accepted nursing students received the consent form in electronic format for personal perusal. The researcher compiled individual packets containing dosage calculation problems with Polýa's (1957, as cited in Pyo, 2011) four step map for solving (see Appendix F). The accoutrements needed for context, i.e., syringes, unit-dose pills, 2 mL vials, sugar cubes, and 30 mL calibrated medication cups were placed in individual plastic bags for distribution. Students were invited to stop by the campus during specified time periods prior to the intervention to collect the packets and baggies and sign the consent form if they consented to their data being used in the study. Each consent form displayed a unique numeric identifier at the top. Students who did not consent were still offered the accoutrements with the packet and the opportunity to participate. This activity was conducted in adherence with Covid-19 cautionary guidelines.

Link to Demographic Tool and Nursing Student's Self-Efficacy for Mathematics Survey

After dispersal of the packets, the demographic tool and NSE-Math Qualtrics survey link was delivered electronically to consenting students. The volunteer course instructor electronically distributed the flyer containing information about the learning intervention including the Zoom (2020) link to all students newly accepted into the nursing program (see Appendix B).

Learning Intervention

The learning intervention consisted of three main stages: activating and engaging the affective domain, learning to conceptualize metric measurements, and practice solving rudimentary dosage calculations using Polỳa's (as cited in Pyo, 2011) four step process.

Stage 1: Activating and Engaging the Affective Domain

Using a PowerPoint presentation, the researcher began by briefly explaining the ideas of conceptualizing and contextualizing medication dosages. Students were assured pre-nursing students around the world encountered similar challenges even though the mathematics requirements were met for nursing school admission.

Affective Domain Level 1: Receiving

In a short open question and answer session, students were asked to offer ways in which math is used in nursing. Students shared their ideas by writing on the virtual white board and in the chat section, whereas other students verbally volunteered their ideas. When no further ideas were forthcoming, the researcher offered examples listed on the PowerPoint slide, many of which were previously identified by the students. This step of the learning intervention addressed the primary level of affective domain learning, *Receiving*, in which students became aware of a belief (Oermann & Gaberson, 2017), in this case, the frequent use of math in nursing practice.

Affective Domain Levels 2 and 3: Responding and Valuing

Next, a 4:21 minute video was shown to the students in which a nurse described the devastating event of administering a miscalculated dose to a patient (Cox, 2017). After the video, the researcher asked students to reflect silently on the following questions suggested by the Quality and Safety Education for Nurses Institute (McCabe, 2016):

1. What were you feeling as the observer?
2. How would you feel if you were involved in this error in clinical practice?
3. Where would you turn for support?
4. What steps could you or would you take to prevent an error of this nature from occurring again?

After 30 seconds, students were then given the opportunity to voluntarily share their thoughts. Several students verbalized their feelings and a few wrote succinct missives in the chat box. The main themes emerging from this activity were recognizing the importance of support from and for peers, becoming more aware of safe practices, and expressing feelings of remorse and forgiveness. These steps of the learning intervention addressed the second and third levels of the affective domain of learning, *Responding* and *Valuing*, in which students reacted to a situation and began internalizing the value (Oermann & Gaberson, 2017), in this case, the value of math skills in performing accurate dosage calculations.

Stage 2: Conceptualizing Units of Measurement

The next phase of the learning intervention focused on the basic units of measure in the metric system—meter (length), liter (volume), and gram (weight)—and the prefixes used to discern measurements: kilo-, milli-, and micro- with emphasis on the 1000-fold difference in meaning. Manipulatives such as syringes, medication cups, and pictures of two babies (one premature and one post-term) were used to help with conceptualizing measurement. Students were instructed to take note of different measurements such as a milliliter of fluid, a gram of sugar, or a two-millimeter fingernail length. Within this learning intervention phase, students were introduced to authentic drug labels that specified the amount of medication contained in the holding vessel. To help conceptualize the amounts indicated on the drug label, items such as acetaminophen tablets were used to represent the words on the label, in this case, 325 mg of acetaminophen per tablet.

Sugar Cubes and Polỳa's Step 2

To conceptualize a drug dose given a certain volume, students were directed to place a four-gram sugar cube in various volumes of liquids with students creating the correct "drug" label for the concentration. Students were asked whether any of their prerequisite courses required them to make various solutions and labeled them accordingly. Some verbalized recognition of the similarities to what they experienced in chemistry. This activity also operationalized the second step of Polỳa's (as cited in Pyo, 2011) process in which learners are encouraged to think about similar problems they had solved previously. The researcher urged them to transfer the knowledge from chemistry to the present activities.

Intervention Kit

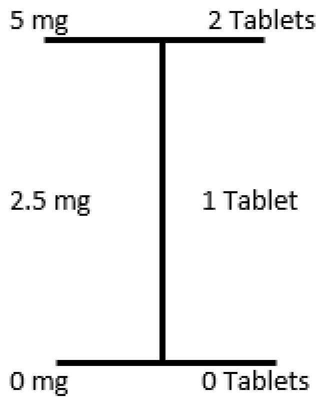
The researcher used the document camera to display various sized vials representing drug doses so students could immediately transfer their conceptual knowledge to the vial solution. Each learning intervention kit contained a Demo Dose® practice vial of medication labeled as "FUROSEMID LASX 20mg (10 mg/mL)" that students looked over and touched to develop a sense for volume (see Appendix G).

Using Capital "I" to Conceptualize Dose

Students were next challenged with computing the amount to administer when the ordered dose did not match the packaged dose. For example, "the primary care provider orders lisinopril 5 mg orally every morning. Lisinopril comes packaged as 2.5 mg/tab. How many tablets will the nurse administer?" Although the problem seemed elementary, many students incorrectly set up an equation to solve it, typically resulting in the answer of "one-half tablet," and not pause to think about whether the answer makes sense (Rollings, 2019; Weeks, Higginson, et al., 2013, 2019). The researcher presented a simple method for conceptualizing the problem and estimating the correct answer by drawing a capital "I" (Carter, 2018). The base of the capital "I" represented the value of zero for mg on the left and zero tablets on the right. The halfway point of the capital "I" represented 2.5 mg on the left and one tablet on the right. The top of the capital "I" represented twice the amount of the middle: 5 mg on the left and two tablets on the right (see Figure 2). Students were encouraged to decide how to divide the capital "I" to depict various ordered doses and corresponding vessels of availability, e.g., tablets or mL, depending on the primary care provider's prescription.

Figure 2

Example of Using Capital "I" to Conceptualize Proportion



(Adapted from Carter, 2018).

Stage 3: Solving Dosage Calculations
Using Polỳa's Four Step Process

The final phase of the learning intervention began with an introduction to Polỳa's (as cited in Pyo, 2011) four-step problem solving process described at length in earlier chapters. The researcher solved a dosage calculation example on paper displayed by the document camera using Polỳa's process as a framework. Two simple problems were provided for students to practice solving using the framework.

Small Group Activities

Using the Zoom (2020) feature for breakout rooms, students were then randomly placed in groups of five to solve several dosage calculation problems, each problem represented by manipulatives contained in their intervention kits. Students had received paper copies of the dosage calculation scenarios complete with Polỳa's (as cited in Pyo, 2011) framework and a capital "I" for helping to solve when they retrieved their intervention kits (see Appendix G).

Each kit contained the corresponding items related to the dosage calculation examples such as syringes, tablets, or vials, to facilitate conceptualizing the solution. Students were able to debate the solving process and the answers with each other in their small Zoom groups while the researcher and the volunteer course instructor visited each group virtually to answer questions and clarify misconceptions.

Return to Main Room

Students were instructed to return to the main virtual room when they had finished their problems. All groups returned within 15 minutes. If the learning intervention had been implemented as originally planned in a large classroom with several round tables and students rotating from table to table to solve the problems, the time requirement would have been longer, perhaps an hour or so. Because the dosage calculation problems were distributed prior to the intervention, most students had already reviewed the problems before attending the session. After return to the main virtual room, the researcher and the volunteer course instructor discussed each of the scenarios and shared the misconceptions that had emerged during the small group visits.

Student Questions and Preferred Calculation Strategy

Questions that arose concerned the meaning of abbreviations that were used in the scenarios such as “STAT” and “mEq.” One group wanted to know what was done with the remaining drug left in a vial when only a portion was needed. Students recognized they did not have enough of the drug dose in their kits to meet the requirements of some of the prescribed doses. Students volunteered their preferred calculation strategies, which ranked anecdotally from the most popular, formulaic, followed by ratio-proportion to dimensional analysis. Students were informed that if the formulaic method was used, it was especially important to pause and ensure the answer made sense since this method was the most removed from context (Rollings, 2019). Two students asked whether the dosage calculation exam would have easy problems similar to those they solved during the intervention. The volunteer course instructor described the ranges of difficulty and to consider the learning intervention as a foundation for solving more complex problems, which were consistent with research findings of Mills (2016). The learning intervention then concluded with 36 students having attended (see Appendix H for Lesson Plan).

Post-Intervention Nursing Student's Self-Efficacy for Mathematics Survey Completion

Five days following the learning intervention, a link to the NSE-Math electronic Qualtrics survey was sent to consenting participants to explore any post-intervention effect on the NSE-Math score (see Appendix I). The survey was open for three days. One reminder was sent the night prior to its closing. Twenty-five of 32 surveys were completed for a 78% return rate.

Contingency Plan

The contingency plan for addressing the unlikely possibility of entire group participation in the learning intervention was not necessary to implement. The plan would have compared the present cohort's dosage calculation exam aggregated data with the pass/no pass aggregated data from the Spring 2019 cohort compiled by the volunteer course instructor.

Data Analysis

Data from the surveys were downloaded from Qualtrics to the researcher's computer. The survey data and the TEAS scores were manually entered into the statistical software (IBM SPSS v26 for Windows) installed on the researcher's computer. For tests of statistical significance, a Type 1 error of 5% was used. Descriptive statistics for all variables were analyzed such as frequency, mean, standard deviation, and normalcy of distribution. Reliability of the NSE-Math instrument was analyzed via Cronbach's alpha for both pre- and post-intervention. The non-parametric Wilcoxon matched-pairs signed rank test was used to test the first null hypothesis. Crosstabulations with the Fisher exact test were used to test the second null hypothesis. Correlation coefficients were used to test the third null hypothesis. All data were checked for meeting the assumptions of the statistical tests.

CHAPTER IV

RESULTS

The purpose of this study was to examine the effects of a contextualized learning intervention on nursing students' math self-efficacy and ability to pass a high stakes dosage calculation exam on the first attempt. In addition, the relationships between the students' TEAS scores, math self-efficacy, and the ability to pass the dosage calculation exam were examined. This chapter describes participant demographics and reports the results of data analysis for the surveys, first-time pass rate for the dosage calculation exam, and TEAS score relationships. Key findings with suggested relationships are highlighted. Instrument reliability is discussed.

Demographics

Of 47 students newly accepted into the nursing program, 33 (70%) initially consented and of those, one withdrew from the program entirely for a net of 32 of 46 (69%). Six of the 32 students (19%) giving consent indicated male gender; the remaining 26 (81%) indicated female gender. The proportion of male gender in the research participant group was larger than the 15% reported by NLN (2020) in the most recent biennial survey of schools of nursing report. Thirty-one of the 32 participants provided their age for a mean of 28.32 years (*SD* = 7.71), ranging from 19 to 50 years. The mean approximated the most populated age categories reported by NLN: aged 25 and under (37.8%) followed by age 26 to 30 (26.4%). For ethnicity, 26 of 32 (81%) students indicated Caucasian, three (9%) indicated African American, two (6%) indicated Asian/Pacific Islander, and one (3%) indicated Hispanic. Students of color were underrepresented in this research study (18.8%) when compared with that reported by NLN for associate degree pre-licensure nursing programs (26.7%) as well as the nursing program's typical proportion (23% to 40%). Table 1 provides this study's demographic statistics.

Table 1

Demographic Statistics

Demographics	*n*	%
Ethnicity		
White/Caucasian	26	81.3
African-American	3	9.4
Asian/Pacific Islander	2	6.3
Hispanic	1	3.0
Gender		
Female	26	81.3
Male	6	18.7
Educational Background		
High School/GED	2	6.3
Some college	16	50.0
Associate Degree	9	28.1
Bachelor's Degree	5	15.6
No Answer	1	3.1
Healthcare Experience		
Yes	16	50.0
NA/PCA/DSP	10	31.2
Medical Tech	3	9.4
LPN	1	3.1
Pharmacy Tech	1	3.1
No Answer	1	3.1
Administer Medications	7	21.8

N = 32

Educational Background

Two (6%) students of 31 reporting educational background indicated having a high school diploma or GED when entering the nursing program. Sixteen (52%) reported having some college and no degree. An associate degree was held by nine (29%) students and a bachelor's degree held by five (16%).

Healthcare Experience

Sixteen of 32 (50%) students reported healthcare experience ranging from three months to 12 years, with a mean of 4.32 years (*SD* = 3.64). Ten (63%) of the 16 students reported healthcare experience gained as a nursing assistant, personal care attendant, or direct support professional. One (6%) student reported experience as an LPN and one (6%) student reported gaining experience as a pharmacy technician. Three (19%) reported experience as medical technicians. Of the 16 students indicating healthcare experience, seven (44%) reported administering medications: five from the NA/PCA/DSP category, one LPN, and one medical technologist. Of the seven students reporting administering medications, two did not pass the dosage calculation exam on the first attempt and both were members of the NA/PCA/DSP category.

Research Question 1 and Hypotheses

Q1 What effect does a contextualized learning intervention have on pre-nursing student math self-efficacy?

$H_0 1$ A contextualized learning intervention has no effect on pre-nursing student math self-efficacy.

$H_A 1$ A contextualized learning intervention does have an effect on pre-nursing student math self-efficacy.

To test the null and alternate hypotheses, participants' NSE-Math scores were compared pre- and post-intervention. Although the data met the measurement level assumption, ordinal or higher, it did not meet the recommendation of at least 30 paired data sets for a parametric analysis (Kellar & Kelvin, 2013). Thus, the non-parametric Wilcoxon matched-pairs signed rank test was used for analysis.

A mean was computed for all items on the instrument for each individual on each survey. If more than two items were missing data, that participant's responses were eliminated entirely. Twenty-five matched-pair surveys met the criteria for inclusion. Once the means were computed, the Wilcoxon matched-pairs signed rank test indicated post-intervention NSE-Math scores were statistically significantly higher than pre-intervention scores ($Z = 3.786$, $p < .001$) with a moderate effect size calculated manually ($r = 0.54$; Field, 2009). The data analysis pointed to support for rejecting the null hypothesis; a contextualized learning intervention might exert a positive effect on nursing students' math self-efficacy. The greatest increase in Math-NSE ratings occurred with five of six items contained within the construct of "Confidence in application of mathematic concepts to nursing practice." The mean item point increased from pre-intervention to post-intervention for all items ranged from 0.459 to 3.737. The items are listed in Table 2 from smallest to largest gain.

Table 2

Increase in Nursing Student's Self-Efficacy for Mathematics Item Scores from Pre- to Post-Intervention: Smallest to Largest

Mean Point Increase	Survey Item Number	Survey Item
0.459	1.	Compare 2 fractions and determine when one is larger (e.g. compare 5/8 with 2/3).
0.765	3.	Subtract two large numbers (e.g. 67225 – 23899) without using a calculator.
0.955	2.	Add two large numbers (e.g. 93499 + 76582) without using a calculator.
0.958	7.	Convert a fluid volume from litres (L) to millilitres (ml).
1.077	6.	Convert a drug dose from grams (g) to milligrams (mg).
1.113	5.	Divide one number with another (e.g. 1000 ÷ 9) without using a calculator.
1.566	4.	Multiply two large numbers (e.g. 5621 x 349) without using a calculator.
2.560	11.	Determine the amount of medication (in mg) when the medication is labelled as a proportion (e.g. 1: 1000 of adrenaline).
2.936	12.	Determine the number of tablets to be given when the medication stock available is of a different strength (e.g. administer 0.25 mg of the drug from a medication stock of 62.5 mcg per tablet).
3.003	8.	Calculate IV drip rates (e.g. give 500 ml over four hours using a giving set with a drip factor of 20 drops/ml).
3.652	9.	Solve problems involving injection drug dose calculations (e.g. the volume of drug required to obtain 5 mg from an ampoule that contains 20 mg in 5 ml).
3.737	10.	Solve problems to determine the dosage of IV medications being administered per hour (e.g. Give 500 mcg of drug per hour from a drug solution with 5 mg in 100 ml)

Note: Likert Scale 1 to 10, 1 = *No confidence at all*, 10 = *Complete confidence.*

Research Question 2 and Hypotheses

Q2 What effect does a contextualized learning intervention have on pre-nursing student ability to pass a high stakes dosage calculation exam on the first attempt?

$H_0 2$ A contextualized learning intervention has no effect on pre-nursing student ability to pass a high stakes dosage calculation exam on the first attempt

$H_A 2$ A contextualized learning intervention does have an effect on pre-nursing student ability to pass a high stakes dosage calculation exam on the first attempt.

To test the hypotheses for Research Question 2, pass/no pass results from the first dosage calculation exam were examined. Forty-seven nursing students sat for the first dosage calculation exam that occurred six weeks after the learning intervention. Of the 47 students testing, 41 (87%) passed on the first attempt. Thirty-six of the 47 (77%) students had attended the learning intervention, of which 34 (92%) passed. The de-identified categorical data were provided by the volunteer course instructor assisting the researcher. To determine whether learning intervention attendance exerted an effect on ability to pass the exam, data were analyzed in SPSS v26 using a 2 x 2 cross-tabulation table indicated when assumptions of nominal, dichotomous, and independence for variables were met (Kellar & Kelvin, 2013). The probability of passing the exam if students attended the learning intervention was 0.94 compared with the probability of 0.64 of passing the exam if the learning intervention was not attended. The difference was statistically significant using the continuity correction and Fisher's exact test, indicated for minimum cell counts below five, X^2 (1, N = 47) = 4.68, p = .021 (OR = 9.71, 95% CI: 1.48, 63.81). A low positive relationship between learning intervention attendance and passing was indicated by *phi* = .391 (Pett, 2016). The data analysis pointed to support for rejecting the null hypothesis; a contextualized learning intervention might have a positive effect on pre-nursing student ability to pass a high stakes dosage calculation exam on the first attempt (see Table 3).

Table 3

Cross-Tabulation Table of Learning Intervention Attendance and Dosage Calculation Exam Pass Counts

	Passed the Exam?						
	Yes		No		Total		
Attended Intervention?	*N*	%	*N*	%	*N*	%	p^a
Yes	34	82.9	2	33.3	36	76.6	
No	7	17.1	4	66.7	11	23.4	.021
Total	41	87.2	6	12.8	47	100.0	

[a]The *p* value is for a two-tailed Fisher's exact test.

Research Question 3 and Hypotheses

Q3 What is the relationship between math self-efficacy, TEAS scores, and dosage calculation exam performance?

$H_0$3 There is no relationship between math self-efficacy, TEAS scores, and dosage calculation exam performance.

H_A3 There is relationship between math self-efficacy, TEAS scores, and dosage calculation exam performance.

To test the hypotheses, a Spearman rank-order correlation analysis was conducted to examine the relationships between each of the TEAS scores and the Math-NSE. The relatively small sample size (N = 32) was not adequate to support the plan for using a logistic regression analysis to examine the predictive value of the TEAS and Math-NSE scores in passing the dosage calculation exam.

Correlation of Test of Essential Academic Skills and Nursing Self-Efficacy-Math Scores

To further examine the relationships among the TEAS and NSE-Math scores, the data were tested for meeting the assumptions of a Pearson correlation analysis. The NSE-Math scores were measured on an ordinal scale that violated the interval or ratio scale assumptions. A Shapiro-Wilk test of normality was performed on the TEAS scores, which demonstrated a significant departure from normality for the TEAS Math, Reading, and English scores, $W(31) = 0.901$, $p = .008$; $W(31) = 0.923$, $p = .028$; and $W(31) = 0.913$, $p = .016$, respectively (Pett, 2016). Because the data did not meet the assumptions for a Pearson correlation, the data were tested for meeting the assumptions of the Spearman test of correlation. The Spearman test of rank-order correlation could be used for ordinal-level data and data not normally distributed (Kellar & Kelvin, 2013). Scatterplots of the data demonstrated general compliance with the monotonic requirement. The correlation matrix is shown in Table 4.

Table 4

Spearman Rank-Order Correlation Matrix for Nursing Self-Efficacy-Math and Test of Essential Academic Skills Composite, Math, Science, Reading, and English Score

Variable	Correlations					
	1	2	3	4	5	6
1. NSE-Math	-					
1. TEAS Composite	.266	-				
2. TEAS Math	.360*	.227	-			
3. TEAS Science	.060	.734**	.033	-		
4. TEAS Reading	.040	.501**	.027	.075	-	
5. TEAS English	.036	.530**	-.189	.141	.216	-

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

The Spearman rank-order correlation coefficient demonstrated that the TEAS Science, Reading, and English scores were statistically significantly associated with the TEAS Composite score, $r_s = .734$, $p <.001$, $r_s = .501$, $p = .003$, $r_s = .530$, $p =.002$, respectively. The strength of the relationship between the TEAS Composite and the TEAS Science score was strong ($r^2_s = .539$) and moderate between the TEAS Composite and TEAS Reading ($r^2_s = .251$) and TEAS Composite and TEAS English ($r^2_s = .281$). A statistically significant association was demonstrated between the NSE-Math scores and the TEAS Math scores, $r_s = .360$, $p = .047$. The strength of the association was weak as suggested by the $r^2_s = .129$ (Pett, 2016). The results pointed to support for rejecting the null hypothesis as it pertained to relationships among the TEAS Composite, Reading, English, and Science scores; moderate to strong positive relationships were demonstrated. The results also pointed to support for rejecting the null hypothesis as it pertained to the relationship between the TEAS Math and Math-NSE scores; a weak positive relationship was demonstrated. The null hypothesis could be neither rejected nor accepted as it pertained to the relationship of the TEAS and Math-NSE scores in passing the dosage calculation exam due to an inadequate sample size.

Summary

Chapter IV presented the analyses conducted to test the hypotheses for each of the three research questions. The results suggested a contextualized learning intervention might help newly admitted pre-licensure nursing students pass their dosage calculation exam on the first attempt, demonstrating statistical significance. Therefore, the null hypothesis was rejected.

The Math-NSE scores increased in a statistically significant manner from pre-learning intervention to post-learning intervention. The null hypothesis stating the learning intervention would have no effect on Math-NSE scores was rejected.

The analyses revealed a statistically significant relationship between the TEAS Composite score and the TEAS Reading, English, and Science scores. The Math-NSE scores did demonstrate a statistically significant relationship with the TEAS Math score in that the higher the Math-NSE score, the higher the TEAS Math score (p = .047).

The relationship of the TEAS and Math-NSE scores with passing the dosage calculation exam could not be explored due to inadequate sample size. Findings revealed in this chapter are discussed in further detail in Chapter V.

CHAPTER V

DISCUSSION AND CONCLUSION

The purpose of this research study was to determine whether a contextualized learning intervention would affect prelicensure nursing students' math self-efficacy and their ability to pass a high stakes dosage calculation exam on the first attempt. The research study also explored the relationships among the TEAS scores, Math-NSE scores, and passing the dosage calculation exam. In this chapter, a more detailed discussion of the results from the previous chapter connects the findings with the literature and the guiding conceptual framework. Limitations of the research study are presented and the conclusion provides for nursing education implications and suggestions for further investigation.

Summary of the Study

The literature review demonstrated a growing recognition by nursing faculty globally of the need to contextualize dosage calculation pedagogy. Students who met the traditional math requirements of nursing programs, yet still struggled with dosage calculation accuracy, underscored this recognition. The published research reflected a concerted effort by nurse educators to meet the challenge, particularly over the past two decades. Attempts to define best practice for teaching dosage calculations included simulation scenarios ranging from very low to very high fidelity, perfunctory dosage calculation problem practice, virtual dosage calculation scenarios available 24 x 7, incorporation of established effective pedagogy such as active classrooms, and deeper collaboration with other higher education disciplines such as mathematics and science (Baginski, 2017; Ellis et al., 2019; Harris et al., 2014; Mackie & Bruce, 2016; Weeks et al., 2019). Much of the research focused on students already in nursing programs and/or practicing nurses who had graduated and were actively employed. Few studies examined interventions targeted at students interested in nursing or students who had not yet begun their nursing courses. Furthermore, a dearth of research existed that examined the role of the affective domain in learning dosage calculation other than confidence with math skills or satisfaction with learning. To close the gap, this study intentionally targeted students about to begin their nursing courses and incorporated activities that tapped the affective domain. It demonstrated that a relatively simple, low cost intervention might be effective in enhancing math self-efficacy and promoting accurate dosage calculations by incorporating a non-threatening learning environment, peer support, and rudimentary dosage calculation scenarios as building blocks for more complex problems.

The study added to the body of knowledge concerning proprietary preadmission nursing exams, in this case, the Test of Essential Academic Skills (TEAS; ATI, 2020), that was used to predict the likelihood of nursing student success. The study revealed student math self-efficacy scores were statistically significantly correlated with their TEAS Math scores.

Discussion of the Findings

Contextualized Learning Environments

Students who attended the contextualized learning intervention were more likely to pass the dosage calculation exam X^2 (1, N = 47) = 4.68, p = .021. The results were consistent with studies completed by Harris et al. (2014), Ramjan et al. (2014), and Hurley (2017) in which student performance on dosage calculation exams were statistically significantly higher when they attended a contextualized learning environment compared with students who did not experience the contextualized environment. In the Harris et al. study, two groups of 79 baccalaureate students each were divided into the control and experimental groups. The control group was exposed to the traditional lecture-type lesson and the experimental group was further divided into small clusters of four students. The clusters rotated through various simulation stations where they worked through the dosage calculation problems using the accoutrements required to administer the medications. All students then took the same paper-pencil exam and a *t*-test was performed to detect any differences. The dosage calculation scores for the experimental group were significantly higher than the scores for the control group ($t = 2.92$, df = 118, $p = .004$).

Hurley (2017) used a pretest-posttest design to determine the effects of a contextualized learning activity. All 78 baccalaureate students completed a dosage calculation pretest that demonstrated no statistically significant difference between scores. The students were then divided into two groups. The control group received the traditional lecture that demonstrated using dimensional analysis, ratio-proportion, and formulaic approaches for solving dosage calculations. The experimental group received the accoutrements needed to prepare and administer the medications. Both groups then took the same dosage calculation posttest. A paired *t*-test demonstrated a significant difference on the posttest scores with the experimental group scoring an average of almost 10 points higher ($t = -0.312$, $df = 37$, $p = .004$).

Ramjan et al. (2014) incorporated context in progressively more prevalence as 95 students repeated dosage calculation exams to achieve the 100% score requirement. Using a backward stepwise logistic regression analysis, the results revealed statistical significance for those students who failed and did not attend the contextualized remediation workshops: Exam 2: $p = 0.001$ and Exam 3: $p = 0.002$.

Huse (2010) assigned 59 associate degree students to either the control group, which experienced a traditional classroom session for teaching dosage calculation, or the experimental group who had access to supplies and a medical record to learn dosage calculations. Both groups were further divided into smaller groups where they participated in discussions concerning problem solving complete with instructor-guided reflection. There was no statistically significant difference between the two groups' dosage calculation exam scores using a Mann-Whitney *U* analysis ($U = 254.000$, $p = .650$). However, students in the experimental group were more satisfied with their instruction and reported more confidence in their acquisition of skills and knowledge ($U = 88.500$, $p = .000$ and $U = 163.000$, $p = .005$, respectively). The findings from Huse's research supported the use of a constructivist environment in which small groups of students discussed problem solving strategies. This appeared to benefit the control group's dosage calculation exam outcomes. In addition, the reports of feeling greater satisfaction and more confidence in the experimental group suggested the involvement of the affective domain in dosage calculation performance.

Further evidence of affective domain involvement with dosage calculation arose from Baginski (2017) whose research resulted in student reports confirming the value of contextualized learning in facilitating deeper appreciation of calculation accuracy. Baginski used 12 low-fidelity scenarios to provide context to 12 calculation problems. Students had one hour to visit the 12 stations containing the equipment and supplies to administer the medications described in the calculation problems. Students could work alone or in groups, exemplifying a constructivist learning environment. Although this study did not directly measure affective domain or constructivist learning environment influence, prior research suggested a positive effect on valuing and striving for dosage calculation accuracy.

Math Self-Efficacy

The relationship of math self-efficacy with math performance was well established in the general education literature, i.e., the higher one's math self-efficacy, the better the math performance (Andrew et al., 2009). This research study yielded data supporting the literature in which students' Math-NSE scores were statistically significantly correlated with their TEAS-Math scores, $r_s = .360$, $p = .047$. Although math self-efficacy in nursing education literature was less prevalent, the relationship was analogous—the higher one's math self-efficacy, the better one was able to perform accurate dosage calculations (McMullan et al., 2012; Melius, 2012).

The learning intervention's effect on student math self-efficacy appeared favorable as demonstrated by pre- and post-learning intervention Math-NSE survey scores. Surveys missing three or more items were excluded, leaving 25 matched pairs. Wilcoxon matched-pairs signed rank test indicated post-intervention NSE-Math scores were statistically significantly higher than pre-intervention scores ($Z = 3.786$, $p < .001$) with a moderate effect size calculated manually ($r = 0.54$; Field, 2009). Although all questions of the survey exhibited an increase in self-efficacy scores, those demonstrating the highest increase were those that pertained specifically to dosage calculation exercises, suggesting a valid intervention effect (see Table 1 in Chapter IV). The increase of confidence in performing arithmetic concepts might be attributed to the simple act of practicing problem solving, which has provided evidence of polishing and maintaining math skills (Bagnasco et al., 2016; McGuire, 2015). The post-intervention survey was completed five to seven days after the intervention, suggesting a lingering effect.

Test of Essential Academic Skills Score Relationships

The literature review surveyed research specifically concerning TEAS score use in prelicensure nursing programs. Most studies focused on the predictive ability regarding nursing student success as defined by program completion and NCLEX pass rates. In addition to investigating the TEAS Math score relationship with math self-efficacy as described previously, this researcher investigated TEAS score relationships with passing the dosage calculation exams. The researcher identified only three studies that examined TEAS score relationships with dosage calculation exam performance. Newton et al. (2009) found statistically significant relationships between the TEAS Math and TEAS Composite scores and first time pass rates of the dosage calculation exam, $r = .264$, $p < .003$ and $r = .336$, $p < .001$, respectively, in a convenience sample of 127 BSN students. In a subsequent study, Newton et al. (2010) found a statistically significant relationship between reading aptitude as measured by the TEAS and first time passing of the dosage calculation exam ($r = .351$, $p < .001$) in a convenience sample of 126 BSN students. Esper (2009) studied the TEAS results from a convenience sample of 107 associate degree nursing students and found a statistically significant relationship between the TEAS Science score and the dosage calculation score, $r = .231$, $p = .05$. The overall results did not clearly elucidate a sound conclusion concerning the TEAS score relationships to dosage calculation exam outcomes. This researcher could not add clarity to the larger picture due to small sample size negating a predictive model. However, the literature findings offered intriguing opportunities for further investigation. The results of prior research that revealed a statistically significant effect of the TEAS Reading score (Newton et al., 2010) suggested solid reading skills might help students correctly interpret dosage calculation word problems.

Upon close inspection of the data for this research study, the two students who did not pass the first dosage calculation exam scored very high on the TEAS Math exam (100 and 96.90, respectively, on a scale of 0 to 100). These findings supported the assertion that math mastery did not guarantee dosage calculation success (Maley & Rafferty, 2019). Furthermore, only one of the studies discussed in this section revealed a statistically significant relationship of the TEAS Math score to dosage calculation performance (Newton et al., 2009).

The Spearman rank-order correlation matrix (Table 3) demonstrated a statistically significant relationship between the TEAS Composite score and the TEAS Science, TEAS Reading, and TEAS English scores ($p < .01$)—an expected finding. What was unexpected was the TEAS Math score did not demonstrate a statistically significant relationship with the TEAS Composite. The TEAS Math score comprised 21% of the composite score; Reading and Science, 31% each; and English 16% (ATI, 2020). Again, the small sample size likely influenced these results.

Limitations

Sample Size

The most limiting factor in this research study was the small sample size, which precluded the use of more robust analysis techniques. A larger sample size would have allowed multiple predictor variables with a logistic regression analysis revealing the more accurate contributions of each in predicting the outcome variable (Tabachnick & Fidell, 2019). Possible additional predictor variables would be age, educational background, gender, and prior healthcare experience. Prior studies revealed statistically significant relationships for these variables with dosage calculation exam performance and math self-efficacy (Bagnasco et al., 2016; Veldman, 2016). The researcher’s community college is part of a consortium of state community colleges. The learning intervention could be standardized and implemented at multiple sites to achieve larger sample sizes, thus yielding data more amenable to robust analyses.

Sampling Method

This study used a non-randomized convenience sample of participants. Convenience sampling provided the researcher ready access to a natural gathering of potential participants (Remler & Van Ryzin, 2015). However, convenience samples might not be true representations of the target population, which limited generalization of the research results. Most nursing research employed nonprobability sampling despite this limitation and interpreters of these statistical results must be cautious due to the selection bias inherent in volunteer participation (Grove et al., 2013).

Research Design

Exploratory field study results by their nature are not easily replicated. This study was carried out with pre-nursing students enrolled in an associate degree program at a large, midwestern community college and generalizations to other contexts are not appropriate.

Instrument

The NSE-Math instrument items examined one's self-efficacy in performing arithmetic operations without the benefit of a calculator, which might be an obsolete practice. Data obtained for the instrument were self-reported and student responses were likely influenced by social desirability bias in which students provided answers that were pleasing to the researcher (Remler & Van Ryzin, 2015). Furthermore, inherent limitations existed with one group pretest-posttest comparisons such as participant maturation and familiarity with instrumentation (Spurlock, 2018). Students were likely to feel fatigued when completing the survey for the second time and might not have read the questions carefully to respond accurately.

Intervening Variables

The effect of the learning intervention on dosage calculation exam first-time pass rates might have been fortified by unmeasured intervening variables. Intervening variables might affect the strength of a relationship (Grove et al., 2013). Students might have performed better because of close interaction with the researcher and the volunteer course instructor during the learning intervention. High performing students might be more likely to benefit from any learning intervention, therefore skewing the results. In this research study, the participants as a whole achieved a mean TEAS Composite score of 86.46 (N = 32, SD = 3.76), which met the TEAS academic preparedness level definition of “advanced” (ATI, 2020). Any effect the affective domain might have exerted on dosage calculation performance was not measured. Likewise, the effect of using Polýa’s (1957, as cited in Pyo, 2011) four-step map for solving problems was not measured.

Implications for Nursing Education

Contextualized Learning

The importance of accurate dosage calculations remains undisputed. Pedagogy that effectively optimizes accurate dosage calculation performance continues to evolve. Literature reviews identified that contextualized learning activities enhanced prelicensure nursing students’ ability to perform dosage calculations (Härkänen et al., 2016; Revell & McCurry, 2013; Sherriff et al., 2011; Stolic, 2014; Zahara-Such, 2013). High fidelity simulations offered experiences that best replicated the authentic professional nursing environment but required considerable resources to implement such as space, equipment, and faculty with simulation expertise. The literature suggested simple contextualized interventions might be just as effective and this research study supported providing the intervention before students started their nursing courses.

The time segment between the moment students experienced a simple contextualized learning activity to the day of their medication administration coursework allows time for concepts to percolate and take hold. Nursing education departments could forge deeper collaborative relationships with the disciplines that provide nursing prerequisites. Such partnerships would promote mutually approved class activities designed to facilitate early development of a sense for volume and measurement as it pertains to medications and how they are packaged. Reducing the cognitive load when students begin their medication administration nursing coursework would be the shared goal.

Use of Test of Essential Academic Skills or Math Self-Efficacy Scores

Using proprietary preadmission nursing exam results to pre-emptively plan targeted interventions for developing dosage calculation skills might not be a valid strategy until the correlation is better understood. The bulk of the research concerning proprietary preadmission nursing exams addressed their predictive accuracy for nursing program success measured by program completion rates and passing the NCLEX upon graduation. Scant literature explicated a statistically significant relationship between proprietary exam scores and the passing of dosage calculation exams. Identifying learners with low math self-efficacy and then providing low-risk activities that help assuage fears and build confidence would likely be more effective. Although this study did not explore the relationship between math self-efficacy and the ability to pass the dosage calculation exam on the first attempt, the literature demonstrated a positive correlation between math self-efficacy and math exam performance (Andrew et al., 2009; Beltrán-Pellicer & Godino, 2019; McMullan et al., 2012; Melius, 2012).

Practice Makes Perfect

The literature supported practicing dosage calculation problems to keep skills sharp (Bagnasco et al., 2016; McGuire, 2015; Shanks & Enlow, 2011). Prelicensure nursing textbooks typically provided electronic resources that included practice problems and case studies involving medication administration. Regularly assigning lessons from these resources and including dosage problems on exams could help maintain calculation expertise. Medication calculations could be easily included in simulations and other small groups activities where students also benefit from peer interaction.

Constructivism in the Virtual Environment

Communities of learning in which students work in small groups are well known for their effectiveness (Weimer, 2013). This study suggested small group activities in the virtual environment provided a reasonable alternative to the physical classroom. Technologies such as Zoom (2020) provided flexibility for course delivery and might enhance accessibility for students unable to travel to campus.

Constructivism and Equity

A small group activity is considered an "equity pedagogy" as it is intentionally inclusive of all students and is ideal for engaging disadvantaged and underrepresented students (Banks & Banks, 1995). Students of color were underrepresented in this research study, particularly when compared with the typical percentage observed in the researcher's community college nursing program (18.8% and 23-40%, respectively). It was unknown how many students of color chose not to participate. Exploring reasons for underrepresentation of diverse learners in learning activities with voluntary participation would be beneficial in rectifying barriers otherwise not recognized by the instructor. Nursing faculty could assure a welcoming environment and be astute for implicit bias that might stifle participation for students of color and for whom English was not the primary language (James, 2019). With the re-emergence of interest in aptitude-treatment interactions, nursing faculty might explore this type of strategy to personalize instruction according to each individual's needs (Tetzlaff et al., 2020).

High Stakes Testing

Opportunities exist for nursing faculty to become involved in the national, interdisciplinary effort to enhance mathematics education for nurses. National League for Nursing (2021) recently distributed the *Convening Recommendations* concerning math and statistics education for nurses that outlined this effort. Among those recommendations was reconsidering the use of high-stakes testing to determine dosage calculation competency and replacing it with a culture of continuous improvement (p. 6). Strategies for promoting such a paradigm shift included provision of contextualized activities that required learners to apply critical thinking and psychomotor skills in authentic scenarios in which medication dosages were calculated. Such experiences could occur frequently throughout the program in the form of validated competency-based assessments, for example.

Recommendations for Future Research

Several factors were identified as contributing to accurate dosage calculation ability including math self-efficacy, virtual and physical contextualized learning environments, and dosage calculation practice opportunities. The contributions of other factors were not so evident such as affective domain involvement and using a guiding framework like Polýa's (1957, as cited in Pyo, 2011) four phases of problem-solving. Opportunities exist to precisely define these concepts and develop instruments to measure their influence as they relate to dosage calculation accuracy.

Nursing Student's Self-Efficacy for Mathematics Instrument

The developers of the NSE-Math instrument identified two main constructs that emerged from factor analysis during reliability and validity testing: confidence in arithmetic concepts and confidence in application of mathematic concepts to nursing practice (Andrew et al., 2009). In the pilot study done by the researcher, a third factor was identified that was named "Confidence with conversions." The instrument would benefit from additional testing and the construct of "Confidence with conversions" could be further explored as it pertains to accurate math self-efficacy and dosage calculations.

Affective Domain

One of the intents of this study was to plant the seed for valuing accurate dosage calculation skills. Longitudinal research is indicated to examine whether a new value for the importance of accurate dosage calculation ability persists over time. Measuring such a value would require determining how the value is internalized and used to guide one's personal philosophy for practice. Perhaps the value for accurate dosage calculation ability could be woven into the larger picture of what it means to be a professional nurse rather than a stand-alone attribute. Further research could illuminate the nuances of this relationship.

Frameworks for Solving Problems

The relationship between problem-solving frameworks and successful dosage calculation performance has not been clearly elucidated. Polýa's (1957, as cited in Pyo, 2011) four problem-solving steps were used in this study. Tanner's (2006) clinical judgment model presented a thinking model analogous to Polýa's model (Good et al., 2020). Tanner identified four stages in clinical reasoning development: noticing, interpreting, responding, and reflecting, which correspond with Polýa's understanding, devising a plan, carrying out the plan, and looking back.

Using Tanner's framework to solve dosage calculation problems with prelicensure nursing students might better facilitate their assimilation of and socialization into the professional nursing identity.

Additional Research Opportunities

Reading Ability and English Fluency

The impact of reading ability and command of English on dosage calculation word problem-solving offers titillating prospects for further research. Studies that focus on multicultural learners in the United States and accurate dosage calculation ability are scarce. Anecdotally, international students attending the researcher's community college have expressed high comfort levels with the metric system because they grew up with it in their native countries. They expressed frustration with understanding the Imperial measurement system and the word problems that required conversion to metric.

Unlicensed Assistive Personnel and Medication Administration

A surprising finding in this study was the portion of nursing assistants, personal care attendants, and direct support professionals who administered medications in their work settings—5 of 10 (50%). Two who did not pass the dosage calculation exam on the first attempt were from this group. The researcher did not perform a literature search to capture categories specific to this population, thus findings regarding the safety of unlicensed healthcare workers administering medications could not be elucidated here. Research concerning training and safety practices for this population is warranted.

Membership in National Organization
Safety Monitor

The National Council of State Boards of Nursing (NCSBN, 2021) launched the Safe Student Reports (SSR) program about four years ago. Schools of nursing might sign up to participate in data collection that included medication administration safety. Individual schools received private, biannual reports. The NCSBN aggregates the data and provides quarterly reports via recorded telephone conferences that are publicly available. The NCSBN provides additional resources regarding teaching practices for safe dosage calculation.

Conclusion

The literature clearly supported contextualized learning environments for teaching dosage calculations and this research added to the body of evidence. Providing context was consistent with situated cognition learning theory and coupling it with additional constructivist tenets created an optimal milieu for developing accurate dosage calculation skills.

Results of this study also suggested a contextualized learning intervention might help increase math self-efficacy, which might then translate to improved math performance. Providing a rudimentary learning activity that contextualizes dosage calculations for nursing students before they begin their nursing curriculum provides time for concepts to percolate and might help with dosage calculation performance after they start their program.

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APPENDIX A

PERMISSION TO USE NURSING SELF-EFFICACY-MATH SURVEY INSTRUMENT

NSE_MathTool.pdf
55 KB

Show all 1 attachments (55 KB) Download Save to OneDrive - University of Northern Colorado

Action Items

Dear Eileen,
Thank you for your interest in this instrument. Attached, a copy of the tool for your use. Best wishes.

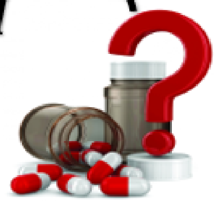
Kind Regards,
Yenna

Yenna Salamonson RN, BSc, CCU Cert, GradDipNEd, MA(Ed&Work), PhD
Professor | Director of Academic Workforce, Campbelltown
School of Nursing and Midwifery | Centre for Applied Nursing Research
Affiliate Member - Ingham Institute for Applied Medical Research
Western Sydney University
Building 7 Room 15, Campbelltown Campus
Narellan Road, Cnr David Pilgrim Drive & Goldsmith Avenue

APPENDIX B

INVITATION TO PARTICIPATE

$\frac{D}{H} \times Q$



New Nursing Students:

LESSEN THE STRESS & ENHANCE YOUR SUCCESS!

LEARN DOSAGE CALCULATIONS IN CONTEXT

DATE AND TIME TBA | YOU'LL BE NOTIFIED BY E-MAIL

You are invited to attend a learning session designed to help new nursing students learn about calculating medication dosages using the actual tools that nurses use. You'll be practicing and learning with your peers. The activities are designed to help you be successful on the dosage calculation exam which requires at least a 90% to pass. Your participation is voluntary.

The learning session will be led by Eileen Weatherby who is a member of the Normandale Nursing Faculty, and who is using the activity as research for her PhD in Nursing Education. If you have any questions, please email Eileen at:

Eileen.weatherby@normandale.edu

APPENDIX C

INSTITUTIONAL REVIEW BOARD INITIAL APPROVAL LETTERS AND SUBSEQUENT APPROVAL FOR INTERVENTION CHANGE FROM IN-CLASS TO VIRTUAL ENVIRONMENT

UNIVERSITY OF
NORTHERN COLORADO

Institutional Review Board

Date:	06/01/2020
Principal Investigator:	Eileen Weatherby
Committee Action:	**IRB EXEMPT DETERMINATION – New Protocol**
Action Date:	06/01/2020
Protocol Number:	2004000229
Protocol Title:	The Effect of a Contextualized Learning Intervention on Pre-nursing Students' Math Self-efficacy and Ability to Pass High Stakes Dosage Calculation Examination on First Attempt.
Expiration Date:	

The University of Northern Colorado Institutional Review Board has reviewed your protocol and determined your project to be exempt under 45 CFR 46.104(d)(701) (702) (703) for research involving

Category **1** (2018): RESEARCH CONDUCTED IN EDUCATIONAL SETTINGS. Research, conducted in established or commonly accepted educational settings, that specifically involves normal educational practices that are not likely to adversely impact students' opportunity to learn required educational content or the assessment of educators who provide instruction. This includes most research on regular and special education instructional strategies, and research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

Category 2 (2018): EDUCATIONAL TESTS, SURVEYS, INTERVIEWS, OR OBSERVATIONS OF PUBLIC BEHAVIOR. Research that only includes interactions involving educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior (including visual or auditory recording) if at least one of the following criteria is met: (i) The information obtained is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained, directly or through identifiers linked to the subjects; (ii) Any disclosure of the human subjects' responses outside the research would not reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, educational advancement, or reputation; or (iii) The information obtained is recorded by the investigator in such a manner that the identity of the human subjects can readily be ascertained, directly or through identifiers linked to the subjects, and an IRB conducts a limited IRB review to make the determination required by 45 CFR 46.111(a)(7).

Carter Hall 3002 | Campus Box 143 | Greeley, CO 80639 | Office 970-351-1910 | Fax 970-351-1934

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Category 3 (2018): BENIGN BEHAVIORAL INTERVENTIONS IN CONJUNCTION WITH THE COLLECTION OF INFORMATION FROM ADULT SUBJECTS through verbal or written responses (including data entry) or audiovisual recording if the subject prospectively agrees to the intervention and information collection and at least one of the following criteria is met: (A) The information obtained is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained, directly or through identifiers linked to the subjects; (B) Any disclosure of the human subjects' responses outside the research would not reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, educational advancement, or reputation; or (C) The information obtained is recorded by the investigator in such a manner that the identity of the human subjects can readily be ascertained, directly or through identifiers linked to the subjects, and an IRB conducts a limited IRB review to make the determination required by 45 CFR 46.111(a)(7). For the purpose of this provision, benign behavioral interventions are brief in duration, harmless, painless, not physically invasive, not likely to have a significant adverse lasting impact on the subjects, and the investigator has no reason to think the subjects will find the interventions offensive or embarrassing. Provided all such criteria are met, examples of such benign behavioral interventions would include having the subjects play an online game, having them solve puzzles under various noise conditions, or having them decide how to allocate a nominal amount of received cash between themselves and someone else. If the research involves deceiving the subjects regarding the nature or purposes of the research, this exemption is not applicable unless the subject authorizes the deception through a prospective agreement to participate in such research.

You may begin conducting your research as outlined in your protocol. Your study does not require further review from the IRB, unless changes need to be made to your approved protocol.

As the Principal Investigator (PI), you are still responsible for contacting the UNC IRB office if and when:

- You wish to deviate from the described protocol and would like to formally submit a modification request. Prior IRB approval must be obtained before any changes can be implemented (except to eliminate an immediate hazard to research participants).
- You make changes to the research personnel working on this study (add or drop research staff on this protocol).
- At the end of the study or before you leave The University of Northern Colorado and are no longer a student or employee, to request your protocol be closed. *You cannot continue to reference UNC on any documents (including the informed consent form) or conduct the study under the auspices of UNC if you are no longer a student/employee of this university.
- You have received or have been made aware of any complaints, problems, or adverse events that are related or possibly related to participation in the research.

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If you have any questions, please contact the Research Compliance Manager, Nicole Morse, at 970-351-1910 or via e-mail at nicole.morse@unco.edu. Additional information concerning the requirements for the protection of human subjects may be found at the Office of Human Research Protection website - http://hhs.gov/ohrp/ and https://www.unco.edu/research/research-integrity-and-compliance/institutional-review-board/.

Sincerely,

Nicole Morse

Nicole Morse
Research Compliance Manager

University of Northern Colorado: FWA00000784

NORMANDALE
COMMUNITY COLLEGE

Subject: Letter of Authorization to Conduct Research at Normandale Community College, Weatherby.

April 6, 2020

Dear University of Northern Colorado IRB Members,

As Chair of Normandale's Institutional Review Board, I am happy to write an authorization letter for Eileen Weatherby to conduct the research project entitled *The effect of a contextualized dosage calculation learning intervention on pre-nursing students' math self-efficacy and ability to pass high stakes dosage calculation examination on first attempt* at Normandale Community College in Bloomington, MN where she is currently a faculty member from April, 2020 through September, 2020.

The research project may be implemented at Normandale Community College upon approval by the UNC Institutional Review Board (IRB) and submission of that approved protocol and approval letter to myself.

If you require additional information, please feel free to contact me.

Sincerely,

PhD, LP

4/6/2020

Bridget V. Reigstad, L.P., Ph.D.
Chair, Institutional Review Board
Normandale Community College

Date

Normandale Community College
9700 France Avenue South
Bloomington, MN 55431-4399

www.normandale.edu
952.358.8200 Office
952.358.8101 Fax

Id: 183
From: nicole.morse
Recipients: nicole.morse , weat4281
Channel: Notification Channel
Producer: Notification System
Type: FYI
Priority: Normal
Send Date: 2020-07-16T11:53:13.000-06:00
Removal Date: none

Title: Protocol 2004000229 IRB Acknowledgement
Content:

The IRB protocol number 2004000229, Principal Investigator Eileen Weatherby has had the action "IRB Acknowledgement" performed on it.
The action was executed by Morse, Nicole. Additional information and further actions can be accessed through the system. Your modification request to carry out protocol online rather than in the classroom approved.

IRB Protocol Number: *2004000229* - Document Number: 4137
This notification was generated by Nicole Morse.

FYI

Weatherby, Eileen
Fri 7/17/2020 5:57 PM
To: Sullivan, Katherine <Katherine.Sullivan@unco.edu>; Bridget.reigstad@normandale.edu <bridget.reigstad@normandale.edu>

Dear Drs. Sullivan and Reigstad,

I am forwarding the IRB approval notice regarding the change from face-to-face to the online environment for my research intervention.

Let me know if you have further questions.

Thank you,
Eileen

...

You forwarded this message on Fri 7/17/2020 5:57 PM

SR Streamlyne Research <production-research@unco.streamlyne.org>
Thu 7/16/2020 9:53 AM
To: Weatherby, Eileen; nicole.morse@unco.edu

The IRB protocol number 2004000229, Principal Investigator Eileen Weatherby has had the action "IRB Acknowledgement" performed on it.
The action was executed by Morse, Nicole. Additional information and further actions can be accessed through the system. Your modification request to carry out protocol online rather than in the classroom approved.

IRB Protocol Number: 2004000229 - Document Number: 4137
This notification was generated by Nicole Morse.

Protocol 2004000229 IRB Acknowledgement

RB Reigstad, Bridget <bridget.reigstad@normandale.edu>
Mon 7/20/2020 4:05 PM
To: Weatherby, Eileen

Got it! Thanks Eileen.

~Bridget

Bridget Reigstad, Ph.D., LP.
Pronouns: she/her/hers; Why Pronouns Matter
Instructor, Psychology Department
Chair, Institutional Review Board
Normandale Community College
9700 France Avenue South
Bloomington, MN 55431
(952) 358-8575
Bridget.Reigstad@normandale.edu

...

APPENDIX D

INFORMED CONSENT FOR PARTICIPATION IN RESEARCH

UNIVERSITY OF
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INFORMED CONSENT FORM FOR PARTICIPATION IN RESEARCH

Title of Research Study: The Effect of a Contextualized Learning Intervention on Pre-nursing Students' Math Self-efficacy and Ability to Pass High Stakes Dosage Calculation Examination on First Attempt

Researcher: Eileen Weatherby, University of Northern Colorado, School of Nursing Number:
email: weat4281@bears.unco.edu
Research Advisor: Katherine Sullivan, PhD. University of Northern Colorado
Phone Number: (907) 351-1703 email: Katherine.sullivan@unco.edu

Procedures: We would like to ask you to participate in a research study. If you participate in this study, you will be asked to complete two 5-minute surveys that ask about demographic information and your confidence with math operations. The next 3 hours starts with a presentation followed by opportunities for you to see, touch, manipulate, and practice with items to help you develop comfort in performing medication calculations. You'll be able to confer with your peers regarding muddy points, just like nurses do in their work settings. To determine whether this activity is effective, with your permission, your dosage calculation exam performance will be compared with nursing students who didn't attend this activity. The relationship between your TEAS scores and the medication calculation exam performance will be examined. A unique numerical identifier will be associated with your name for data collection and entry into the statistical program. No individual data will be reported. We will strive to protect your information and maintain confidentiality. Once all the data has been entered in the statistical program, all documents with names will be shredded.

Questions: If you have any questions about this research project, please feel free to contact Eileen Weatherby at eileen.weatherby@normandale.edu. If you have any concerns about your selection or treatment as a research participant, please contact Nicole Morse, Research Compliance Manager, University of Northern Colorado at nicole.morse@unco.edu or 970-351-1910.

Voluntary Participation: Please understand that your participation is voluntary. You may decide not to participate in this study and if you begin participation you may still decide to stop and withdraw at any time. Your decision will be respected and will not result in loss of benefits to which you are otherwise entitled.

Please take all the time you need to read through this document and decide whether you would like to participate in this research study.
If you agree to participate in this research study, please sign below. You will be given a copy of this form for your records.

______________________________ ____________
Participant Signature Date

______________________________ ____________
Investigator Signature Date

APPENDIX E

NURSING SELF-EFFICACY FOR MATHEMATICS SURVEY INSTRUMENT

Nursing Self-Efficacy for Mathematics (NSE-Math) tool

Please cross the appropriate number to indicate how much confidence you have in successfully performing the following skills:

1. Compare 2 fractions and determine when one is larger (e.g. compare 5/8 with 2/3).

No confidence at all					Some confidence					Complete confidence
0	1	2	3	4	5	6	7	8	9	10

2. Add two large numbers (e.g. 93499 + 76582) without using a calculator.

No confidence at all					Some confidence					Complete confidence
0	1	2	3	4	5	6	7	8	9	10

3. Subtract two large numbers (e.g. 67225 – 23899) without using a calculator.

No confidence at all					Some confidence					Complete confidence
0	1	2	3	4	5	6	7	8	9	10

4. Multiply two large numbers (e.g. 5621 x 349) without using a calculator.

No confidence at all					Some confidence					Complete confidence
0	1	2	3	4	5	6	7	8	9	10

5. Divide one number with another (e.g. 1000 ÷ 9) without using a calculator.

No confidence at all					Some confidence					Complete confidence
0	1	2	3	4	5	6	7	8	9	10

6. Convert a drug dose from grams (g) to milligrams (mg).

No confidence at all					Some confidence					Complete confidence
0	1	2	3	4	5	6	7	8	9	10

7. Convert a fluid volume from litres (L) to millilitres (ml).

No confidence at all					Some confidence					Complete confidence
0	1	2	3	4	5	6	7	8	9	10

8. **Calculate IV drip rates (e.g. give 500 ml over four hours using a giving set with a drip factor of 20 drops/ml).**

No confidence at all					Some confidence					Complete confidence
0	1	2	3	4	5	6	7	8	9	10

9. **Solve problems involving injection drug dose calculations (e.g. the volume of drug required to obtain 5 mg from an ampoule that contains 20 mg in 5 ml).**

No confidence at all					Some confidence					Complete confidence
0	1	2	3	4	5	6	7	8	9	10

10. **Solve problems to determine the dosage of IV medications being administered per hour (e.g. Give 500 mcg of drug per hour from a drug solution with 5 mg in 100 ml).**

No confidence at all					Some confidence					Complete confidence
0	1	2	3	4	5	6	7	8	9	10

11. **Determine the amount of medication (in mg) when the medication is labelled as a proportion (e.g. 1: 1000 of adrenaline).**

No confidence at all					Some confidence					Complete confidence
0	1	2	3	4	5	6	7	8	9	10

12. **Determine the number of tablets to be given when the medication stock available is of a different strength (e.g. administer 0.25 mg of the drug from a medication stock of 62.5 mcg per tablet).**

No confidence at all					Some confidence					Complete confidence
0	1	2	3	4	5	6	7	8	9	10

Reference:

Andrew, S., Salamonson, Y. & Halcomb, E.J. (2009) Nursing students' confidence in medication calculations predicts math exam performance. *Nurse Education Today*, **29**(2), 217-223.

APPENDIX F

EXAMPLE OF POLÝA'S PROBLEM SOLVING WORKSHEET

Example of Worksheets for Each Dosage Calculation Scenario

Polýa's Problem Solving Approach

Problem: Primary care provider prescribes Lisinopril, 5 mg by mouth every day. How many tablets does the nurse administer?	
1. Understanding the Problem: What is the problem asking you to solve? What will the answer tell you, e. g., how many milliliters per hour, how many units, how many capsules, etc. Draw a picture such as the "I" technique. Estimate the answer.	2. Develop a Plan: Have you solved a similar problem before? Discuss possible methods with your peers.
4. Looking Back & Reviewing: Take time to reflect on the answer. Does it make sense? How does it compare with your estimate?	3. Carry out the Plan: Work out each step of the problem and check for accuracy of each step. Can you clearly see that each step is correct? If the plan doesn't work, discard it and formulate a new one.

(Adapted from Carter, 2018; Polýa, 1957; Wilmes et al., 2018; Wright, 2009)

APPENDIX G

INTERVENTION KIT


10ml Syringe
2 mL Single Dose
DEMO DOSE
FUROSEMID
LASX
20 mg (10 mg/mL
Distributed By
Pocket Nurse
Reorder# 06-93-0726
Levothyroxn Sodim
SYNTHROD
Reorder# 06-93-0714
Potassim Chlorid
K-DOR
20mEq
6 64113 30714 4
LOT/EXP 4708/03 2039
NOT FOR HUMAN OR
ANIMAL USE
Reorder#06-93-0045N
Lisinoprl
ZESTRL
2.5MG
6 64113 30045 9
LOT/EXP 1080/06 2036
NOT FOR HUMAN OR
ANIMAL USE

APPENDIX H

LESSON PLAN FOR INTERVENTION

LEARNER OBJECTIVES	**CONTENT (Topics)**	**TIME FRAME**	**Lead Person**	**TEACHING METHODS**
Phase I: Introduction, Affective Domain Activation *Upon completion of this session, participants should be able to:* 1. Describe purpose of intervention 2. Identify ways math is used in nursing practice 3. Verbalize the importance of math skills in nursing	1. Introduction to contextualized learning environment 2. Math in Nursing Practice 3. Nurse experiences with calculation error	45 min	Researcher	Q & A Video Group discussion
Break 10 minutes				
Phase II: Conceptualizing Dosages *Upon completion of this session, participants should be able to:* 1. Identify metric units of measurement 2. Describe the numeric relationship among the metric prefixes 3. Create accurate "drug" labels for various sugar solutions 4. Correctly interpret authentic drug labels 5. Demonstrate the "I" method for conceptualizing drug doses	1. Metric units of measure 2. Common metric prefixes used with drug doses 3. Making drug concentrations 4. Deciphering drug labels 5. "The 'I's have it"	45 min	Researcher	Discussion, white board use Hands-on use of manipulatives Small group activities
Break 10 minutes				
Phase III: Using Polỳa's Process to Solve Dosage Calculations *Upon completion of this session, participants should be able to:* 1. Describe Polỳa's problem solving process 2. Demonstrate use of Polỳa's problem solving process 3. Correctly solve at least eight dosage calculation problems	1. Polỳa's problem solving process 2. Using Polỳa's problem solving process for dosage calculations 3. Discussion of results from group activities 4. Final Q & A	70 min	Researcher and Course Faculty Volunteer	Discussion, white board use Hands-on use of manipulatives Small group activities

APPENDIX I

QUALTRICS SURVEY (ABRIDGED)

Block 4

Dear Future Nurse,

Thank you for participating in my study! Please review the procedures and terms of consent before proceeding. (It is the same consent that was sent via email)

Consent document

Block 2

Please write in your unique numeric identifier. (This is listed on the signed consent form. If you can't remember, please write in your initials).

Block 1

What is your age in years?

Please enter age to nearest year	0
Total	0

Please list your gender.

Choose one or more races that you consider yourself to be:

White
Black or African American
American Indian or Alaska Native
Asian
Native Hawaiian or Pacific Islander
Other

What is the highest level of school you have completed or the highest degree you have received?

Less than high school degree
High school graduate (high school diploma or equivalent including GED)
Some college but no degree
Associate degree in college (2-year)
Bachelor's degree in college (4-year)
Master's degree
Doctoral degree

If you have a degree, what is the focus? If no degree, simply skip this question.

Do you have health care experience?

Yes
No

If you have health care experience, what was your job title? (e.g., LPN, CNA, EMT, PCA, etc.)

Did you administer medications in this job?

Yes

No

How many years experience do you have in health care?

Use the slider bar to indicate how much confidence you have in performing the

Please use the slider bar to indicate how much confidence you have in successfully performing the following skills:

Compare 2 fractions and determine when one is larger (e.g. compare 5/8 with 2/3).

	0	1	2	3	4	6	7	8	9	10
0 = no confidence at all; 5 = some confidence; 10 = complete confidence										

Add two large numbers (e.g. 93499 + 76582) without using a calculator.

	0	1	2	3	4	6	7	8	9	10
0 = no confidence at all; 5 = some confidence; 10 = complete confidence										

Subtract two large numbers (e.g. 67225 – 23899) without using a calculator.

	0	1	2	3	4	6	7	8	9	10
0 = no confidence at all; 5 = some confidence; 10 = complete confidence										