MATHEMATICS ANXIETY AND MATHEMATICS SELF-EFFICACY IN RELATION TO MEDICATION CALCULATION PERFORMANCE IN NURSES

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Dissertation Prepared for the Degree of

DOCTOR OF EDUCATION

UNIVERSITY OF NORTH TEXAS

May 2012

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The purpose of this study is to identify and analyze the relationships that exist between mathematics anxiety and nurse self-efficacy for mathematics, and the medication calculation performance of acute care nurses. This research used a quantitative correlational research design and involved a sample of 84 acute care nurses, LVNs and RNs, from a suburban private hospital. The participants filled out a Mathematics Anxiety Scale, a Nurse Self-Efficacy for Mathematics Scale and also completed a 20-item medication calculation test. Significant practical and statistical relationships were discovered between the variables utilizing multiple linear regression statistics and commonality analysis. As the Nurse’s Mathematics anxiety score increased the scores on the medication test decreased and the scores on nurse self-efficacy for mathematics scale also decreased. The demographic item of “Hours a nurse worked in one week” had the greatest significance. The more hours a nurse worked the lower their score was on the medication calculation test. This study agrees with others that nurses are not good at mathematics. This study also correlated that as the number of hours worked increased so did the medication calculations errors. And many nurses have a measurable level of anxiety about mathematics and dosage calculations and this may influence calculation ability. Suggestions for further research include refinement of instruments used in study, further differentiation of barriers to successful medication calculation performance, and testing of interventions used to teach, train and evaluate accurate medication administration in nurses.
I want to acknowledge the assistance and support of my friends, colleagues, and professors. This has been a long and difficult journey, and I learned along the way that I need to ask for help and that there are many people willing to go out of their way to help.

I first want to thank Carl, my husband; he knows when to talk to me and when not. Carl has encouraged me not to give up. He has also done housework, shopping, and whatever it took to help me complete this project. And also I thank the pets who tell me when I need to get up and stretch and eat.

I want to thank Catherine Turner, Bonnie Gnadt, Lavonne Adams, Linda Johnson, Dawn Cox, Carolyn Mann, and Kathy Atwell. These women have been coworkers and have supported my slow and tedious process. They have all been willing to help lighten my workload, edit my writing, discuss the process, and remind me I should be working on my paper.

Thanks to Professor Jeff Allen for putting up with me for 10 years.
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CHAPTER 1

INTRODUCTION

This chapter includes the following sections: (a) Background, (b) Significance of Study, (c) Theoretical Framework, (d) Purpose of the Study (e) Research Questions and Statistical Hypothesis, (f) Delimitations, (g) Limitations, (h) Definition of Terms, and (i) Summary.

Background

Safety in the medical profession has become an increasingly central issue in the field due to medical errors, including medication calculation errors. Public outcry has magnified the issue of patient safety and has become a debated topic in the socio/economic, political, and medical communities. Safety has been improved in the aviation, nuclear, and chemical industries over the last several decades (Amalberti, Auroy, Berwick, & Barach, 2005), but the medical profession is considered to be far behind in putting in place “safety nets” in medication procedures and practices leading to a great number of medical errors. “Experts agree that as many as 98,000 patients die in any given year from medical errors that occur in hospitals. That’s more than by motor vehicle accidents, breast cancer or AIDS” (Kohn, Corrigan, & Donaldson, 2000; Schoening, Sittner, & Todd, 2006, p. 253). To demonstrate the gravity of this issue; Figure 1 shows fatal iatrogenic adverse events to be nearly as common as fatal events in Himalayan mountaineering (Amalberti et al., 2005, p. 758). In other words, a person has almost the same risk of dying when going to the hospital as when attempting to climb Mount Everest. “Every year, an estimated one million errors occur and as many as 100,000 people die from medical mistakes” (Pioneer Institute, 2009, para. 2). Fatal iatrogenic adverse events that occur in the health care facility include wrong site surgery, patient falls, transfusion errors, medication errors including wrong drug, wrong dosage, and wrong route of administration, among others (Joint
The Joint Commission (2010) reports that as many as 8% of the sentinel events are due to medication errors and 67% of the sentinel events end in patient death.

Another alarming element of medical errors is that many believe the number to be quite conservative. A punitive environment continues to exist in health care; consequently, many health care workers do not report all errors and almost never report near misses (McBride-Henry & Foureur, 2006; Wolf & Serembus, 2004). The number of errors reported and observed in several studies notes huge discrepancies in reported number of errors and actual observed errors (Milch et al., 2006; Shane, 2009). Flynn, Barker, and Pepper et al. (2002, as cited in Shane, 2009) state that using the “observation methodology detected 300 errors, compared with 17 errors identified by chart review and one error detected by incident report review” (p. S46).

Figure 1. Average rate per exposure of catastrophes and associated deaths in various industries and human activities (adapted from Amalberti et al., 2005).
research needs to be done in this area to detect and remedy the errors/mistakes. Patient care delivery needs to change from a system of punitive solutions and blame to a system approach focusing on health work environments and positive patient outcomes. Reason (2000) describes a system approach that looks at errors as opportunities to improve process and remove many of the negative approaches that lead to fear, blaming, and shaming. The premise is that “we cannot change the human condition; we can change the conditions under which humans work” (p. 768).

The most alarming thing about medication errors is that they occur more often in vulnerable populations. “Critically ill patients are prescribed twice as many medications as patients outside of the intensive care unit (ICU) and nearly all will suffer a potentially life-threatening error at some point during their stay” (Moyen, Camiré, & Stelfox, 2008, p. 1). “Medication dosing errors are more common in pediatrics than adults because of weight-based dosing calculation, fractional dosing (e.g., mg vs. Gm), and the need for decimal points” (“Preventing Pediatric Medication Errors,” 2008, p. 1). The rate of potential adverse events may be as much as three times higher in pediatrics and many were preventable or could have been identified earlier. ICU patients are also at risk because they “are prescribed twice as many medications” as others (Moyen et al., 2008, p. 208) and ICU patients have many more IV infusions.

Medication dose calculation errors are among the various types of medication administration errors. Several researchers agree that one in six medication errors involve calculations (Capriotti, 2004; Lesar, Briceland, & Stein, 1997). Medication calculation errors are between 7%-14% of all medication errors (Polifroni, McNulty, & Allchin, 2003). The OR Manager (2006) indicates that “patients in the operating room (OR) received the wrong amount of a drug . . . 33% of errors in children versus 16% in adults” and “in the PACU [post anesthesia
care unit], wrong amounts, calculation errors, and misplaced decimals were many times more common in children” (p. 1). The most common types of harmful medication errors were improper dose/quantity (37.5 %), omission error (19.9%), unauthorized/wrong drug (13.7%), and prescribing error (9.4%), followed by other errors (United States Pharmacopia (USP) Medmarx, as cited in OR Manager, 2006). Human factors, such as miscalculations of dosage or infusion rate, accounted for 42% of the medication errors reported in 2001 (Thomas, Holquist, & Phillips, as cited in Harne-Britner et al., 2006). Some possible human factors related to medication errors are staffing issues, stress, fatigue, distractions, not double checking, not being familiar with the medications, and not having adequate skills. Some of the identified reasons for committing a medication error include performance deficit (43%), knowledge deficit (29.9), procedure/protocol not followed (20.7%), miscommunication (16.8%), calculation errors, and improper use of pumps (USP, as cited in Tang, Sheu, Yu, Wei, & Chen, 2007).

Many errors related to medication calculations and administration can be prevented. “It is the responsibility of every health care provider, including nurses, to continually work toward a safer health care delivery system” (Bell, 2010, p. 510). Nursing, the largest group of health care professionals, has a responsibility to improve safety processes and decrease medication calculation errors. Nurses are the last line of defense for averting many medication errors because they are at the patient’s bedside.

**Significance of Study**

Errors in medication doses and intravenous (IV) rates can be fatal. The media has recently reported several cases of patient deaths due to the administration of inappropriate doses of medications (Institute for Safe Medication Practices [ISMP], 2007, 2008a, 2008b, 2008c; “Methodist Hospital Admits,” 2006; “National Pharmacist Group,” 2008; Stokowski, 2008).
Also, many other cases of medication errors have caused complications that did not result in death, but did cause injury, suffering, or increased medical care. One case in California involved the overdose of heparin to three infants, including a celebrity’s twins ("Cedars-Sinai Fined," 2008; Errico, 2007; Finn, 2008; “Heparin Overdose,” 2007). The calculation errors were made by doctors, anesthesia personnel, nurses, and pharmacists (Finn, 2008; “Heparin Overdose,” 2007; ISMP, 2007, 2008a, 2008b, 2008c; “Methodist Hospital Admits,” 2006). The system should have enough check systems in the process to catch such errors (Horns & Loper, 2002; Mullner, 2003; Shane, 2009). Calculation errors should be infrequent; there should be several steps in the process/system to check and recheck the calculations. A significant need exists to determine what can be done to minimize medication dosage errors. Nurses are the most common providers of care at the drug administration stage of the medication process. One important element to improving patient safety would be to analyze the medication calculation attitudes and skills of bedside nurses in the hospital. Nurses need to improve performance and skills in preparing and administering medications accurately, including calculating dosages, determining IV infusion rates, and operating medication delivery devices.

Chang and Mark (2009) describe several antecedents that relate to medication errors such as work environment factors, team factors, person factors, and medication-related support services. Human factors can include attitudes, emotional states, stress levels, and many other personal variables. Greenfield, Whelan, and Cohn (2006) believe that “the current failure of hospital-based initiatives to significantly reduce calculation errors may be a signal that this issue needs to be addressed at the educational level” (p. 91). The training and competency of practicing nurses needs to be reinforced and mathematic skills mastered for accurate medication
administration. The Joint Commission’s “sentinel events data shows 60% of medication errors were linked to orientation and training” (OR Manager, 2006).

A pilot study by Oldridge, Gray, McDermott, and Kirkpatrick (2004) found that less than 14% of health care providers sampled (physicians, pharmacists, and nurses) could calculate correctly five medication questions. The poorest performers in their study were the nurses. Harne-Britner et al. (2006) found poor medication calculation skills in nurses and nursing students. Nurses at all levels of experience, type of degree, type of nurse and specialty demonstrate limited accuracy in medication and intravenous infusion calculations (Ashby, 1997; Bayne & Bindler, 1991; Cinar, Akunduran, & Dogan, 2006; McMullan, Jones, & Lea, 2010; Morgan, Luo, Fortner, & Frush, 2006; Wright, 2009). “Patient acuity, staff shortages, decreased preceptor availability, elimination of unit-based clinicians, and shortened orientation time contribute to the need for new graduated to be highly proficient in medication calculation abilities” (Greenfield et al., 2006).

Knowledge of basic mathematic skills, multiplication, division, ratio, and proportions are some of the basic elements needed to perform medication calculations. Positive attitudes toward mathematic performance and critical thinking skills are also essential. Mastery of basic mathematic skills and the ability to focus on the task at hand with less anxiety and more confidence should decrease medication calculation errors and are key elements that need to be investigated when designing a medication calculation training program. Other skills related to medication administration are demonstrated by following the established procedures consistently. Attitudes related to mathematic performance are more difficult to determine. Attitudes regarding medication calculations may relate to motivations, emotions, confidence including self-efficacy, defensive behaviors, and socialization. Pekrun, Elliot, and Maier (2009)
linked the influence of goals and accomplishments to emotions and performance. They described enjoyment, boredom, anger, hope, pride, anxiety, hopelessness, and shame in a model of positive and negative emotions that influence performance. These emotions may also be manipulated or controlled in order to affect performance (Pekrun et al., 2009, p. 118). Positive or negative emotions are linked to performance and the choice to engage in or avoid a task or activity. A person’s lack of comfort or confidence (mathematic self-efficacy) with mathematics leads to increased levels of mathematic anxiety and is linked to performance, career choices, and motivation (Betz, 2000; Godbey, 1997; Hendel & Davis, 1978; Ho et al. 2000; Hopko, Mahadevan, Bare, & Hunt, 2003; Zakaria & Nordin, 2008). Finding ways to lower nurses’ mathematic anxiety level, and develop a realistic level of mathematic confidence will improve overall mathematical performance, leading to improved work performance and patient safety.

Mastery of solid mathematics skills and expertise at using these skills in a stressful practice arena can improve patient outcomes, health care provider confidence, and job satisfaction. Educators and trainers can develop simulations, mastery exercises, and other system measures to promote a healthier and safer medication administration environment.

The focus of this study is on determining the strength of the relationships between mathematics anxiety, mathematics self-efficacy, and actual performance on a medication calculation test between different types of nurses working in a hospital. If several of the underlying elements can be identified, then work can begin to improve orientation and training, thus improving the medication administration system. Medication errors are multifactored, and this study focuses on medication calculation errors and factors related to such errors.
Theoretical Model and Hypotheses

The theoretical model illustrates the relationships between mathematic anxiety, mathematic self-efficacy, type of nurse (RN or LVN), and performance on a medication calculation test. Mathematic self-efficacy, mathematic anxiety, and beliefs about mathematics have been correlated with mathematic ability \( r = 0.44, p = 0.001 \) (Hackett & Betz, 1989; Walsh, 2006).

Medication Calculation Performance

Accurate medication calculation performance is imperative for safe patient care. Nurses administer most medications and are the last line of defense for patients. Medication errors are more common in pediatrics and intensive care and are often involve multistep calculations using weight-based dosing, decimals, and fractions and require the use of infusion devices (Moyen et al., 2008; Rashidee, Hart, Chen, & Kumar, 2009; “Preventing Pediatric Medication Errors,” 2008; Shane, 2009). According to Hughes and Edgerton (2005), children are at a higher risk for harmful medication errors, and dosing errors are the most common type of drug errors in pediatrics because many of their medications are weight based. They also agree that with small patients, such as premature babies, dosing errors are more harmful and many times have devastating consequences (Hughes & Edgerton, 2005; “Preventing Pediatric Medication Errors,” 2008; Shane, 2009). Adult patients are at risk because they are severely ill and getting more medications, have longer hospital stays, are older, and often are sedated (Shane, 2009).

The Food and Drug Administration (FDA) reviewed 273 medication reports and classified each report into categories: communication, name confusion, labeling, human factors (knowledge deficit, performance deficit, miscalculation of dosage or infusion rate, drug preparation error, transcription error, stress), and packaging/design (Thomas et al., 2001). They
found that 7% of the errors were miscalculation of dosage or infusion rate, 2.3% drug
preparation errors, and the majority of errors, 42%, were the human factors combined.
Medication calculations prone to errors usually involve dosages or dilutions (McDowell, Ferner,
& Ferner, 2009).

Medication risk factors are the types of medications, actual number of medications,
number of medications that are injected or infused, number that are based on the patient’s
weight, those that require calculations and careful monitoring, and use of sophisticated pumps
that require programming (Moyen et al., 2008). Calculations using dilution for liquid
medications for oral administration, IV, and injections are more difficult than calculating the
number of pills (Bayne & Bindler, 1991; Walsh, 2006). Some IV infusions have to be given
based on a dose of micrograms per kilogram per minute, and the infusion pump is set in
milliliters per hour. The calculation of weight-based doses and/or infusion rates would be most
difficult for the nurse who cannot do the simpler dose calculations with accuracy. Many errors
may simply be because nurses have limited skills in doing simple medication calculations, and
fixing these skills may improve the system and create safer nurses (Polifroni, Allchin, &
McNulty, 2005).

Several researchers agree that one in six medication errors involve calculations (Capriotti,
2004; Lesar et al., 1997). Medication calculation errors are between 7% and 14% of all
medication errors (Polifroni et al., 2003, p. 455). The calculations involved in most medication
calculations are estimated to be at a 7th-grade mathematics level or below and involve simple
arithmetic, multiplication, division, fractions, decimals, percentages, and conversions to the
metric system (Hughes & Edgerton, 2005; Polifroni et al., 2003; Rainboth & DeMasi, 2006).
Many medication errors are related to dose errors, and it is documented that nurses are not good at mathematics (Calliari, 1995; Gladstone, 1995; Grandell-Niemi, Hupli, & Leino-Kilpi, 2001; Jukes & Gilchrist, 2006; Lee, 2001; Wright, 2006). Jones (2009) stated, “Nurses poor mathematical competency has been identified as a key cause of medication administration errors” (p. 41). Harne-Britner et al. (2006) found that 41.6% of students and 54.8% of nurses could not calculate IV medication or IV flow rates with 90% accuracy. McMullan et al. (2010) found no statistical significant difference between the medication calculation ability of registered nurses (RNs) and nursing students; the failure rate was 45% and 55%, respectively, on a mathematic test. Many schools and health care agencies do not have consistent practices in assuring medication calculation skills. Polifroni et al. (2003) indicate that many acute care agencies require specific passing scores ranging from 70% to 100% and most require a score of 80% and above.

Mathematics Anxiety

Mathematics anxiety is defined as “feelings of tension and anxiety that interfere with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations” (Richardson & Suinn, 1972, p. 551) and may manifest itself in avoidance of certain situations, including courses in math and statistics, in feelings of inadequacy, or in added pressure and physiological symptoms (Betz, 1978; Richardson & Suinn, 1972). Mathematics anxiety is such a negative experience to some people that they actively and purposely avoid mathematics situations (Alexander & Cobb, 1984). Richardson and Suinn (1972) have noted that “it has been demonstrated that mathematics anxiety exists among many individuals who do not ordinarily suffer from any other tensions” (p. 551).
Richardson and Suinn (1972) studied 397 college students and noted that “among nonstudents, mathematics anxiety may be a contributor to tensions during routine or everyday activities, such as handling money, balancing bank accounts, evaluating sales prices, or dividing work loads” (p. 552). Mathematics anxiety is sometimes referred to as a phobia (Richardson & Suinn, 1972) and “mathophobia as an irrational and impending dread of mathematics” (Lazarus, 1974, as cited in Hendel & Davis, 1978, p. 429). Mathematics anxiety may be triggered by just the mention of a mathematics problem, medication administration, or a testing situation (Ho et al., 2000).

Mathematic anxiety is learned from childhood, influences career choices and college majors, and influences performance as an adult. Gómez-Chacón (2000) describes emotional factors that may influence how students learn early in life to deal with mathematics. She believes that the evolution of an adult or high school student’s mathematic performance is socially and emotionally learned early in the school-aged child. Mathematics anxiety may develop based on home and school influences, performance expectations of parents, peers, and teachers, previous negative experiences, and/or their perception of an intense situation. Alexander and Cobb (1984) researched mathematics anxiety and determined that students who had high grades in math courses and had taken algebra II in high school had less mathematics anxiety. Mathematic anxiety and the affective component were found to have a significant relationship to mathematics achievement in the negative direction (Ho et al., 2000).

Mathematic anxiety can be positive or negative and is aroused by various underlying factors and influences. Mathematic anxiety is one of the emotions aroused when a nurse has to do medication calculations. If anxiety levels increase too high the nurse may not be able to perform adequately. The nurse’s level of mathematic anxiety can also influence whether the
nurse will approach or avoid the tasks and whether the nurse will persist or desist to task completion as described in elements of motivation and performance expectations in Bandura’s (1977) self-efficacy model.

Mathematics anxiety is linked to the medication calculation performance of nursing students and nurses. Roykenes and Larsen (2010) studied 116 baccalaureate nursing students and determined that there was a relationship between previous mathematic likes/dislikes and self-assessment of mathematic ability. An additional finding indicated that the student's requirement of getting 100% on the test was anxiety producing and that the anxiety was higher for students who had done poorly in mathematics prior to college.

In 1991 Bayne and Bindler studied 110 nurses and determined that there was a significant relationship between the nurses’ comfort level and medication calculation ability ($F_{13.0518}, p < 0.001$). The comfort level showed significant differences between the categories of comfort and calculation ability (comfort level above average and below average, $p = 0.0001$; above average and average, $p = 0.0060$; average and below average, $p = 0.0029$).

Ashby (1997) studied 62 practicing medical-surgical nurses and found that fewer than 20% of the nurses rated their skill as above average, but 43.5% scored 90% or higher, and almost 60% of the nurses reported that the medication calculation and administration was a stress-producing task. She concluded that because 56.4% of the nurses in the sample could not pass a calculation test at 90% there is an urgent continued need to reevaluate the medication calculation ability of practicing nurses and also to research ways to enhance remediation processes. Confidence levels and the stress of doing calculations may be mathematics anxiety. Improving skill levels may decrease perceived stress.

Through investigation of the underlying system and acknowledging the human and latent
factors, the health care provider can improve performance and improve safety. Underlying human factors affect how stress, fatigue, and the work environment influence one's medication calculation ability. Stress may include mathematic anxiety and low confidence levels regarding mathematical tasks.

Hypothesis 1. The perception of mathematics anxiety is negatively related to performance of medication calculations.

Nurse Self-Efficacy for Mathematics

Self-efficacy is referred to as “beliefs in one’s capability to organize and execute the courses of action required to manage perspective situations” (Bandura, 1977, p. 2). Personal beliefs that actions will produce a desired outcome influence the incentive or persistence in performance while facing difficulties (Parajas, 1997). Low self-efficacy expectations regarding a behavior lead to avoidance of the behavior, and as the self-efficacy increases, the frequency of approaching the behavior should increase (Betz & Hackett, 1993).

Self-efficacy regarding mathematics is defined by Betz and Hackett (1993) as perceptions of one’s performance capabilities related to math problems, math tasks, and math-related coursework. Mathematics self-efficacy is in part one’s confidence in personal performance of mathematics and may be related to prior experiences, innate beliefs, successes, and/or failures. Mathematics self-efficacy is a self-referent process that individuals use to judge their ability to self-regulate and succeed in an activity (Stevens, Olivarez, Lan, & Tallent-Runnels, 2004). Bandura (1997) has postulated that “self-efficacy develops from prior mastery experiences, vicarious learning, verbal persuasion, and evaluations of emotional states” (as cited in Stevens et al., 2004, p. 209). Self-efficacy develops after personal experiences or by learning from the experiences of others, what a person is taught or convinced of, and how the experiences affected the person emotionally. A person can have self-efficacy at different levels for different activities.
People with high self-efficacy for a task believe in their own capabilities more positively than those with a low level of self-efficacy (Nielsen & Moore, 2003). It is postulated that persons who have positive self-efficacy approach a task and persist in their efforts to complete the task with a positive sense of self-confidence. In turn, outcome expectations related to self-efficacy have the potential to predict performance expectations (Betz, 1978). Individuals acquire their sense of self-efficacy during their life experiences, which are influenced by the environment and the variety of information sources.

Mathematics self-efficacy and nurses’ medication calculation abilities are linked. Nurses and nursing students’ medication calculation skills have been positively related to their comfort and confidence levels in the calculating medication including IV medications (Andrew, Salamonson, & Halcomb, 2009; Grandell-Niemi et al., 2001; Harne-Britner et al., 2006; Roykenes & Larsen, 2010). Comfort and confidence levels are part of self-efficacy. Andrew et al. (2009) describe two factors combined to measure nurse self-efficacy for math; one factor is “confidence in application of mathematic concepts to nursing practice,” and the second factor is “confidence in arithmetic concepts” (p. 220). The tool they tested for nurse self-efficacy in math had predictive validity with the medication calculation test administered.

Hypothesis 2. The perceptions of nurse self-efficacy for mathematics is positively related to performance on a medication calculation test.

Mathematics anxiety and mathematics self-efficacy are two factors related to mathematic performance, and one may augment the other or vice versa (Roykenes & Larsen, 2010). They suggest that if the students had few mastery experiences and had experienced failures in mathematics that decreased their self-belief. There may be a connection between nursing students’ perceived stress related to the no-error requirement, previous mathematic skills, and perceptions of their ability to perform the drug calculation test (Roykenes & Larsen, 2010).
Stressful requirements can be related to mathematic anxiety and perceptions of ability math self-efficacy. They suggest the need for more research to validate this connection.

Mathematics anxiety and mathematics self-efficacy were indicated as contributors to student mathematics competency (Middleton & Spanias, 1999). If people cannot perform mathematics problems successfully, their self-esteem and confidence are affected (Ho et al., 2000). Mathematics anxiety has been extensively discussed in the literature and the construct established; however, more research needs to be done that may link it with mathematics self-efficacy, and the combination of mathematics anxiety and mathematics self-efficacy may help guide mathematics instruction and training to find solutions or interventions to improve mathematics performance (Ho et al., 2000).

Hypothesis 3. The perceptions of mathematics anxiety and the perceptions of nurse self-efficacy for mathematics are negatively related.

Type of Nurse

Research findings have not found significant differences in the calculation abilities of nurses versus nursing students. Several studies use the term nurse and define it as RN and may delineate the college degree type in the demographics, but the type of nurse used in most studies is not clear. American hospitals hire licensed vocational (Practical) nurses (LVNs), and registered nurses (RNs), and the studies may include both types of nurses. Studies have not investigated directly the possible differences in LVN and RN performance of medication calculations or mathematics skill, including factors contributing to or detracting from performance. However, one study looked at RNs and how their experience and education level related to their medication performance on a test and in the number of medication errors (Calliari, 1995). Calliari found a significant association between the RNs’ level of education and the number of medication errors (p < 0.05) and that if RNs passed the medication test in nursing
orientation, they were less likely to make medication errors than the RNs who failed the test (p < 0.02). There also may be another association of LVN education to RN education related to performance on a medication administration test. The NCLEX-PN exam is for the LVN licensure, and the NCLEX-RN exam is for RN licensure. The NCLEX exam is a national exam, but each state board or nursing legislates and regulates the licensure and practice of the different types of nurses, LVNs, RNs, and advanced practice nurses such as Nurse practitioners (NPs) and Nurse Anesthetists (CRNAs). Nurses (RNs and LVNs) have different levels of education, practice guidelines, and employment expectations.

The LVN has 9-18 months of technical training, and is supervised in the care of stable predictable patients (TBON, 2010). LVNs have basic technical task-oriented training. A few of the expected competencies of the LVN are (a) contributes to the plan of care, (b) performs basic interventions in patient care, (c) has knowledge of fundamental principles of disease prevention, and (d) health promotion/restoration for individual clients (Poster et al., 2005). The national exam for LVNs/LPNs is based on the competencies listed above. In order to practice nursing the LVN has to be supervised by an RN or physician (TBON, 2010).

Nurses working in acute care have a variety of education levels and therefore different backgrounds in medication calculation training. According to the National League of Nursing (NLN), one in five licensed nurses working in the United States is an LVN (Kaufman, 2009). Texas utilizes a mixture LVNs and RNs in acute care patient care. About 25% of all LVNs work in hospitals (U.S. Dept of Labor, 2011). Many hospitals in Texas have both LVNs and RNs. Acute care training for LVNs should entail specialized training to work with IVs, certain procedures, and specialized equipment (if allowed in by the state licensing organization), but that training is not part of their basic education. In Texas LVNs cannot administer hemodialysis, so
the concepts of dialysis treatment and management would not be taught in a Texas LVN program. In some states LVNs cannot start IVs or administer any IV medication or fluids (LPNs and IV, 2011), and therefore the education programs in those states would not teach any IV content. But LVNs in Texas can administer IV medications via peripheral and central lines; therefore, some of the basic concepts are taught. LVN educators teach basic medication calculations the same way RN educators do, except many LVN programs do not focus on detailed IV concepts.

An RN may have an associate of science degree, associate of applied arts, a diploma, or a baccalaureate of science degree. RNs all take the same national NCLEX-RN exam. Associate degree RNs are trained to be the bedside acute care nurses with limited amounts of leadership training. The baccalaureate-prepared RN has leadership, research, and community courses in addition to the bedside nursing care focus. All RNs are taught critical thinking skills and are expected to be able to care for all types of patients. The RNs’ basic education entails critical thinking including delegation and leadership skills, complex patient care planning, delivery, and evaluation (Poster et al., 2005). RNs are the charge nurses, team leaders, and managers in the acute care nursing units. LVNs must be able to work under close supervision and be able to follow orders. LVNs also may not perform the duties of charge nurse or team leader in the hospital setting (Spetz, Dyer, Chapman, & Seago, 2006). The RN has a college degree and is expected to be more confident and competent in medication calculations, including complex IV calculations.

Because a mixture of RNs and LVNs work in acute care and current research does not delineate whether there are differences between them in regards to mathematics performance,
this study evaluates the possible relationships between the LVN and RN related to mathematics performance.

Hypothesis 4. RNs will perform significantly better on a medication calculation test than LVNs.

In a study by Porter-Wenzlaff and Froman (2008), the authors discussed how the LVN differs from the RN in that many LVNs have disadvantaged personal and academic backgrounds, lower grades in high school and college, and English may not be their first language. Many LVNs do not see themselves as college candidates, and their family background may have a limited number of people who attended college. The LVN’s exposure to critical thinking, advanced vocabulary, and complex concepts may be limited due to family and personal experiences. These factors were related by the authors by challenges to success in a RN-BSN program.

The above factors may also influence the ability of LVNs to perform mathematics, and they may experience different levels of comfort and confidence in testing, calculation, and medication administration. Mathematics anxiety does not seem to have a single cause; the nurses may have different levels of anxiety because they do not handle frustration well, have low self-esteem, do not understand mathematic concepts, and have been influenced by family, teachers, and peers and their beliefs and attitudes about mathematics (Godbey, 1997). The RN has more education in mathematics and critical thinking and is the person who supervises the LVN; this may influence their mathematics anxiety levels. Current literature does not investigate the differences between the types of nurse in regards to mathematics anxiety or self-efficacy. However, considering the differences in the LVN and RN related to education, licensure, and responsibilities, this is worthy of investigation.

Hypothesis 5. RNs will have less mathematics anxiety than LVNs.
Hypothesis 6. RNs will have more nurse self-efficacy for mathematics than LVNs.

The relationship of mathematics anxiety to nurse self-efficacy regarding mathematics and to medication calculation performance was studied.

**Purpose of the Study**

The purpose of this study is to identify and analyze the relationships that exist between mathematics anxiety and nurse self-efficacy for mathematics, and the medication calculation performance of acute care nurses.

**Research Questions**

Research Question 1. To what degree are the perceptions of mathematics anxiety or perceptions of nurse self-efficacy for mathematics related to performance on a medication calculation test by nurses?

The independent variables are mathematics anxiety and nurse self-efficacy for mathematics, and the dependent variable is medication calculation performance.

Research Question 2. To what degree are the type of nurse and the perceptions of mathematics anxiety or perceptions of nurse self-efficacy for mathematics related to performance on a medication calculation test?
The independent variables are type of nurse, mathematics anxiety and nurse self-efficacy for mathematics, and the dependent variable is the medication calculation test.

Delimitations

This study is delimited to nurses employed at one mid-sized private Texas suburban hospital. The Texas Board of Nursing (TBON) controls nursing practice specifically for Texas with regulations based on legislation. All subjects are at least temporary residences of the North Central Texas area. The hospital is representative of other acute care hospitals in Texas because it is accredited by the same governmental agencies. The LVNs and RNs are typical of nurses in the north central Texas region.

Limitations

The study is limited by the data which were self-reported and those who chose to participate. The participants were encouraged to fill out the instruments, but were not required to participate.

Definition of Terms

The following terms are defined for the purpose of this study:

Registered nurse (RN): Texas-licensed RN who has successfully passed the national examination (NCLEX-RN). The RN is practicing at the bedside in an acute care environment.

Licensed vocational nurse (LVN): Texas-licensed LVN who has successfully passed the national examination (NCLEX-PN) (TBON, 2010). The LVN is practicing at the bedside in an acute care environment. Texas utilizes LVNs often in acute care practice. They fill many positions; 25% of LVNs work in acute care (U.S. Department of Labor, 2011).
Nurse: Texas licensed RN or LVN. For the purpose of this research, this term is referred to as nurse. The nurses in this study were working in an acute care (hospital) facility.

Summary

Since medication calculation errors continue to happen and nurses are the final defense, this topic is timely and needs to be addressed. Acute care nurses continue to make medication calculation errors, and the evidence for decreasing, preventing, or improving the system is limited. Self-belief systems such as mathematics anxiety and mathematics self-efficacy are believed to influence medication calculation performance. Therefore, the research questions to be investigated are To what degree are the relationships between the perceptions of mathematics anxiety, or perceptions of nurse self-efficacy for mathematics, to performance on a medication calculation test by nurses. Also, to what degree is there a relationship between the type of nurse and the perceptions of mathematics anxiety, or perceptions of nurse self-efficacy for mathematics, to performance on a medication calculation test. Chapter 1 includes a review of the background of nursing and health care supports and the significance and purpose of the study. Bandura’s self-efficacy theory guides the development of the plan for investigation.

Chapter 2 reviews the research related to the medication process and errors, global medication safety initiatives, nurses’ medication errors, Texas nurses’ qualifications and medication calculation training,mathematics performance of nurses, mathematics performance factors, mathematics self-efficacy and mathematics anxiety, suggestions for improving nurses’ calculation ability, and measurement tool evolution. Studies suggest that more research is required to establish clearer relationships to determine how to compensate for the issues (Chang & Mark, 2009; Jones, 2009; Tang et al., 2007; Walsh, 2006). Issues in the entire health care system and the medication system, specifically the administration of medicine, have many
factors yet to be determined that influence safety. System issues need to address in other studies; however, the beginning can be at the bedside with the nurses who are administering medications.

Chapter 3 includes specific information about the population and sample, research design, study instruments, and a detailed synopsis of how the research process was organized and planned, including how data was gathered and analyzed.
CHAPTER 2

REVIEW OF THE LITERATURE

The purpose of this study is to identify and analyze the relationships that exist between mathematics anxiety, nurse self-efficacy for mathematics, and medication calculation performance of acute care nurses. This chapter includes the following sections: (a) Medication Process and Potential for Errors, (b) Medication Safety Initiatives, (c) Medication Errors, (d) Nurses Mathematics Ability, (e) Nurses’ Education, Licensure and Medication Expectations, (f) Acute Care Nurses Medication Calculation Training and Competency, (g) Mathematics and Medication Calculation Performance Factors, (h) Mathematics Self-efficacy and Mathematics Anxiety, and (i) Summary. This review of the literature does not cover the larger areas of belief systems; behavioral theories of motivation; skill evaluation of mastery or degradation; psychomotor learning; or learning transfer.

Medication Process and Potential for Errors

An understanding of the basic elements of the medication process is essential in evaluating medication errors, including calculation errors. The medication process has multiple stages with a variety of health care providers involved in each stage of the process. The stages of the medication process are prescribing, transcribing, preparing, dispensing, and administration (Jones, 2009; McDowell et al., 2009; Moyen et al., 2008; see Figure 3). Documentation is part of the process that must be done during all stages. Because the multiple stage process involves a variety of health care professionals the process is prone to errors. The exact reason each error occurs can be difficult to determine because of the wide range of possibilities. McDowell et al. (2009) state the following:

Tasks that require the calculation of a dosage or dilution are especially susceptible to error. . . . The error rate increases when health-care professionals are inexperienced,
inattentive, rushed, distracted, fatigued, or depressed . . . and medication error rates are higher in hospital pediatric and intensive care departments. (p. 605)

![Diagram of medication process]

*Figure 3. Stages in the medication process.*

Prescribing is the source of about 11% of medication errors, and administration accounts for 40% of the mistakes (USP, 2000, as cited in Tang et al., 2007). Transcribing is usually done by an assistant and checked by the pharmacist or nurse; the order or prescription is then transmitted to the pharmacist in handwritten form or digitally by computer. Potential errors during the prescribing stages are related to wrong treatment prescribed, handwriting issues, several people handling the order, and the multistep process. Preparing and dispensing are generally done by the pharmacy under sterile controlled conditions; however, nurses may also be responsible for dispensing and preparing some medications that have to be mixed and prepared immediately prior to administration. According to McDowell et al. (2009), there are as many as 12 steps to perform in order to give an IV injection (p. 606). Errors during the preparation
process may be partially due to the fact that the nurse may only prepare certain medications
during a critical situation or crisis. Potential dispensing errors of the pharmacist and nurse may
be the dispensing of the wrong drug, or wrong dose, or they may be due to “look alike” names of
drugs, and similar packaging for different doses of the same drugs or different drugs (Amalberti
et al., 2005; Horns & Loper, 2002; Rashidee et al., 2009). Errors in preparation may be mixture
of calculation errors of dilution or concentration of oral and injectable medications as well as
intravenous infusions. The preparation step is usually done in the pharmacy by staff or by
pharmacists themselves. The pharmacist, or technician, labels the medication and delivers it to
the patient care area for administration. Some medications are sold to the facility in prepackaged
and premixed forms, and others must be prepared. Sometimes the preparation has to be done at
the bedside immediately prior to administration, and in most instances this is done by the nurse.
Some research findings have suggested having a “satellite pharmacy” in or near patient care
areas that require a substantial volume of medications (Grandell-Niemi et al., 2001; Taxis &
Barber, 2004; Wirtz, Taxis, & Barber, 2003).

The satellite pharmacy is a “mini pharmacy” on specific units, stocked with unit-specific
items that can immediately be prepared and dispensed, making the process quicker and possibly
deterring time lags and decreasing errors. Some acute care facilities have satellite pharmacies in
surgical areas, critical care areas, and between high patient volume floors such as oncology or
orthopedics. The satellite pharmacy has become more popular because it is thought that the
pharmacist is not as close to the stressful situation, is more familiar with mixing drugs and doing
calculations, and will therefore make fewer mathematic mistakes (Taxis & Barber, 2003; 2004;
Wirtz et al., 2003). The pharmacy prepares and dispenses medications; however, the nurse
usually administers the medication.
The administration stage is the last step in the process before the medication reaches the patient and is the last chance to prevent an error. Preparation and administration are the steps when most medication calculation errors occur, with more errors occurring during administration (Kuitunen, Kuisma, & Hoppu, 2008; Shane, 2009; Williams & Maddox, 2005). Since nurses predominantly administer most of the medications they need to be the “last potential barrier between a medication error” (Hughes & Edgerton, 2005, p. 79). The administration stage can be a simple process such as giving oral medications in the form of a tablet or capsule to an alert, oriented, and cooperative patient. Or the process may be complicated such as when giving liquids and parenteral (other than by gastrointestinal tract) medications. Liquid medications for oral or gastrointestinal use must first be measured into a measuring device and then given to the patient by mouth or placed into feeding tubes. Some liquid medications have to be converted from teaspoons to milliliters. An error in mixing up milliliters with teaspoons can be quite harmful; 5 milliliters is a very different dose from 5 teaspoons. Not all patients are cooperative when receiving medication; for instance, infants and toddlers have to be coaxed. Additionally, many pediatric medications have to be dosed and administered according to the patient’s weight. Since many pediatric medications are liquid, it is important to administer the medication by the correct route. Devastating errors, including death, have been made by giving liquid doses in the wrong route, wrong device, and/or wrong dose (Brehio, 2009; ISMP, 2000). An 18-year-old was prescribed oxycodone oral solution for a sore throat; however, he mistakenly received 100 mg instead of the 5 mg prescribed (Brehio, 2009). The patient suffered organ failure, was put on a ventilator, and remains in a coma. The ISMP has had reports of more than 30 mix-ups between milliliters to teaspoons, and several cases have required treatment or hospitalization (Brehio, 2009). The potential for errors can become more probable with the increase in the number of
steps the health care provider must take in the administration process. Medications that have to be prepared, then measured, and finally administered to the patient are at a high risk for error.

Injectable medications often require several steps in the preparation and administration stages of the medication process. Injectable medications (intramuscular, subcutaneous, and intravenous) may have to be reconstituted or diluted and drawn into a syringe to be injected into the patient using the proper technique for administering in the proper site. Injectable medications may be prepackaged and premixed from a manufacturer, or they may have to be reconstituted or mixed by the nurse or pharmacist. The preparation process may take several steps. An injection, intramuscular or subcutaneous, could be a simple procedure such as a one-time dose dispensed in a prepackaged form, requiring fewer steps to prepare and administer than one that has to be reconstituted, calculated for weight and proper dose, and then measured before administering to the patient. Intravenous infusions generally require more steps and additional skills in using infusion devices and calculating infusion rates. Intravenous drugs are given intermittently by IV infusion or IV bolus, while others are given by continuous infusion. Some drugs are more dangerous than others and have stricter protocols for administration. Many IV medications have specific guidelines to follow regarding the rate of administration, dose parameters, indications, and contraindications. Often, standards of medication administration and hospital policies dictate the use of infusion devices for certain high-risk medications or populations. High-risk medications include critical care drugs to increase blood pressure, potassium, and certain antibiotics; high-risk vulnerable populations include the elderly and pediatric patients. Some medications and IV infusions not only require infusion devices but must also be given in specialized areas such as intensive care and administered by specially trained personnel (physician, anesthesia person, chemotherapy-certified RN or ICU RN, etc.) with close
monitoring of patients. Monitoring of patients, depending on the type of medication and the condition of the patient, may be conducted in a specialized unit with specially trained nurses.

When medications are to be administered via an infusion device, nurses usually take care of the device set-up and operation. Most infusion devices require a rate set with a reference to time and/or can be programmed for many standard infusions. The pharmacy can print the rate at which to set the device or print it on the medication administration record (MAR). The nurse administering the medication must double-check the doses programmed into the infusion device or that the pharmacy calculated. Failure to double-check doses with another source is cited to be a cause of medication errors (Jones, 2009).

Medication calculations are necessary to determine the volumes of additives and diluents for accurate injections, infusions, and safe medication administration. Some calculations are simple and require the use of seventh-grade mathematics (Polifroni et al., 2003), multiplication and division and simple fractions which require only a couple of steps. Other calculations are more complex and involve metric conversions, teaspoons to milliliters, weight-based dosing, pounds to kilograms, and infusion calculations which add time, minutes, and hours to the equation and increase the number of steps required to complete the calculation. Complicated infusion calculations may involve micrograms per kilogram per minute first, then must be converted to milliliters per hour, the most common setting for infusion pumps.

Medication Safety Initiatives

Safety initiatives have been suggested to decrease errors across all stages of the medication process and are promoted worldwide (Doormaal et al., 2010; Shamliyan, Duval, Du, & Kane, 2008; Taxis & Barber, 2004; Wirtz et al., 2003). In the United States, payment providers and accreditation agencies such as the Center for Medicare and Medicaid Services
(CMS) and the Joint Commission strongly promote technological initiatives intended to improve patient safety. The Joint Commission, the primary accrediting agency for acute care institutions, publishes the National Patient Safety Goals (NPSG) with multi-part guidelines for accredited agencies to implement with prescribed outcome goals. Several suggested initiatives to improve patient safety are computerized physician order entry (CPOE), automated dosage systems, bar code technology, and computerized infusion pumps (Moyen et al., 2008, p. 210). These initiatives involve implementation of new equipment, hardware, software, or major changes in the work process of health care providers.

The current focus on decreasing errors and improving health care is on the computerized physician order entry (CPOE) system. “Physician ordering and transcription were responsible for 50 to 61% of all medication errors” (Bates et al., 1995, Leape et al., 1995, as cited in Shamliyan et al., 2008). The CPOE system will be a dramatic change in traditional physician ordering and prescribing practice. Physicians typically have not used computers to write orders; they wrote out the orders in long-hand, filled in a printed order set, or simply gave orders to the nurse verbally or by phone. The CPOE system requires physicians to enter orders into a computerized charting system and do their documentation via the computer. Many CPOE systems have a built-in decision support system that will activate alerts regarding drug-to-drug interactions, allergy alerts, and reminders about checking certain other patient parameters regarding the medications and treatments ordered (Doormaal et al., 2010; Williams & Maddox, 2005). The CPOE system has been associated with a significant 66% reduction in total prescribing errors, but further research is needed to evaluate the true impact on medical errors overall (Shamliyan et al., 2008).

CPOE is being strongly promoted because of legislated and monetary incentives provided for in the economic stimulus bill. According to King (2009) the legislation provides monetary
incentives to hospitals that adopt qualified electronic health records and reduce Medicare payments for non-adopting hospitals beginning in 2016. CPOE purports to decrease errors and save money by improving physician prescribing and transcription; however, many other types of errors occur. Preparation and administration medication errors are just as significant in the well-being of the patient. Other solutions are proposed to prevent preparation, distribution, and administration errors such as automated dosage systems (ADS), satellite pharmacies, and bar coding systems.

The ADS represent another safety initiate suggested to decrease medication errors. ADS are designed to prevent wrong dose, wrong time, wrong patient, wrong route, and wrong drug errors, and at the same time decrease the usual time lag between when the medication was ordered to when it was given. ADS are computerized cabinets that require authorization to fill and remove medications for patients’, they are designed to make medications readily available and yet prevent nurses from taking out medications inappropriately and committing an error. Pharmacy personnel will add the medications from the new orders to the patients profile; the nurse will then be authorized to remove the medication from the system. Systems can be simple when medications are in stock and the nurse removes them as needed; the system controls the stock. Systems can be more complex when the medication profile set for the patient in the computer allows only a certain caregiver to take certain medications out at a certain time. The nurse still has to give the medication correctly to the prescribed patient.

Bar code technology has been in use for a few years in some systems (Cummings, Bush, Smith, & Matuszewski, 2005). The bar code system encodes patients and their medication into the electronic system; a bar code reader is used at the bedside (point-of-care) by the nurse to scan their name badge, the patients arm band, and the medication in order to correctly administer the
medications (Cummings et al., 2005; Fowler, Sohler, & Zarillo, 2009). The bar code system does not speed up the medication process, which is believed to take up to 40% of the nurse’s time, but it will improve safety of the patient, through right time, right dose, right route, and right medication (Fowler et al., 2009). The initial capital costs may be between $1 million and $5 million, depending on the facility size, infrastructure, hardware, software, and other computer capabilities, and there will be ongoing costs for support, upgrades, and training. The return on investment of the bar code system has not been established; however, the cost may be small in comparison to treating patients who have suffered because of a medication error. Administration errors have been documented to be reduced by 60% using a bar coding system (Cummings et al., 2005).

Infusion devices such as smart pumps, patient-controlled analgesia pumps, infusion pumps, and auto-injectors are some of the machines used to make giving injectable medications easier. Rates of flow and other parameters have to be set into the machines. Some machines do some of the calculations for the nurse. For instance, some infusion pumps have a menu of common infusions and standard concentrations from which to choose; the care provider has to select the correct item and enter the dose ordered, and the pump will calculate the infusion rate. If the infusion is weight-based, the care provider will be prompted to enter the patient’s weight, in kilograms, and the pump will then calculate the more complex infusion rate. However, the nurse has to calculate volumes to be infused and infusion rates per hour that are programmed into the pump. Nurses’ lack of understanding in how to operate infusion devices has been associated with errors (Shane, 2009), and alerts have been found to be bypassed 25% of the time (Rothschild et al., 2005).
In spite of these new strategies, Moyen et al. (2008) feel that there is little evidence of substantial performance improvement with a decrease in errors because human factors continue to be a frequent cause of errors. New equipment, software, and revised medication processes are only part of the remedy for correcting medication errors. Nurses and other health care providers need adequate knowledge and skills to effectively implement and utilize the changes. Nurses must be familiar with the medication’s use, usual dose, side effects, and reasons for why the patient is taking the medication and prerequisites to check before administration. Nurses need adequate resources, medical calculators, drug books, and other materials, including the patient’s medical record, for bedside medication preparation and administration.

Medication Errors

Rashidee et al. (2009) analyzed medication errors reported on the MEDMARX data repository and ISMP medication error reporting program from 2006 to 2008. They identified 443,683 medication errors from approximately 537 facilities of which 98% were from inpatient settings. In these inpatient settings 32,546 (7%) were related to the high-alert medications. High-alert medications have a high volume of use and high potential of greatest harm if not given properly (i.e., insulin, heparin, warfarin, digoxin, etc). While the majority (54%) was located in inpatient care units, 21% were reported in the inpatient pharmacy departments, and 7% were reported in all ICUs combined. Table 1 itemizes types and distribution of medication errors reported in Rashidee et al. The most common type of errors was omission errors (26%), directly followed by improper dose and quantity (22%). Figure 3 shows that most high-alert medication errors occurred in the dispensing (29%) and administration (29%) stages followed closely by transcribing/documenting (25%).
Table 1

*High-Alert Medication Errors by Type of Error Category*

<table>
<thead>
<tr>
<th>Type of error category</th>
<th>Number</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Omission error</td>
<td>8,461</td>
<td>26%</td>
</tr>
<tr>
<td>Improper dose/quantity</td>
<td>7,124</td>
<td>22%</td>
</tr>
<tr>
<td>Unauthorized/wrong drug</td>
<td>5,463</td>
<td>17%</td>
</tr>
<tr>
<td>Prescribing error</td>
<td>2,923</td>
<td>9%</td>
</tr>
<tr>
<td>Wrong time</td>
<td>2,300</td>
<td>7%</td>
</tr>
<tr>
<td>Extra dose</td>
<td>2,256</td>
<td>7%</td>
</tr>
<tr>
<td>Wrong patient</td>
<td>1,786</td>
<td>5%</td>
</tr>
<tr>
<td>Mislabeling</td>
<td>646</td>
<td>2%</td>
</tr>
<tr>
<td>Wrong dosage form</td>
<td>586</td>
<td>2%</td>
</tr>
<tr>
<td>Wrong administration technique</td>
<td>335</td>
<td>1%</td>
</tr>
<tr>
<td>Drug prepared incorrectly</td>
<td>311</td>
<td>1%</td>
</tr>
<tr>
<td>Wrong route</td>
<td>252</td>
<td>1%</td>
</tr>
<tr>
<td>Other</td>
<td>113</td>
<td>0%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>32,556</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

(Adapted from Rashidee et al., 2009, p. 18)

*Figure 4. High-alert medication errors by administration process node 2006-2008 (Rashidee et al., 2009, p. 19)*
Errors are often made in the preparation and administration phases, and they are made by a variety of health care providers. Findings describe errors made by physicians, pharmacists, nurses, and families (Loannidis & Lou, 2001; Moyen et al., 2008; Rolfe & Harper, 1995; Taxis & Barber, 2004; Wirtz et al., 2003). The medical system is a complex culture of many types of health care professionals; many medication errors are made, and the causes are often obscure. Taxis and Barber (2003) suggest that causes may include a lack of perceived risk, lack of good role models, and lack of available technology. Underlying problems were identified as related to the cultural context allowing unsafe drug use, the failure to teach practical aspects of drug handling, and design failures. Taxis and Barber concluded in their study of IV drug errors that a coordinated approach from practitioners, regulators, and the pharmaceutical industry must address training needs and design issues to reduce the rate of IV drug preparation and administration errors. The steps in the infusion-preparation process were evaluated by Parshuram et al. (2008) to identify factors associated with preventable medication errors. They studied 118 health care professionals who regularly prepared IV infusions (RNs, anesthesia professionals, pharmacy personnel). The participants prepared several infusions after receiving instructions for proper infusion preparation. The infusions were then chemically analyzed to determine medication concentration. Errors were found in 4.9% of drug-volume calculations; of 464 infusion preparations, 34.7% contained concentration errors. Factors most likely associated with the errors included fewer infusions prepared in previous week, increased years of professional experience, and preparation of smaller volumes; larger magnitude errors were associated with fewer hours of sleep in the previous 24 hours.

Another study by Moyen et al. (2008) “reviewed medication errors in ICU and identified risk factors for medication errors and suggested strategies to prevent errors and manage their
consequences” (p. 1). They stated that “medication errors account for 78% of serious medical errors in the ICU (Rothschild et al., 2005, p. 1 as cited in Moyen et al., 2008).

The risk factors for medication errors described by Moyen et al. (2008) are patient factors, medications, and the ICU environment. Patients are at risk because they are severely ill and receiving more medications, have longer hospital stays, are older, and often are sedated. Medication risk factors include the types of medications, actual number of medications, number of medications that are injected or infused, number that are based on the patient’s weight, those that require calculations and careful monitoring, and use of sophisticated pumps that require programming. The environmental risk factors are related to the complexity of the situation, the many different care providers, and difficult working conditions, to name a few. Moyen et al. (2008) suggest optimization of the medication process, elimination of situational factors, and oversight, and error interception for preventing errors (see Table 2 for more detail).

Table 2

*Simple Strategies to Prevent Medication Errors*

<table>
<thead>
<tr>
<th>Optimize the medication process</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Medication standardization</td>
</tr>
<tr>
<td>2. Computerized physician order entry and clinical decision support</td>
</tr>
<tr>
<td>3. Barcode technology</td>
</tr>
<tr>
<td>4. Computerized intravenous infusion devices</td>
</tr>
<tr>
<td>5. Medication reconciliation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Eliminate situational risk factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Avoid excessive consecutive and cumulative working hours</td>
</tr>
<tr>
<td>2. Minimize interruptions and distractions</td>
</tr>
<tr>
<td>3. Trainee supervision and graduated responsibility</td>
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<table>
<thead>
<tr>
<th>Oversight and error interception</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Intensivist participation in ICU care</td>
</tr>
<tr>
<td>2. Adequate staffing</td>
</tr>
<tr>
<td>3. Pharmacist participation in ICU care</td>
</tr>
<tr>
<td>4. Incorporation of quality assurance into academic education</td>
</tr>
</tbody>
</table>

(Moyen et al.)
Also suggested is an environment that incorporates an error-reporting systems to capture near misses and analyze them as constructive data and also to capture process issues that include active failures and latent conditions. The common environment does not encourage active reporting of errors or near misses. Many health care providers are fearful of punishment and adverse consequences from administration, peers, and colleagues. There are many barriers to reporting errors and near misses such as lack of knowledge of routines and rules, being too busy to report errors, and simple neglect to report, as well as nurse’s attitudes, personality, and compliance (Ulanimo, O’Leary-Kelley, & Connolly, 2007). National and state legislative, licensing, and accrediting agencies are concerned with the number of medical errors and have instituted several safety initiatives in an attempt to help health care facilities improve medical error rates and the work environment.

Nurses administer medications in health care settings throughout the world and encounter similar medication calculation issues. Jones (2009) examined medication errors in England and Wales. In her literature review she found that the main causes of medication administration errors of nurses were person-centered factors, lack of calculation competency, not following the protocols appropriately, and system factors such as distractions and time pressures. She also noted that nurses lack confidence in their math skills, especially those of infusion calculations.

Nurses make many of the medication errors, in part because they administer most of the medications. Findings from a study of the origin of errors indicated that 38% of preventable medication errors occurred at the administration step (Bates et al., 1995, as cited in Shane, 2009). Wrong drug and wrong dose are medication errors at the administration stage. Kuitunen et al., (2008) analyzed medication errors made by health care professionals in a Finnish poison control center that receives calls from the hospital when medication errors occur. They found that in
pediatrics, the most common error was wrong dose (23.8% of the errors), and in adults the most common error was wrong drug (60.9% of the errors). Six newborns were given a 10-fold overdose. A 10-fold error could be a calculation error, an error of the vial of two different concentrations looking alike, with the nurse picking up the wrong vial; or the nurse not carefully checking and picking the vial in that location by habit. Whatever the cause, it does not change severity of the error to the patient.

According to Hughes and Edgerton (2005), children are at a higher risk for harmful medication errors than are adults. Dosing errors are the most common type of drug errors in pediatrics because many of their medications are weight based. In patients who are small, such as premature babies, dosing errors are more harmful, and many times have devastating consequences. Calculations using dilution for liquid medications for oral administration, IV, and injections are more difficult than calculating the number of pills. The most common calculations use fractions, decimals, percentages, and ratios (Hughes & Edgerton, 2005).

The Food and Drug Administration reviewed 273 medication reports and classified each report into categories: communication, name confusion, labeling, human factors (knowledge deficit, performance deficit, miscalculation of dosage or infusion rate, drug preparation error, transcription error, stress), and packaging/design (Thomas et al., 2001). They found that the majority of errors (42%), were human factors.

Researchers in Germany and the United Kingdom worked together and studied the incidence and causes of intravenous medication errors in hospitals in two countries and three pharmacy services (Taxis & Barber, 2003; 2004; Wirtz et al., 2003). They observed nurses preparing and giving IV medications and found a high incidence of intravenous drug errors at all the hospitals, suggesting that changes in practice are needed urgently. Preparation error rates
were between 22% and 31% of total preparations, and administration error rates were between 22% and 49% of total administrations, with the majority of errors likely to have moderate to severe outcomes (Wirtz et al., 2003, p. 104). Many of the errors occurred when the caregiver gave the medication too fast, or the drug required multiple steps to prepare. Taxis and Barber (2003) found an error rate of 14% in doses that required multiple steps to prepare and administer, and they suggest that nurses may be unaware that they have committed an error. Some of the causes they suggest are lack of perceived risk, poor role models, and available technology (did not know how to use the technology available or simply did not use resources available) (Taxis & Barber, 2003, p. 343). They suggest fewer unit-based IV drug preparations, improved staff training, and satellite pharmacies in addition to bar coding systems, CPOE, and unit dose systems.

Results from Parshuram et al. (2008) indicated that in the preparation of IV infusions 34.7% had concentration errors. The authors evaluated steps in the preparation of infusions in order to identify factors related to preventable medication errors. The 118 health care professionals, pharmacists, registered nurses, pharmacists, and pharmacy technicians (largest number being registered nurses), performed 1,180 drug-volume calculations, 1,767 syringe-volume measurements, and prepared 464 morphine infusions. The researchers detected an average of 4.9% errors in drug-volume calculations, 1.6% errors in volume measurements, and 1.6% errors in drug mixing. In the morphine infusions the researchers found an average of 34.7% errors in contained concentrations. Larger magnitude errors were associated with fewer hours of sleep in the previous 24 hours ($p = 0.02$), the use of more concentrated solutions ($p < 0.001$), and preparation of smaller infusion doses ($p < 0.001$) (Parshuram et al., 2008, p. 42). Professionals with more than 10 years experience made more rounding errors ($p = 0.0003$), and other
professional demographics had no significant relationship to any other errors. They suggested reducing worker fatigue, manufacturer premixed preparations, and pediatric premixed preparations.

The role of nurses in medication administration errors was investigated by McBride-Henry and Foureur (2006). They argue that the common practice is to identify the nurse as the deliverer of unsafe practice because the nurse gives most of the medications and one in five medication doses are administration errors. They proposed looking at more system-related issues that may contribute to medication errors. System issues may include patient acuity; available nursing staff; resources (reference materials); organizational culture, including communication, routines and reporting of events; and pharmaceutical issues etc (McBride-Henry & Foureur, 2006, p. 35-36). Professional issues involve understanding of how errors occur, failure to adhere to policies and procedures, number of hours on shift, distractions, lack of knowledge of medications, dosage calculations, and workload (McBride-Henry & Foureur, 2006, p. 37).

Historically the majority of incidents have not been reported due to fear of the consequences and the cumbersome nature of the reporting system (McBride-Henry & Foureur, 2006; Milch et al., 2006; Sheu et al., 2008; Ulanimo et al., 2007). McBride-Henry and Foureur (2006) conclude that the nursing profession needs to be proactive in changing the system, “throw off the culture of ‘blame and shame’ and … actively drive change within both the clinical and research setting” (p. 39).

Morgan et al. (2006) studied the opportunity to improve the practice of medication administration during a simulated pediatric stabilization event. Thirty emergency nurses (52% BSN-RN, and 48% ADN-RN, diploma, and LVN) were evaluated (including time to convert doses and draw up medications) at five steps in the medication administration process. Of the
150 medication orders 120 were converted from milligrams to milliliters, and of these, 14.2% were converted incorrectly, with the maximum dose deviating 400%. Dextrose was not diluted, as required for children in 17% of the orders, and in 12% it was diluted improperly. An antibiotic which required reconstitution was not properly reconstituted approximately 40% of the time. Morgan et al. also noted that the nurses took a “prolonged” time to convert the doses and draw up the medications. The conclusion was that nurses need “improved education, training, and use of clinical aids or adjuncts for pediatric emergency nurses” (p. 179) and that the process of medication administration should be simplified. If nurses make this many errors in a simulation, they are probably making many more in the practice environment. It becomes imperative to improve the delivery of nursing care to patients in the health care system.

Many factors may be related to medication errors and error reporting. In a study in Arizona (Patanwala, Warholak, Sanders & Erstad, 2010), emergency department nurses were observed by pharmacists for twenty-eight 12-hour shifts regarding the medication process. “There were 178 medication errors in 192 patients... At least one error occurred in 59.4% of the patients... and medication administration accounted for 34.8% of the errors” (p. 522). Variables such as boarded patient status, number of medication ordered and administered, and nurses’ employment status (full-time vs. part-time) were correlated with error rate.

Sheu et al. (2008) investigated possible error-related circumstances and to identified high-alert situations. Eighty-five nurses reported 328 administration errors, 69 of them near misses, and found that most errors were on the medical surgical units of teaching hospitals, during the day, and were committed by nurses with less than 2 years experience. More than 60% of the errors were wrong dose and wrong drug. The majority of errors were discovered by double checking with another person. High-alert situations were related to potassium, insulin, and
pitocin infusions; use of intravenous pumps; and implementation of cardiopulmonary resuscitation (CPR). They suggested double checking all high-risk medications and medications given in high-alert situations. Understanding the use and programming of infusion devices and double checking carefully are not stressed enough in the practice environment.

The percentage of errors due to calculation errors alone is not known because, if an error is wrong dose, was it an actual error in computation or an error in selecting the correct medication strength from the supply? Errors can be due to wrong amount measured into syringe, diluted wrong or wrong strength, and vial or capsule among others. Depending on the definition a 10-fold error may not be a calculation error but a prescribing or transcription error (Wright, 2010). Many studies use an observational approach, and this method cannot determine what was going on in the thinking of the caregiver, just that the action or behavior was in error. Wright (2010) suggests that research be done with a clear definition of calculation error and “the number of errors caused by miscalculation and ascertain possible causal factors” (p. 96).

Table 3

<table>
<thead>
<tr>
<th>Causes</th>
<th>% of nurses</th>
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<tbody>
<tr>
<td>Nurse fails to check name band with MAR</td>
<td>45.8</td>
</tr>
<tr>
<td>Nurse is tired and exhausted</td>
<td>33.3</td>
</tr>
<tr>
<td>Physician prescribes wrong dose</td>
<td>30.4</td>
</tr>
<tr>
<td>Nurse miscalculates dose</td>
<td>30.4</td>
</tr>
<tr>
<td>Confusion between 2 drugs with similar names</td>
<td>29.2</td>
</tr>
<tr>
<td>Physician’s writing is illegible</td>
<td>28.0</td>
</tr>
<tr>
<td>Nurse distracted by patients, coworkers, and events in the unit</td>
<td>25.0</td>
</tr>
<tr>
<td>Nurse confused by different types and functions of infusion device</td>
<td>25.0</td>
</tr>
<tr>
<td>Medication labels/packaging poor quality/damaged</td>
<td>25.0</td>
</tr>
<tr>
<td>Nurse sets up/adjusts infusion device incorrectly</td>
<td>24.0</td>
</tr>
</tbody>
</table>

(Ulanimo et al.)
Ulanimo et al. (2007) investigated nurses’ perceptions of causes of medication errors and found 10 frequent causes of medication errors (see Table 3): first, not following routine procedure; second, fatigue; and fourth, dose miscalculation by nurse. Studies may not be able to measure calculation errors directly, but nurses perceive that calculation errors are a common cause of medication errors.

Some tasks are prone to error, for example, a task with which the person is unfamiliar and is trying to accomplish under pressure, such as setting up an infusion device or drawing up pediatric medication in an emergency, or doing a multistep mathematics problem related to a critical infusion while everyone is waiting. Medication administration requiring a calculation of a dosage or dilution is especially susceptible to error (McDowell et al., 2009). Medication errors are more common in pediatrics and intensive care and often involve multistep calculations and require the use of infusion devices. Gladstone (1995) reviewed 79 incident reports and found that more than 50% of the medication errors were dose related, and the majority of those were incorrect infusion rates (17.7%). Improving mathematic skills may be one way to decrease calculation issues.

Calculations involved in most medication calculations are estimated to be at a seventh-grade mathematics level or below (Polifroni et al., 2003; Rainboth & DeMasi, 2006). Most calculations involve simple arithmetic, multiplication, division, fractions, decimals, percentages, and conversions to the metric system. The most difficult mathematics required in medication calculation involves multiple steps such as when calculating weight-based doses and IV infusion rates. Some IV infusions have to be given based on a dose of micrograms per kilogram per minute, and the infusion pump is set in milliliters per hour. The calculation of weight-based doses and/or infusion rates would be most difficult for the nurse who cannot do the simpler dose
calculations with accuracy. Many errors may simply be because nurses have limited skills in doing simple medication calculations, and fixing these skills may improve the system and create safer nurses (Polifroni et al., 2005).

**Nurses’ Mathematics Ability**

Many medication errors are related to dose errors and it is documented that nurses are not good at mathematics (Calliari, 1995; Gladstone, 1995; Grandell-Niemi et al., 2001; Jukes & Gilchrist, 2006; Lee, 2001; Wright, 2006). Jones (2009) stated, “Nurses poor mathematical competency has been identified as a key cause of medication administration errors” (p. 41).

McMullan et al. (2010) found no statistical significant difference between the medication calculation ability of registered nurses (RNs) and nursing students; the failure rate was 45% and 55%, respectively, on a mathematics test. They also administered a 20-item medication calculation test to the same sample of RNs and nursing students, comparing age, status, and years qualified with calculation ability; no significant relationships were found between the variables except that the participants who were older than 35 did significantly better (p = 0.028). The authors speculated that perhaps anxiety about performing mathematics influences performance.

Bayne and Bindler (1991) developed a 20-item instrument in 1984 to measure dosage calculation skills of nurses and nursing students, and it has been used in several research projects. In 1991, Bayne and Bindler studied 110 nurses to determined that there was a significant relationship between the nurses’ comfort level and medication calculation ability (F 13.0518, p = 0.000), and the comfort level showed significant differences between the categories of comfort and calculation ability (comfort level above average and below average, p = 0.0001; above average and average, p = 0.0060; average, and below average, p = 0.0029). Nurses could predict skill level as above average, average and below average with “great” accuracy (F =
18.1194, p = 0.000). There was not a significant difference between (age and years in practice) and scores. In an experimental study by Bayne and Bindler (1997), three types of instruction were compared with a control group; the three types of instruction were classroom, self-study, and computer aided instruction (CAI). Scores improved most for the classroom group, next for the control group, with no change in the self-study group. The CAI group was least satisfying, and there were no significant differences. Scores on the pretest ranged from 25% to 100%, with a mean of 75.7%, and scores on the posttest ranged from 30% to 100%, with a mean of 80%. They also found a strong positive correlation (p < 0.001) between the nurses’ self-assessment of comfort and skill level with medication calculation pretest and posttest scores. Questions requiring the most steps in the process of calculation were found by the participants to be the most difficult to answer.

Ashby (1997) studied 62 practicing medical-surgical nurses to determine if there are more errors with IV medication calculations when conversion formulas are not provided, when more than one calculation is required, or when fractions or decimals are used. Differences were investigated between years functioning as a medical-surgical nurse, type of RN degree, experience with IV medications, skill perception, and self-reports on whether medication calculation and administration are stressful tasks. On the Bayne-Bindler Medication Calculation test (1988), the scores ranged from 45% to 100%. Years of experience, educational preparation, and IV experience showed no statistical significant differences. Fewer than 20% of the nurses rated their skill as above average, but 43.5% scored 90% or higher, and almost 60% of the nurses reported that the medication calculation and administration was a stress-producing task (Ashby, 1997). She concluded that because 56.4% of the nurses in the sample could not pass a
calculation test at 90%, there is an urgent, continued need to evaluate the medication calculation ability of practicing nurses and also to research ways to enhance remediation processes.

Harne-Britner et al. (2006) examined IV calculations of 22 RNs and 31 senior nursing students, finding that 54.8% of nurses and 41.6% of students could not calculate IV medications or IV flow rates with 90% accuracy. The nurses’ pretest scores correlated positively with the frequency of medication calculations in practice ($p = 0.017$). There were no statistically significantly differences between the students and nurses on pre- and posttest scores. It was noted that the students had significant positive correlations ($p = 0.024$, IV med doses; $p = 0.011$, IV flow rates) between self-rating of comfort level and IV medication doses and IV flow rates on pre- and posttests. The authors discussed the need for skill practice; because students and nurses continue to have weaknesses in calculations, nurse educators have an opportunity to find some new and creative ways to develop, improve, and maintain skills.

In order to improve nurses’ poor mathematic performance three areas of the problem need to be addressed: relationships, practice, and expectations (Polifroni et al., 2005). Relationships between acute care staff development educators and nursing student educators need to be enhanced to improve the connection of what is being done to master good medication calculation skills and share information about teaching and learning methods that produce better results. The practice environment must emphasize the importance of accurate calculations, promote regular practicing of mathematical skills, and have clear expectations that excellence in practice is to be the standard (Polifroni et al., 2005).

Attitudes, beliefs, and work ethics also influence performance in the practice area. Mathematics self-efficacy, mathematics anxiety, and beliefs about mathematics have been correlated with mathematic ability (Hackett & Betz, 1989; Walsh, 2006). Andrew et al. (2009)
examined the properties of a newly-developed Nursing Self-Efficacy for Mathematics (NSE-Math) test, administering it to second-year baccalaureate nursing students and found the NSE-Math test to have a Cronbach alpha of 0.88 for the full instrument. The researchers also found that the NSE-Math had predictive validity with the medication calculation test that was also administered to the students ($p= 0.009$). The 12-item instrument is discussed in Chapter 3. Two factors identified within the NSE-Math instrument were “confidence in application of mathematic concepts to nursing practice” and “confidence in arithmetic concepts” with the Cronbach alphas of 0.90 and 0.87 for each factor, respectively (Andrew et al., 2009, p. 221). Students in the sample were least confident in multiplication and were not confident in using fractions or ratios. Multiplication, ratios, and fractions are the mathematics used in most medication calculations.

Wilson (2003) concluded that written mathematics tests are not the best way to improve nurses math skills and that a more practical approach should be utilized. Wilson studied 55 nurses who took two IV drug calculation tests. One was the traditional pencil and paper test, and the other was a test using a simulated clinical environment. The results were significantly better when the practical test was given first. A practical simulated environment may be a good way to augment remediation or testing of medication calculations.

Findings from several investigations have indicated that medication calculation skills could be improved by periodical calculation programs, compulsory remediation programs, simulations, and collaboration between educators at nursing schools and health care facilities (Ashby, 1997; Bayne & Bindler, 1997; Grandell-Niemi et al., 2001; Polifroni et al., 2005; Rainboth & DeMasi, 2006; Wilson, 2003). Although there is agreement that there should be an annual medication calculation competency to ensure ongoing skill, health care institutions rarely
gave a medication calculation test after initial hiring of an employee (Bayne & Bindler, 1997; Polifroni et al., 2005). “No service setting surveyed responded that these skills [mathematical calculations] are routinely assessed as part of an annual competency process” (Polifroni et al., 2005, p. 81).

Research findings have not found significant differences in the calculation abilities of nurses versus nursing students. Several studies use the term nurse and define it as RN and may delineate the college-degree type in the demographics, but it is not clear of the type of nurse that is used in most studies. American hospitals hire licensed vocational (Practical) nurses (LVNs) and registered nurses (RNs), and the studies may include both types of nurses. The education and licensure of the two types of nurses is different and are detailed in the next section.

Nurses’ Education, Licensure, and Medication Calculation Expectations

Nurse educators at most hospitals give a medication administration or calculation test, pen and pencil, to new nursing employees during their original orientation and do not check calculation competence further. The test is usually simple, and the employee is remediated right after the test with discussion; a repeat test is not always given. If a test is given for the critical care areas it is combined with pharmacology; mathematics is not the focus. Most hospitals do not have periodic tests for medication dosage calculations, and some hospitals never give a medication calculation test. There may be counseling when an error is identified, but there is no formal plan to improve mathematic abilities. The ability to pass a medication calculation test during RN orientation and the likelihood of future medication errors was studied by Calliari (1995), who found a significant direct correlation ($p = 0.028$) between initial test failure and future increased rate of medication errors. She also found that the more educated the RNs the less likely they were to make an error ($p < 0.05$) (Calliari, 1995).
There is apparently no clear standard concerning what constitutes mathematical competency. Several issues related to mathematical competency are validation procedures, actual test used, scoring criteria, outcomes when passing is not achieved, and remediation procedures. Polifroni et al. (2003) indicate that acute care agencies required specific passing scores ranging from 70% to 100% and most required a score of 80% and above. All acute care institutions reported validation of medication calculation skills prior to medication administration using an institution-designed test with no attention to grade level of mathematics and test-taking skills. The institutions provided remediation with some practice problems before repeating the same test; however, they did not report additional testing after initial passing of the examination.

Hospital educators are concerned with new graduates’ abilities regarding medication administration; however, most are not clear in expectations and do not address the ongoing mathematical skills in regards to medication calculations (Calliari, 1995; Polifroni et al., 2003). It has been recommended that nurses who calculate infusions have their competency periodically checked as often as annually (McMullan et al., 2010; Pietsch, 2005; Polifroni et al., 2005).

Harne-Britner et al. (2006) found that nurses and nursing students had limited medication calculation skills and showed significant improvement of scores on a 20-item medication calculation test with various interventions. The interventions were a 30-minute classroom tutorial session, a self-study using a published workbook, a self-study using their own reference, and no intervention. The average pretest score for the senior baccalaureate nursing students was 15.9, and the posttest average was 17.4; the average pretest score for practicing nurses was 15.5, and the posttest average was 18.6. No statistically significant differences were noted; however, both groups significantly improved test scores ($p < 0.01$). The RNs posttest scores improved regardless of the type of educational strategy used although none were statistically significant. There was a
significant correlation with the nursing students’ comfort level and calculating IV medication doses (pretest $p = 0.008$; posttest $p = 0.024$) and IV flow rate (pretest $p = 0.004$; posttest $p = 0.011$) with test scores. There was also a correlation of the pretest scores of practicing nurses with the frequency of performing medication calculations ($p = 0.017$). There were no significant differences among the four interventions. Simply bringing their calculation skills and the possibility of making errors to their attention may have influenced their improvement.

Calculation skills required by nurses vary according to the clinical areas in which they are working (Wright, 2009). Depending on the clinical area, nurses have the opportunity to use certain medication calculation skills more often than others. For instance, a nurse working on a general medical floor may not use pediatric calculations or complex intravenous drips. The pediatric, neonatal, or nursery nurse may use small doses and not be familiar with adult drugs and doses. The nurse working in an adult intensive care unit may not know pediatrics, but may be able to calculate the complex intravenous drips.

Skill assessment and ongoing competency evaluation need to be tailored to the safety needs of the patient. Medication calculation errors can be decreased by ongoing practice, by evaluation of basic dosage calculations, and by ameliorating other factors. Many hospitals currently do not routinely evaluate calculation skills or medication calculation competency. Since many nursing programs give a calculation test every semester or before all clinical courses, it is assumed that the graduate nurse comes with calculation skills. As discussed in a previous section, this is not the case. Hospital educators and nursing education programs must collaborate on methods to systematically evaluate medication calculations skills. Further research is needed to identify performance factors and implement teaching/learning/training systems to promote
best practice and improve patient safety regarding medication calculations. According to Hadley (2006),

> Mathematical anxiety and an accompanying lack of mathematical competence are often a factor in major life decisions of individuals. Mathematically anxious people steer their lives and careers away from mathematical applications, hampering their career development and future potential. (p. 1)

It may be thought that mathematics skills are not important when making career choices such as nursing. But medication calculations use simple mathematics and a basic skill in seventh-grade arithmetic is essential to bedside acute care nursing performance. The following sections will describe performance factors that may be involved in nurses’ poor mathematics performance including mathematics anxiety and mathematics self-efficacy.

Acute Care Nurses’ Medication Calculation Training and Competency

Nurse educators at most hospitals give a medication administration or calculation test, pen and pencil, to new nursing employees during their original orientation and do not check calculation competence further. The test is usually simple, and the employee is remediated right after the test with discussion; a repeat test were not always given. If a test is given for the critical care areas it is combined with pharmacology, and mathematics is not the focus. Most hospitals do not have periodic tests for medication dosage calculations. Some hospitals never give a medication calculation test. There may be counseling when an error is identified but no formal plan to improve mathematic abilities.

The ability to pass a medication calculation test during RN orientation and the likelihood of future medication errors was studied by Calliari (1995), who found a significant direct correlation between initial test failure and future increased rate of medication errors. (Polifroni et al., 2003, p. 455)

> “The literature does not offer any clear standard related to what constitutes mathematical competency” (Pape, 2001, as cited in Polifroni et al., 2003, p. 456). Several of the issues related
to validation of mathematical competency are validation procedures, actual test used, scoring criteria, outcomes if passing not achieved, and remediation procedures (Polifroni et al., 2003, p. 456). Acute care institutions had specific passing rates ranging from 70% to 100%; most required 80% and above. According to Polifroni et al. (2003), all acute care institutions reported validation of medication calculation skills prior to medication administration using an institution designed test with no attention to grade level of mathematics and test-taking skills. The acute care institutions provided remediation with some practice problems before repeating the same test and did not report testing after initial passing of the examination. Pietsch (2005) discussed the need for continued competency measurements of medication calculation ability in nurses and nursing students. She states that since the mathematical competency is also linked to health care institutions many hospitals have started testing mathematical competency annually. There is concern about nursing teacher’s practice of allowing the student to take the medication calculation test three times. Nurses do not get three tries to give medication correctly. Pietsch concludes with the question of how the medication calculation administration tests impact medication errors.

Hospital educators are concerned with the new graduates’ ability regarding medication administration (Polifroni et al., 2003). However, most are not clear in expectations and do not address the ongoing mathematical skills in regards to medication calculations (Polifroni et al., 2003, p. 81). It has been recommended to test nurses who use these types of infusions and have their competency periodically checked as often as annually (McMullan et al., 2010; Pietsch, 2005; Polifroni et al., 2005). Harne-Britner et al. (2006) found that nurses and nursing students had limited medication calculation skills and showed significant improvement of scores on a 20-item medication calculation test with the various interventions. The interventions included a 30-
minute classroom tutorial session; a self-study using a published workbook; a self-study using their own reference; no intervention (Harne-Britner et al., 2006, p. 192). The average pretest score for the senior baccalaureate nursing students was 15.9 and posttest 17.4, and the average pretest score for practicing nurses was 15.5 and posttest 18.6. The researchers found “a significant correlation with the nursing students’ comfort level and calculating IV medication doses and IV flow rate with test scores” (p. 192), and a correlation of the pretest scores of practicing nurses with the frequency of performing medication calculations (p. 193). The researchers found no significant difference among the four interventions. They concluded that simply bringing their calculation skills and the possibility of making errors to their attention may have influenced their improvement. However, it was of concern that few subjects made 100% on the tests, and it was wondered how that would correlate with an error rate.

Mathematic and Medication Calculation Performance Factors

Many factors influence medication calculation performance. The acute care environment has many activities occurring simultaneously while a nurse is required to prepare and administer medications. Medication error risk factors may include work shifts, workloads, inadequate staffing, medication distribution systems, distractions and interruptions, poor mathematical skills of nurses, lack of knowledge of medications, not double-checking doses, and poorly written orders (Balas, Scott & Rogers, 2004; Jones, 2009; Kuitunen et al., 2008; Parshuram et al., 2008; Tang et al., 2007). Lack of knowledge may include not knowing how to use resources such as setting up the infusion device; using the automated dosage system; using the reference materials and lack of basic knowledge in anatomy, physiology, pharmacology, and mathematics. Staffing issues and workload issues include such factors as fatigue, stress, skill levels of nurses and other staff, and poorly trained or oriented staff. Currently the CPOE initiative is directed at decreasing
the poorly written order issue, while automated dosage systems and satellite pharmacy systems are initiatives to decrease the medication distribution issues.

One’s problem-solving ability can be influenced by the environment as well as one’s own innate ability. Grandell-Niemi et al. (2001) found a statistically significant correlation between results on a medication calculation test and confidence in the nurse’s mathematics skills ($r_S .427$ and $p < 0.01$). They also found that the nurses who did calculations more often and attended updates had more confidence and performed better on the medication calculation test. As discussed in previous sections nurse are not proficient at medication calculations. The problem may be inadequate basic mathematic skills. Roykenes and Larsen (2010) studied 116 baccalaureate nursing students and determined that there was a relationship between previous mathematic likes/dislikes and self-assessment of mathematic ability. An additional finding indicated that the student’s requirement of earning 100% on the test was anxiety producing, and the anxiety was higher for students who had done poorly in mathematics prior to college. The limited mathematical skills may be related to poor role models, inadequate critical thinking skills, or inadequate practice. McMullan et al. (2010) investigated the drug calculation ability of nurses and found that most of their sample worked in primary care did not perform IV calculations often and seemed to get “rusty”; they concluded that nurses need to practice calculations and double-check answers. In order to prevent loss of skills they suggest that regular practice and assessment be performed to reinforce learning and mastery.

Past experiences in school and encouragement from others may increase or limit the use of long-term memory for solving current problems. A person’s previous mathematics learning may also influence medication calculation performance. Memory allows nurses to use their
learned calculation ability for solving the current problem, and their belief about mathematics or calculations can influence a person’s problem-solving ability (Wright, 2009).

Human factors include those things that happen just because people are fallible, make choices, and have physical limitations. Human factors such as experience level, attention level, haste, distraction, fatigue, lack of skills, lack of knowledge, or depression may increase error rates. Pediatrics, intensive care settings, and high-stress situations may also be more error prone due to the more complex procedures, calculations (based on patient weight), and higher stakes involved in a more critical environment.

One’s education level, age, experience, emotional state, and stress level all contribute to one’s personal performance level. Personal issues can impact overall performance, attitude, and capability. A person who is fatigued may not be thinking clearly or may have blunted responses. “After 17 hours of sustained wakefulness cognitive psychomotor performance decreases to a level equivalent to the performance impairment observed at a blood alcohol concentration of 0.05%” (Dawson, & Reid, 1997, p. 235). Working with too little sleep or for more than 40 hours a week are attributed to poorer productivity. Working long hours, feeling one is efficient even when fatigued, and not taking enough time between shifts are all documented contributors to unsafe work conditions (“Needlesticks,” 2008; Rogers, Hwang, Scott, Aiken, & Dinges, 2004; Trinkoff, Geiger-Brown, Brady, Lipscomb, & Muntaner, 2006).

Rogers et al. (2004) found that the likelihood of a nurse making an error after working 12.5 hours or more was tripled and working overtime increases the odds of an error. Number of hours worked per week, overtime, and length of work shifts were related to an increase in errors. The Institute of Medicine (IOM) recommends that “nurses work no more than 12 hours in a 24-
hour period and no more than 60 hours in a seven-day period, in order to reduce error-producing fatigue” (IOM, as cited in Trinkoff et al., 2006).

The working environment can elicit emotions that may impede or enhance successful skill performance. Emotions and stressors are different from an attitude in that an attitude is a preconceived mind-set about the situation that can influence the emotional state and add to the stressors. Emotions are the feelings and sensations a person experiences in certain situations and circumstances. Stressors are underlying phenomena that may lead to physical, emotional, and psychological symptoms. Symptoms can be negative or positive, depending on type and presentation. For instance, anxiety can increase the person’s awareness of the importance of the situation, or anxiety can paralyze the person and keep him or her from doing anything. Other emotions may be anger, frustration, joy, happiness, boredom, hope, pride, or shame. These emotions may all be involved in critical situations (Pekrun et al., 2009).

Symptoms of heightened awareness and a sense of urgency may be helpful in a critical situation, whereas symptoms of panic, confusion, and nervous tension may be “unhealthy or harmful,” that is, may make a person forget prior knowledge or make a mistake in the same critical situation. Students, nurses, and teachers who are anxious about math may experience high levels of stress any time they encounter a math situation, which can lead to poor performance.

Choking under pressure may be another form of stress in critical situations. Distraction theories suggest that the working memory can become filled to capacity when one is under pressure because the added thoughts of the crisis or critical situation compete for attention. The person’s attention would normally be focused entirely on the task, and the working memory would not be distracted but would bring to mind the elements necessary to successfully perform
the task or find a solution to the problem. Beilock, Kulp, Holt, and Carr (2004) have suggested that repeated practice of certain elements of a skill or problem-solving exercise, such as solving math problems, diminishes the distraction when other elements cause the stress level to rise. They propose that the repeated practice will be more useful in math problem-solving ability under stress than the explicit monitoring theory of learning steps for skill performance and focusing on performing the skills automatically.

Latent factors are related to the elements that are not usually an issue, but if the right circumstances occur, can contribute to a problem. A latent factor leading to an error is something that is “waiting to happen” because there are system issues that may be potentially unsafe if all the variations line up and become a problem (McDowell et al., 2009). Inadequate use of technology, work-arounds, and unfamiliarity with equipment can be potential sources of a problem in certain situations.

Human factors influence how people function in the patient care environment. In order to ensure good safety measures, health care systems need to be acutely aware of the human element in the initiation of new programs. By investigating the underlying system, as well as human and latent factors, the health care provider can improve performance and improve safety. Underlying human factors related to stress, fatigue, the work environment, mathematics anxiety, confidence and mathematics self-efficacy, and many other factors are related to medication calculation ability.

Mathematics Self-Efficacy and Mathematics Anxiety

Both fear and anxiety regarding mathematics are real to many people. Mathematics self-efficacy or a person’s confidence in the performance of mathematics may be related to prior experiences, innate beliefs, successes, and/or failures. Mathematics self-efficacy is a self-referent
process that individuals use to judge their ability to self-regulate and succeed in an activity (Stevens et al., 2004).

Bandura (1997) has postulated that “self-efficacy develops from prior mastery experiences, vicarious learning, verbal persuasion, and evaluations of emotional states” (as cited in Stevens et al., 2004, p. 209). Self-efficacy develops after personal experiences or by learning from the experiences of others (vicarious learning), what a person is taught or convinced of, and how the experiences affected the person emotionally. A person can have self-efficacy at different levels for different activities. People with high self-efficacy for a task believe in their own capabilities more positively than those people with a low level of self-efficacy (Nielsen & Moore, 2003). Warwick (2008) noted that a feedback loop for self-efficacy leads to engagement in learning, engagement leads to outcomes, and positive outcomes lead to engagement in learning. The feedback loop, however, can be positive or negative. Therefore, a negative self-efficacy may lead to less engagement and poorer outcomes (Warwick, 2008).

Stevens et al. (2004) studied 358 ninth- and 10th-grade students and found that self-efficacy could predict motivation orientation and mathematics achievement with Hispanic and Caucasian students (Hispanic students had a slightly better predictability). It was suggested that self-efficacy influences mathematics achievement: (a) Ability and prior experience influence self-efficacy, (b) Mathematics self-efficacy influences motivational orientations, (c) Mathematics self-efficacy, motivational orientation, and mathematics performance influence the student to take other courses in mathematics.

Measurements of self-efficacy should be specific to the task and measured simultaneously with the task. Bandura (1986) cautioned that “a self-efficacy instrument must assess the specific skills needed for performing an activity and must be administered during the
time that the performance is being assessed” (as cited in Lee, 2001, para. 4). Self-efficacy measurements must be specific to the performance they are measuring; the available tools are not specific enough to measure specific performance outcomes (Kranzler & Pajares, 1997) such as nursing medication calculations. The tools can measure only general, common mathematics tasks that may be similar. “A generalized measure is unlikely to be of much value as a more specific assessment that is directly related to the outcome one wishes to predict” (Kranzler & Pajares, p. 217). Nielson and Moore (2003) suggest that since self-efficacy assessment needs to be specific, it should be domain specific rather than task specific. They use the example that high self-efficacy for algebra may not lead to high-self efficacy for geometry. They postulate that “it is important to establish what level of specificity prevails to inform practical treatments (e.g., teaching, counseling) as well as future research applications” (p. 129). Finally, the level of specificity needs to relate closely to the critical tasks against which the performance is measured.

Nielson and Moore (2003) established the psychometric data for their specific mathematics self-efficacy scale used to study 302 high school students. They made the content of the self-efficacy scale specific to the content of the student’s math core curriculum material. Construct validity was established with a previously tested subscale designed to assess mathematics self-concept. Their findings indicated that the differences in scores and self-efficacy were related to the low self-efficacy scores more than high self-efficacy scores. The usefulness of the self-efficacy measurement may be helpful in planning intervention strategies for persons with low self-efficacy and low mathematics performance.

Mathematics self-efficacy was studied in college freshmen who had to take a remedial math class compared with students in regular college algebra and calculus (Hall & Ponton, 2005). The plan was to see whether there was a relationship between the students enrolled in
developmental courses and cognitive factors such as self-efficacy. Because confidence in math
skills, self-efficacy, math anxiety, goals, performance, and actual mathematics attainment may be
related, Hall and Ponton (2005) investigated factors that may help in planning effective teaching
strategies to help the remedial students do well in the class and improve performance. There was
no relationship between gender and self-efficacy; however, there was a relationship between
math self-efficacy and the class in which the student was enrolled. They suggested that teachers
of developmental mathematics may hold the key to developing self-confidence and promoting
college success, and those students need to have small successes to design mastery experiences
for them to develop a positive self-efficacy.

Studying mathematics and working on mathematics problems may be a positive or a
negative experience. Bandura stated, “‘A person’s belief or confidence in their ability to be
successful for any given behavior or task has a direct influence on their performance, persistence,
and behavioral choices’” (as cited in Maag, 2006, p. 112). If the experience was positive and the
outcome was encouraging, future attitudes are more positive. For instance, if students are
assisted in learning mathematics concepts at an early age and understand the concepts, they may
use the experience to be confident of a solution at a later encounter. Or if students feel inferior or
if the assistance is punitive or threatening, future encounters could be frightening and students
may not be as confident and/or self-assured as when they had a positive experience.

Middleton and Spanias (1999) reviewed the current research and concluded that “there is
a relationship between mathematics as a socially constructed field and a student’s desire to
achieve” (p. 1). People tend to have a desire to succeed or a desire to avoid failure. The two
opposing tendencies motivate humans to behave in certain ways, and this behavior is many times
a socially driven response. The authors concluded that two goals of educators are to help student’s value mathematics and become confident in their own ability.

Motivation can be general or task specific, intrinsic or extrinsic or a blend. According to Ames (1992), “Motivations are reasons individuals have for behaving in a given manner in a given situation. They exist as part of one’s goal structures, one’s beliefs about what is important, and they determine whether or not one will engage in a given pursuit” (p. 261).

Common intrinsic rewards include self-efficacy, competence, curiosity, task-involvement, enjoyment, self-regulation, and self-determination (Amabile, Hill, Hennessay, & Tighe, 1994; Hardré & Miller, 2006). Students who are intrinsically driven have several attributes, such as spending more time on task; persisting in spite of failure; selecting more difficult tasks and having a better comprehension of the underlying processes and concepts; and not requiring extrinsic rewards. Developing intrinsic motivation in mathematics may take time.


Motivation for nurses may lead to the same behaviors as the students, and it also may include no punishment, no blame, no guilt, a good outcome, not wanting to look stupid in front of peers (physicians, pharmacists, friends), or the motivation not to make mistakes. Many nurses are uncomfortable with mathematics and have a difficult time assisting others with dosage calculations. Many are unable to estimate mathematics and see that their answer is not feasible. Many nurses can do the mathematics in a controlled environment, but cannot think when rushed,
stressed, tired, distracted, or frightened (Hughes & Edgerton, 2005; Oldridge et al., 2004; Ulanimo et al., 2007; Wolf & Sersembus, 2004).

Mathematics anxiety is defined as “feelings of tension and anxiety that interfere with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations” (Richardson & Suinn, 1972, p. 551) and it may manifest itself in avoidance of certain situations, including courses in math and statistics, in feelings of inadequacy, or in added pressure and physiological symptoms (Betz, 1978; Richardson & Suinn, 1972). Mathematics anxiety is such a negative experience to some people that they actively and purposely avoid mathematics situations (Alexander & Cobb, 1984). Richardson and Suinn (1972) have noted that “it has been demonstrated that mathematics anxiety exists among many individuals who do not ordinarily suffer from any other tensions” (p. 551).

Richardson and Suinn (1972) studied 397 college students and noted that “among nonstudents, mathematics anxiety may be a contributor to tensions during routine or everyday activities, such as handling money, balancing bank accounts, evaluating sales prices, or dividing work loads” (p. 552). Mathematics anxiety is sometimes referred to as a phobia (Richardson & Suinn, 1972), and “mathphobia as an irrational and impending dread of mathematics” (Lazarus 1974, as cited in Hendel & Davis, 1978, p. 429).

Richardson and Suinn (1972), among early researchers who defined mathematics anxiety, were instrumental in establishing normative data, reliability, and validity of the Mathematics Anxiety Rating Scale (MARS), a 98-item, psychometric scale to measure mathematics anxiety specifically. The research before Richardson and Suinn’s (1972) study differentiated mathematics anxiety from test anxiety and social evaluative anxiety (Suinn, 1968; Watson & Friend, 1969). Richardson and Suinn suggested the usefulness of measuring mathematics as
follows (a) Mathematics is a common problem in college students and a tool could diagnose early issues; (b) The tool could pretest and posttest for testing interventions; (c) The test could measure levels of anxiety and be used to aid “desensitization” treatments and develop normative data for further research (p. 552). They concluded that the MARS instrument is an effective assessment tool for use in investigating interventions in measuring mathematics anxiety and the effect of interventions.

Hendel and Davis (1978) observed that mathematics anxiety may be a common variable in poor mathematics performance. They investigated the effectiveness of an educational intervention and a counseling intervention to decrease anxiety in a sample of 69 adult women returning to college and found that the combination of the counseling intervention and course enrollment maximized intervention effectiveness. They suggested that further research was needed to explore the implications of mathematics anxiety and treatment options.

Alexander and Cobb (1984) further researched mathematics anxiety and attempted to factor out dimensions of the MARS and determine whether personal and academic background variables are predictors of mathematics anxiety. Using the MARS scale with 197 college students, they factored 21 items; the top 2 were math test/course anxiety and numerical task anxiety. Analysis of variance determined that students who had high grades in math courses and had taken algebra II in high school had less mathematics anxiety. They suggested that early interventions should be implemented to decrease mathematics anxiety in college students. Alexander and Martray (1989) refined the rating scale using Alexander and Cobb’s 1984 research on factors of the MARS and introduced a revised scale of 25 items. The mathematics anxiety construct is used to explain mathematics performance issues (Alexander & Cobb, 1984; Richardson & Suinn, 1972).
Studying a group of 78 undergraduate students enrolled in a mathematics class, Bai, Wang, Pan and Frey (2009) refined the Mathematics Anxiety Scale (MAS) into a 14-item bidimensional scale. They concluded that using negatively worded items and positively worded items increased the internal reliability, consistency, and construct validity of the scale, and they suggested further research into “causal relationships between mathematics anxiety and performance” (p. 191) noting that mathematics anxiety is a multidimensional psychological construct that involves complex factors and that understanding mathematics anxiety or measuring it will assist in the planning and implementing of measures to improve performance.

Mathematics anxiety is experienced by some people because of their learned attitude from childhood, previous negative experiences, and/or their perception of an intense situation. According to Ho et al. (2000), “The affective factor of math anxiety was significantly related to mathematics achievement in a negative direction” (headnote) and their study of three national samples found that “gender by nation interactions were also found to be significant for both affective and cognitive math anxiety” (headnote). Tobias and Weissbrod (1980), in studying differences between gender and mathematics anxiety, noted that there is probably a “link between poor mathematical skills and the cultural, educational, and occupational barriers experienced by women, and more important, the discovery that persistence rather than ability could account for male-female differences in mathematical performance” (as cited in Ho et al., 2000, p. 63). Mathematics anxiety may be triggered by just the mention of a mathematics problem, medication administration, or a testing situation. If people cannot perform mathematics problems successfully, their self-esteem and confidence are affected.

Personal attitudes and motivations are influenced by many underlying ideas, rational or irrational, and each may evoke emotional and possibly stressful responses. Mathematics anxiety
has been extensively discussed in literature and the construct established; however, more research needs to be done that may link it with mathematics self-efficacy. The combination of mathematics anxiety and mathematics self-efficacy may help guide mathematics instruction and training to find solutions or interventions to improve mathematics performance.

Summary

Medication calculation errors can have devastating consequences; therefore, improving medication calculation skills should be a simple way to decrease many medication errors. Nurses continue to have limited math skills. Measuring medication calculation ability and determining the relationship between performance and math anxiety, mathematics self-efficacy, and other factors are important data. Medication calculations and mathematics skills are part of a complex process involving many factors related to skill acquisition and retention. Overcoming issues related to mathematics anxiety and mathematics self-efficacy, which influences medication mathematics performance, will improve safety in the health care environment. Nurses are challenged to improve the medication administration process and significantly decrease the number of medication errors. This chapter outlines several of the possible issues related to medication mathematics calculation performance. A plan for collecting and analyzing data regarding these issues is discussed in Chapter 3.

Chapter 3 includes the description of the population, sample, research procedures, pilot study testing research process, and the instruments used to study the sample. Included in the instrument discussion are descriptions of how validity and reliability were established, for this study. Chapter 3 outlines the statistical analysis that was used to evaluate the research described for each hypothesis.
CHAPTER 3

RESEARCH METHODOLOGY

The purpose of this study is to identify and analyze the relationships that exist between mathematics anxiety, nurse self-efficacy for mathematics, and medication calculation performance of acute care nurses. This chapter includes the following sections: (a) Research Design, (b) Population, (c) Sample, (d) Instruments, (e) Data Collection, (f) Pilot Study, (g) Analysis, and (h) Summary. Each section is discussed in detail.

Research Design

The research design used in this study was a quantitative correlational research design using multiple linear regression statistics.

Population

The population studied in this research includes nurses licensed by the Texas Board of Nursing (TBON) working in an acute care facility in Texas. Because each state has varying regulations in practice, this study was limited to Texas.

Nurses around the world have the same basic skill sets in regards to medication administration, and nursing standards are universal concerning giving medication accurately. Nurses take a national examination for licensure, and each state has a Nurse Practice Act (NPA) that legislates nursing practice in order to protect the public. Employers expect graduates from nursing programs to be competent and safe in performing medication calculations and administration.

Sample

The sample was from LVNs and RNs from one acute care hospital. The hospital was a
private suburban, nonprofit, Joint Commission-accredited, acute care hospital with 213 licensed beds. The hospital has approximately 324 RNs, 97 LVNs, but many are per diem and work only occasionally, so the full-time equivalent (FTEs) of 264 was the base for sampling.

As suggested by Hinkle, Wiersma, and Jurs (1998) the alpha was set a priori to 0.05 using one-tailed directionality. The effect size expected was 0.30 based on reported effect sizes of similar research reported by Coe (2002). The effect size in this research was not an implication of causality but an implication of the strength of the effect on the relationships (Coe, 2002; Tabachnick & Fidell, 2007). A minimum sample size of 51 was calculated apriori using G*Power3.1.2 software based on a medium a priori effect size of 0.3, α of 0.05, power of 0.95 (Faul, Erdfelder, Lang, & Buchner, 2007), with three predictor variables and one-tailed directionality (see Figure 5. G*Power3.1.2 output).

<table>
<thead>
<tr>
<th>Exact</th>
<th>Linear multiple regression: Random model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Options</td>
<td>Exact distribution</td>
</tr>
<tr>
<td>Analysis</td>
<td>A priori: Compute required sample size</td>
</tr>
<tr>
<td>Input</td>
<td>Tail(s) = One</td>
</tr>
<tr>
<td></td>
<td>H1 $\rho^2$ = 0.2872846</td>
</tr>
<tr>
<td></td>
<td>H0 $\rho^2$ = 0</td>
</tr>
<tr>
<td></td>
<td>$\alpha$ err prob = 0.05</td>
</tr>
<tr>
<td></td>
<td>Power (1-$\beta$ err prob) = 0.95</td>
</tr>
<tr>
<td></td>
<td>Number of predictors = 3</td>
</tr>
<tr>
<td>Output</td>
<td>Lower critical $R^2$ = 0.1517327</td>
</tr>
<tr>
<td></td>
<td>Upper critical $R^2$ = 0.1517327</td>
</tr>
<tr>
<td></td>
<td>Total sample size = 51</td>
</tr>
<tr>
<td></td>
<td>Actual power = 0.9502368</td>
</tr>
</tbody>
</table>

Figure 5. G*Power3.1.2 output.

Instruments

Three instruments were used in this study. The first instrument is a 14-item tool, the Mathematics Anxiety Scale (MAS), used to measure mathematics anxiety (Bai et al., 2009). The
second instrument, Nurse Self-Efficacy for math (NSE-math), is a 12-item tool describing a nurse’s confidence in accomplishing mathematic and arithmetic tasks related to medication calculations common math problems (Andrew et al., 2009). The third instrument is the Bayne-Bindler Medication Calculation Test (BB), a 20-item fill-in-the-blank medication calculation test, which was used to measure medication calculation performance (Bayne & Bindler, 1984). Table 4 lists the measurement tools, number of items, ranges of possible scores, and the scale used.

Table 4

<table>
<thead>
<tr>
<th>Measurement tools</th>
<th>Number of items</th>
<th>Range of possible scores</th>
<th>Scale</th>
<th>Cronbach $\alpha$</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAS</td>
<td>14</td>
<td>14-70</td>
<td>1-5 scale, beginning with <em>strongly disagree</em> to <em>strongly agree</em></td>
<td>.92</td>
</tr>
<tr>
<td>NSE-math</td>
<td>12</td>
<td>12-120</td>
<td>1-10 scale, beginning with <em>no confidence at all</em> to <em>complete confidence</em></td>
<td>.83</td>
</tr>
<tr>
<td>BB</td>
<td>20</td>
<td>0-20</td>
<td>One point per item answered correct</td>
<td>.64</td>
</tr>
</tbody>
</table>

Instrument data was analyzed using SPSS version 19.0. Reliability coefficients for each measure are math anxiety (MAS) Cronbach alpha .92, nurse self-efficacy for math (NSE-math) Cronbach alpha .83, and the Bayne-Bindler (BB) medication calculation test Cronbach alpha .64.

The three tools were compiled into a packet for distribution. The forms were converted into scannable forms, and two versions of the instruments were compiled. One version was compiled with the BB test first, followed by the questionnaires and the demographics last (Sample in Appendix). The second version had the questionnaires first, followed by the BB test and the demographics last (Sample in Appendix). The front of the packet had a cover letter with
a brief explanation concerning the intended purpose and requirements to complete the process; it also explained that if the person fills out the questionnaire he/she consented to participate. The papers were inserted into a large envelope with instructions on the outside requesting help with research and indicating how to return the completed instruments.

Mathematics Anxiety Scale (MAS)

The MAS is a 14-item questionnaire measuring the subject’s perception of apprehension of the questions regarding certain mathematics activities. The apprehension scale uses a 1-5 scale, from strongly disagree to strongly agree. On the scale, 43% of the questions are worded positively, and 57% of the questions are worded in the negative. The scale is scored by adding up the numbers, with a high score indicating a high level of mathematics anxiety. The minimum score is 14, and the maximum score 70. The positively worded items are reverse scored (Items 1, 3, 5, 10, 12, 13) (Bai et al., 2009). Because of the 0.91 Cronbach’s alpha assessing the internal consistency of the entire instrument, Bai et al. determined that their revised 14-item MAS scale, with the bidimensional form, measured the mathematic anxiety construct adequately. The bidimensional scale with positively worded items and negatively worded items were correlated but with separate dimensions of mathematics anxiety; when used together they can accurately locate high anxiety or low anxiety in the subjects (Bai et al., 2009). The Bai et al. form of the MAS instrument, with permission to use, was obtained from the original author and was not modified.

Bai et al. (2009) improved the 14-item Mathematics Anxiety Scale-Revised (MAR-S) as utilized by Betz (1978) and described in detail the tool’s psychometric properties. The researchers adapted the MAS and then administered it to 78 undergraduate college mathematics students to collect the data. Internal consistency was determined using Cronbach’s alpha
coefficient of the total scale of 0.91. Pearson’s correlation between each item and the total scale was calculated, and the correlations for positive-affect items ranged from .26 to .74, with a median .51 and the negative-affect items ranged from .57-.75, with a median of .67. Bai et al. recommended that the two items in the positive-affect with a low (.31 and .26) item-total correlation remain in the instrument because they augment the positive dimension.

Nursing Self-Efficacy for Mathematics (NSE-math)

The NSE-Math is a 12-item questionnaire measuring the nurse’s confidence in performing arithmetic operations and medication calculation related to nursing practice (Andrew et al., 2009). Each item on the NSE-Math instrument uses a 1-10 scale, beginning with no confidence at all to complete confidence. The questionnaire is scored by summing the numbers, with a high score indicating a high level of self-efficacy. The minimum score is 12, and the maximum score is 120. There are two factors demonstrated in the questionnaire, confidence in application of mathematic concepts to nursing practice (Items 1, 6, 7, 8, 9, 10, 11, 12) and confidence in arithmetic concepts (Items 2, 3, 4, 5) (Andrew et al., 2009). The original test, with permission to use, was obtained from one of the original authors and has not been modified.

Face validity was established by a panel of experienced nursing teachers who also teach medication calculations to nursing students (Andrew et al., 2009). Construct validity was established by using an oblique rotation and factor loading. The NSE-math demonstrated two factors, confidence in application of mathematic concepts to nursing practice and confidence in arithmetic concepts. These two factors explained 63.5 of the variance. Predictive validity was tested comparing students with NSE-math scores (high or low) with their scores on the mathematics test and found that second-year nursing students with low self-efficacy had lower scores on the mathematics exam. The Cronbach alpha, calculated to determine internal
consistency for the entire combined scale was 0.88; for the factor confidence in application of mathematic concepts to nursing practice, 0.90, and for the factor confidence in arithmetic concepts, 0.87.

The NSE-math is a math-self efficacy scale designed following the suggestions of Bandura (1986) (as cited in Lee, 2010). “Bandura (1986) cautioned that a self-efficacy instrument must assess the specific skills needed for performing an activity and must be administered during the time that the performance is being assessed” (as cited in Lee, 2010, para. 4). Self-efficacy needs to be contextually related specifically to the skills performed (Nielsen & Moore, 2003). Since self-efficacy describes the self-evaluation of one’s personal ability to perform a skill, the reliability of the measure will be improved with context specificity.

Bayne-Bindler Medication Calculation Test

The BB is a 20-item, fill-in-the-blank medication calculation test (Bayne & Bindler, 1984) and has been modified for current abbreviations, metric measurements and current practice. The participants were allowed to use a calculator if they desired because calculators are readily available to nurses. Minimum score is 1, and maximum score is 20. Seven items are calculations for oral doses (Items 1, 2, 3, 5, 7, 8, 9); five items are calculations for intramuscular or subcutaneous injections (Items 6, 10, 12, 13, 14); and eight items are calculations related to intravenous medications or flow rates (Items 4, 11, 15, 16, 17, 18, 19, 20). These medication calculations are commonly used in the acute care hospital environment. The questions include basic mathematics problems involving the number of tablets of a medication or fractions thereof, conversions from pounds to kilograms, and simple volume calculations used to calculate injections. Several problems are more complex and involve calculation of intravenous (IV) drip rates, IV infusion calculations, and weight-based dosing. The problems are more complex
because they use more than one mathematical operation. The original test, with permission to use, was obtained from the original authors (Bayne & Bindler, 1984).

The BB medication calculation test has been used in several studies involving nurses and nursing students (Ashby, 1997; Bayne & Bindler, 1988, 1991, 1997; Serembus, 2001). Nursing students and nurses were evaluated regarding their skill in accurately calculating medication doses. Content validity was verified by comparison with pharmacology and medical-surgical textbooks and expert nurses (Ashby, 1997; Bayne, & Bindler, 1988, 1991, 1997; Serembus, 2001). Internal consistency was comparable between Bayne and Bindler’s previous research (1988, 1991), reliability 0.82 and Serembus (2001), using the Kuder-Richardson formula calculated at 0.81. Bayne and Bindler (1997) used their medication calculation test again as a pretest and posttest with a Cronbach alpha for the pretest of 0.72 and 0.74 for the posttest. The Bayne and Bindler medication calculation test was used because it had documented validity and reliability information. Even though the reliability coefficients are less than 0.80, they are sufficient to work with and glean more data to improve on the test in the future. Many nursing studies use teacher-made exams and document no validity and reliability information, but they are similar in composition and structure with the current test (Cinar et al., 2006; Conti & Beare, 1988; Oldridge et al., 2004; Walsh, 2006; Wilson, 2003).

Data Collection

The IRB process was completed at UNT and accepted at hospital, approval received prior to research (see Appendix B). The unit managers were sent an email requesting a number of nurses per unit to distribute research packets. Arrangements were made for packet delivery, and instructions were attached to the outside of envelope to return them via inner office mail addressed to the Education Department of the hospital where they were given to the researcher.
Another note was taped to the front of the envelope/packet promising a pizza party for departments that had at least 50% of instruments returned. Three weeks were allowed for return of packets. The packets included permission document, instructions, and Version I or Version II of the instruments including demographic items for completion. Instructions included anonymity preservation, completion instructions, and directions for how to return the completed documents.

The packets were delivered to the unit managers, and the unit managers distributed the packets to the nurses. An email was sent in 1 week to the managers to encourage the nurses to complete the instruments and return via the inner-office mail. The researcher returned to the nursing units personally with sweetbread and fruit with a colorful note on the tray requesting participation. Trays were left for the day shifts and night shifts on all units.

Pilot Study

The pilot study sampled 14 nurses using the instruments and research process. The instruments were packaged in a packet as described above. The specific units’ nurse managers were contacted and the process discussed. The packets (25) were taken to the manager, and the manager distributed the packets to the nurses. The instruments were returned via the inner-office mail to the Education Department. The return of completed instruments was slow, and the process was extended another week. During the waiting time (3 weeks) the researcher contacted the manager who encouraged the nurses to finish the instruments. The unit manager was concerned about the return rate because the case load was low, the nurses were being asked to stay home, and it had been difficult to distribute the packets. While on the unit several nurses talked to the researcher; they were concerned about their math skills and did not want to finish the instrument. The researcher encouraged them to do the best they could and reassured them
that the forms were anonymous and would not identify participants specifically. When the weeks were over, 14 out of 25 (56%) were returned.

The instruments was formatted in a professional graphic format by the university’s Computing and Information Technology Center (CITC) and made into a scannable form. The instruments were returned to the data management department where the completed forms were scanned and compiled into SPSS format and emailed to the researcher in Microsoft Excel format as requested. The raw data were picked up from the data management department the next week. The data were coded into the SPSS 19.0 program in usable format. The coding included transforming the MAS, NSE, and BB medication test into scores, including reverse scoring the positive items from the MAS scale. The instruments were analyzed for reliability and modification was not deemed necessary. The data was also analyzed using multiple regression statistics, and the correlations between the variables were in the direction hypothesized. The demographic data were coded into categories or ranges but had to be further delineated when full data collection was completed because the pilot sample was from a unit that has only RNs, with the nurses in one specialty.

The data distribution and collection process worked adequately except the time frame was modified to 3 instead of the originally-planned-on 2. The data were analyzed, and one participant returned the form blank and was deleted from analysis. The data analysis was completed using SPSS 19.0 graduate pack. The data had to be corrected for some input errors. After the correction of the input errors the data behaved as expected. Assumptions, outliers, missing data, and correlations were reviewed; sample was small but no problems noted. The items on the demographics of college GPA and college algebra grades were consistently omitted, so the items were removed from further analysis.
Analysis

Chapter 4 includes the final analysis using multiple linear regression statistics and SPSS 19.0. For all inferential testing in this study, an a priori level of significance of 0.05 was used, with a moderate effect size (0.3) and statistical power of 0.8 expected. “A significance criterion (α level) which should be specified a priori” (Erdfelder, 2010, p. 1).

Research Question 1. To what degree are the perceptions of mathematics anxiety and perceptions of nurse self-efficacy for mathematics related to performance on a medication calculation test by nurses.

The independent variables are mathematics anxiety, nurse self-efficacy for mathematics, and the dependent variable is medication calculation performance.

Research Question 2. To what degree is there a relationship between the type of nurse and the perceptions of mathematics anxiety or perceptions of nurse self-efficacy for mathematics, to performance on a medication calculation test.

The independent variables are type of nurse, mathematics anxiety, and nurse self-efficacy for mathematics, and the dependent variable is the medication calculation test.

All variables were examined for missing data prior to conducting any analysis. The missing data were coded using the neutral score (3) for the MAS item missing, the “some confidence” score (5) for any NSE-math items missing, and a zero (0) for a BB item not answered.

Study data were analyzed using SPSS version 19.0. Descriptive statistics were calculated and basic percentages of demographics and basic characteristics of the sample described. The scores, for each participant, from the instruments were tabulated in a SPSS data set.

For all inferential testing in this study, an a priori level of significance of 0.05 was used, a moderate effect size (0.3) and statistical power of 0.8 was expected. “A significance criterion (α level) which should be specified a priori” (Erdfelder, 2010, p. 1).
The distributional assumptions of reasonably normal distributions, linearly related, and homoscedasticity using inspection of residuals were done before statistical analysis was completed (Erdfelder, 2010; Foster, Barkus, & Yavorsky, 2006). Field (2009) details several criteria about how to check the assumptions: The variable types have to be quantitative or at least have two categories; the predictors have to have some variation and not be zero, with no perfect linear relationships between two or more predictors; and homoscedasticity checked by examining the residuals at each level of predictor should have same variance. If the assumptions are not met then corrections will be made prior to data analysis. Scatter plots of the residuals, “the differences between the scores predicted by the multiple regression equation and the actual scores” (Foster, Barkus, & Yavorsky, 2006, p. 38), will be examined comparing each independent variable with the dependent variable to determine normal distribution, linearity, and homoscedasticity. “If all three assumptions are met, the plot of the residuals against predicted scores will be roughly rectangular” (Foster et al., 2006, p. 38).

The data were examined for outliers in data using frequency distributions. “Outliers are items of data which are deviant, a long way from the mean” (Foster, Barkus, & Yavorsky, 2006, p. 36). If outliers were found they were examined and a determination made whether removal, square root transformation, or inverse transformation would be best for the data analysis by running data without the outliers than with the transformed outliers (Osborne & Waters, 2002).

Standard multiple regression and a commonality analysis were used to examine the variables’ relationships. The commonality analysis was used to more fully interpret the regression effects of the variables and the variances (Nimon & Reio, 2011). The descriptive statistics reviewed the distribution of scores and variances. A summary table of the Pearson correlations between the variables is provided delineating all six hypotheses. The regression
statistics are described, R, R², structure coefficient, β, ρ, commonality coefficients. “The structure coefficient is a bivariate correlation between a predictor and the predicted criterion resulting from the regression model” (Nimon & Reio, 2011). The structure coefficient squared is equivalent to the percent of variance explained by each variable (Nimon, 2010). The relationships between these regression statistics are described and a variance table provided in the Results section. Commonality analysis, using a script file (Nimon, 2010, http://profnimon.com/commonality.sbs) developed for use with the SPSS software was conducted to analyze the variance between the tests and calculation performance and determine whether the instruments and type of nurse have common or unique properties to explain the performance scores on the medication calculation test. A variable’s uniqueness is identified by the unique commonality coefficient and the variables common effects with two or more variables are identified with the common coefficient (Nimon, 2010). If the coefficient has a mixture of many of the variables to equal the total variance then the instrument is not as specific in the concept it is trying to measure. The calculations of variances explain probable relationships between math anxiety, nurse self-efficacy related to math, and the type of nurse relating to the performance of medication calculations.

Summary

The population of Texas nurses was sampled from a local acute care hospital. The subjects gave informed consent by filling out the instruments. Anonymity was protected, managers did not handle the completed forms, and the researcher did not compile the raw data. A pilot study was conducted, and the process and questionnaire edited. After the pilot study, revisions were made and the final research process was conducted. This chapter has a complete
description of the population; sample and sampling procedure; instruments, including validity and reliability; data collection procedures; pilot study; and analysis procedure.

In Chapter 4 the statistics are discussed in relation to practical and statistical significance. The variances are discussed and displayed, with tables, and graphs to explain the results.
CHAPTER 4
DATA ANALYSIS AND DISCUSSION OF THE RESULTS

The purpose of this study is to identify and analyze the relationships that exist between mathematics anxiety, nurse self-efficacy for mathematics, and medication calculation performance of acute care nurses. This chapter includes the following sections: (a) Research Findings, (b) Instrument Reliability and Validity, (c) Data Assessment, (d) Data Analysis, (e) Results and Analysis for Each Hypothesis, and (f) Summary. Each area is discussed in detail.

Research Findings

The final sample consisted of 84 nurses, licensed vocational nurses (LVNs) and registered nurses (RNs), from one acute care hospital. Instruments were distributed to approximately 270 nurses, and 85 were returned completed (30% return rate). One form was eliminated from analysis due to outliers. The managers distributed the forms, and the nurses completed them at work or when off duty. A couple of managers encouraged their nurses to complete the forms, and at least one manager was reluctant to give the forms to the nurses. Most managers were noncommittal and put the instruments in the employee’s communication boxes. The researcher went to each unit each week and talked with nurses encouraging them to complete surveys and telling them that if they did not know how to do the math they should leave the item blank. The hospital census was down from the usual and not as many nurses were on duty, which made it more difficult to contact as many nurses and encourage participation.

The demographic data items from the instruments are displayed in Table 5. College algebra grades and college GPA were not reported consistently (over 50% left blank) and were not tabulated for analysis. The nurses worked in a variety of acute care areas, and a few nurses
held administrative and education positions (see Table 6). Demographic data gathered for this study are summarized in Table 7.

The majority of the nurses had an associate degree in nursing (54%), were Caucasian (92%), females (83%), with English (97.6%) as their first language (see Table 7). The nurse’s average age was 46, ranging from 25 to 68 years, and averaged 19 years experience. The majority of the nurses were RNs (92%). The education levels were 8% LVN or no degree, 54% associates degree, 25% bachelors degree, 11% masters degree, and 2% other. The ethnicity reported in the sample was 92% Caucasians, 2.4% African Americans, 1.2% Asian Americans, and 4.7% missing. The gender of the sample was 83% female, 15% male, and 1% missing. Ninety-nine percent of the nurses had household sizes between 1-8 averaging 3.09 persons, however one outlier was an Asian American reporting 15 people living at home.

A comprehensive correlation matrix was examined to identify all possible relationships of the potential variables relating to medication calculation performance. Table 8 shows the correlations to significant items gleaned from the demographic items. Ethnicity was correlated to medication test, mathematics anxiety, and hours worked, but the size of the category of Other (3.6%) was too small to make sound conclusions and warrants further investigation. The correlations between nurse having another degree was significant between the medication calculation score and nurse self-efficacy for mathematics, but this is not relevant to the current discussion. The relationship of other degree to self-efficacy and test performance also warrants further study. Further discussion of participants are in the Data Analysis section as it pertains to the relationships between variables.
Table 5

_Demographics Data Items_

1. How many years have you worked in a hospital?
2. On what type of unit do you work? (Spell out abbreviations)
3. What classification of nurse are you? i.e. LVN, RN, APN etc.
4. How many years have you been a nurse?
5. What is your highest level of education?
6. Do you plan on getting more education? Yes No
7. Do you have a degree that is not nursing? Yes No
8. College GPA
9. College Algebra Grade
10. Age
11. Gender Male Female
12. Ethnicity
13. Number of people living at home including yourself?
14. Is English your native language? Yes No
15. How many hours do you work a week?
16. How much sleep do you average each night?

Table 6

_Descriptive Statistics of Types of Units Where Nurses Worked_

<table>
<thead>
<tr>
<th>N= 100</th>
<th>Type of unit</th>
<th>Frequency</th>
<th>Percent</th>
<th>Cumulative percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Progressive Care</td>
<td>3</td>
<td>3.6</td>
<td>3.6</td>
</tr>
<tr>
<td>2</td>
<td>Surgical Services</td>
<td>18</td>
<td>21.7</td>
<td>25.3</td>
</tr>
<tr>
<td>3</td>
<td>Emergency Department</td>
<td>7</td>
<td>8.4</td>
<td>33.7</td>
</tr>
<tr>
<td>4</td>
<td>Women’s Services/Obstetrics</td>
<td>11</td>
<td>13.3</td>
<td>47.0</td>
</tr>
<tr>
<td>6</td>
<td>Intensive Care</td>
<td>13</td>
<td>15.7</td>
<td>62.7</td>
</tr>
<tr>
<td>7</td>
<td>Medical/Surgical Care Units</td>
<td>7</td>
<td>8.4</td>
<td>71.1</td>
</tr>
<tr>
<td>8</td>
<td>Post Anesthesia Care Unit</td>
<td>6</td>
<td>7.2</td>
<td>78.3</td>
</tr>
<tr>
<td>9</td>
<td>Other</td>
<td>18</td>
<td>21.7</td>
<td>100.0</td>
</tr>
</tbody>
</table>
Table 7

Sample Characteristics

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Range</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yrs Hosp</td>
<td>84</td>
<td>41</td>
<td>1</td>
<td>42</td>
<td>17.55</td>
</tr>
<tr>
<td>Age</td>
<td>82</td>
<td>43</td>
<td>25</td>
<td>68</td>
<td>45.61</td>
</tr>
<tr>
<td>Gender</td>
<td>83</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1.84</td>
</tr>
<tr>
<td>Ethnicity</td>
<td>84</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1.11</td>
</tr>
<tr>
<td>Living in Home</td>
<td>84</td>
<td>14</td>
<td>1</td>
<td>15</td>
<td>3.20</td>
</tr>
<tr>
<td>Higher Education</td>
<td>84</td>
<td>4</td>
<td>1</td>
<td>5</td>
<td>2.45</td>
</tr>
<tr>
<td>Other Degree</td>
<td>84</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1.55</td>
</tr>
<tr>
<td>Type of Unit</td>
<td>84</td>
<td>8</td>
<td>1</td>
<td>9</td>
<td>5.16</td>
</tr>
<tr>
<td>Hrs Worked</td>
<td>84</td>
<td>48</td>
<td>12</td>
<td>60</td>
<td>36.98</td>
</tr>
<tr>
<td>Hrs Sleep</td>
<td>84</td>
<td>6</td>
<td>4</td>
<td>10</td>
<td>6.69</td>
</tr>
</tbody>
</table>

Table 8

Descriptive Statistics

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>BB</td>
<td>16.54</td>
<td>2.356</td>
<td>84</td>
</tr>
<tr>
<td>MAS</td>
<td>36.98</td>
<td>7.923</td>
<td>84</td>
</tr>
<tr>
<td>NSE</td>
<td>99.39</td>
<td>14.277</td>
<td>84</td>
</tr>
<tr>
<td>Hrs Worked</td>
<td>36.49</td>
<td>10.489</td>
<td>84</td>
</tr>
</tbody>
</table>

MAS Mathematics Anxiety Scale; NSE Nurse Self-Efficacy for math; BB Bayne-Bindler medication calculation test; Hours worked

Table 9

Correlation Matrix

<table>
<thead>
<tr>
<th></th>
<th>Version</th>
<th>MAS</th>
<th>NSE</th>
<th>Other degree</th>
<th>Ethnicity</th>
<th>Hrs worked</th>
</tr>
</thead>
<tbody>
<tr>
<td>BB</td>
<td>.070</td>
<td>-.269**</td>
<td>.225*</td>
<td>-.218*</td>
<td>-.349***</td>
<td>-.250**</td>
</tr>
<tr>
<td>Version</td>
<td>.188*</td>
<td>-.090</td>
<td>.144</td>
<td>.090</td>
<td>.198*</td>
<td></td>
</tr>
<tr>
<td>MAS</td>
<td>-.506***</td>
<td>.119</td>
<td>.167*</td>
<td>.057</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NSE</td>
<td></td>
<td>-.238*</td>
<td>-.150</td>
<td>.185*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other Degree</td>
<td></td>
<td>-.015</td>
<td>-.094</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
<td></td>
<td>-.342***</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Pearson Correlations: *p < .05, **p<.01, ***p<.001. MAS Mathematics Anxiety Scale; NSE Nurse Self-Efficacy for math; BB Bayne-Bindler medication calculation test
The scores on the medication test ranged from 11(55%) to 20(100%) with a mean of 16.54(83%) points (see Table 9). Only 9.5% of the nurses earned a perfect score of 20(100%), and 18% of the nurses had scores less than 75%. All questions had at least one person answer them incorrectly. A simple question calculating 2½ tablets was missed by one nurse. The item most missed (67% of nurses answered it incorrectly) was a complex question calculating a dopamine drip in micrograms per kilogram per minute. The question calculating a dose of Heparin was answered correctly by 70.6% of the nurses. Another question calculating a simple drip factor was answered correctly by 67% of the nurses.

Table 10

Bayne-Binder Medication Calculation Test Score Frequencies

<table>
<thead>
<tr>
<th>Score</th>
<th>Frequency</th>
<th>Percent</th>
<th>Score percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>4</td>
<td>4.8%</td>
<td>60%</td>
</tr>
<tr>
<td>13</td>
<td>6</td>
<td>7.1%</td>
<td>65%</td>
</tr>
<tr>
<td>14</td>
<td>5</td>
<td>6.0%</td>
<td>70%</td>
</tr>
<tr>
<td>15</td>
<td>12</td>
<td>14.3%</td>
<td>75%</td>
</tr>
<tr>
<td>16</td>
<td>13</td>
<td>15.5%</td>
<td>80%</td>
</tr>
<tr>
<td>17</td>
<td>11</td>
<td>13.1%</td>
<td>85%</td>
</tr>
<tr>
<td>18</td>
<td>13</td>
<td>15.5%</td>
<td>90%</td>
</tr>
<tr>
<td>19</td>
<td>12</td>
<td>14.3%</td>
<td>95%</td>
</tr>
<tr>
<td>20</td>
<td>8</td>
<td>9.5%</td>
<td>100%</td>
</tr>
</tbody>
</table>

n=84

Instrument Reliability and Validity

The instruments were compiled into two versions, with the scales and medication test in different order. One version had the BB test first, and the other had the MAS and NSE-math first (both versions had demographics last). In the analysis there were no significant differences in the two versions compared to other variables (see Tables 8 and 9). Thus, the different versions were not discussed in the final analysis.
Three instruments were used in this research, the Mathematics Anxiety Scale (MAS) (Bai et al., 2009), the Nurse Self-Efficacy for Math (NSE-math) (Andrew et al., 2009), and the Bayne-Bindler Medication Calculation Test (BB) (Bayne & Bindler, 1984). Instrument parameters are illustrated in Table 11. The instrument reliability analysis is discussed in this section.

Table 11

Measurement Tools Descriptions and Reliability

<table>
<thead>
<tr>
<th>Measurement tools</th>
<th>Number of items</th>
<th>Range of possible scores</th>
<th>Scale</th>
<th>Cronbach α</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAS</td>
<td>13</td>
<td>14-65</td>
<td>1-5 scale, beginning with <em>strongly disagree</em> to <em>strongly agree</em></td>
<td>.92</td>
</tr>
<tr>
<td>NSE-math</td>
<td>12</td>
<td>12-120</td>
<td>1-10 scale, beginning with <em>no confidence at all</em> to <em>complete confidence</em></td>
<td>.82</td>
</tr>
<tr>
<td>BB</td>
<td>20</td>
<td>0-20</td>
<td>One point per item answered correct</td>
<td>.64</td>
</tr>
</tbody>
</table>

MAS Mathematics Anxiety Scale; NSE Nurse Self-Efficacy for Mathematics; BB Bayne-Bindler medication calculation test

The first instrument is the 14-item tool, the Mathematics Anxiety Scale (MAS), used to measure mathematics anxiety (Bai et al., 2009). One of the items (no. 3) about which Bai et al. reported a low item-total correlation score ($r=0.31$) had an even lower ($r=0.165$) item-total correlation in this study. Since the Cronbach alpha improved only slightly for total score from 0.918 to 0.924 the scale was left intact. Comparisons were made between the positive, negative, and total MAS scales, there was no appreciable differences in using the two dimensions, therefore the scale was use in total.

The next instrument, Nurse Self-Efficacy for Math (NSE-math), is a 12-item scale describing a nurse’s confidence in accomplishing mathematic and arithmetic tasks related to medication calculations and common math problems (Andrew et al., 2009). Andrew et al. (2009)
found Cronbach’s alpha for the entire scale to be 0.88, for the confidence in application to nursing practice to be 0.90, and for confidence in arithmetic to be 0.87. This study’s results are similar. The reliability of the NSE-math scale for this study was calculated using the Cronbach alpha for the entire scale, 0.83; for confidence in arithmetic concepts, 0.90; and for confidence in application to mathematics to nursing practice, 0.83. The two factors and the full NSE scale delineated comparable correlations.

The last instrument is the Bayne-Bindler Medication Calculation Test (BB), a 20-item fill-in-the-blank medication calculation test, used to measure medication calculation performance (Bayne & Bindler, 1984). The questions are a mixture of oral, injectable, and IV calculations, which may influence the reliability score. Some items are simple and take no conversions while other items require more than one calculation or conversion and the answer may involve decimals. The test had been updated for current dosage forms and conversions, which may relate to the lower reliability score. The modified BB medication calculation test for this study had a Cronbach alpha of 0.64. The BB Cronbach alpha was analyzed and recalculated multiple times, eliminating individual items from the test or groups of items with no increase in the reliability score. A moderate Cronbach alpha value greater than 0.60 is common in exploratory research, but an alpha greater than 0.70 would be better (Garson, 2011; Tan, 2009). Further research is recommended using the BB medication calculation test to refine the items and standardize the test for further use with nurses and nursing students.

Data not established on whether a specific type of questions might be predictive of calculation performance, drug administration safety, critical thinking capacity, mathematic anxiety levels, and/or mathematic self-efficacy; the test was used in total and not divided. Further
research should be done to standardize medication administration tests and fine tune measurement tools.

Data Assessment

All variables were examined for missing data prior to conducting any analysis. The missing data accounted for less than 5% of the data. There were no missing data in the MAS or NSE-math items, so no recoding was done to these. Recoding was to be done using the neutral score (3) for the MAS item missing, the “some confidence” score (5) for any NSE-math items missing, and a zero (0) for a BB item not answered. The most common items left blank were IV calculations. Missing data in the demographics were coded the same as the majority for nominal data and the average for the interval or ratio data. Since nearly 92% reported Caucasian or White and 4.7% did not say, two categories, Caucasian and Other were coded.

Descriptive statistics were calculated and examined for determining basic distributional assumptions. The distributional assumptions of reasonably normal distributions, linearly related, and homoscedasticity using inspection of residuals were done as planned before statistical analysis was completed (Erdfelder, 2010; Foster et al., 2006). Field (2009) detailed several criteria about how to check the assumptions: The variable types have to be quantitative or at least have two categories, the predictors have to have some variation and not be zero, no perfect linear relationships between two or more predictors, and homoscedasticity checked by examining the residuals at each level of predictor should have same variance. Data met assumption of normalcy, linearity, and homoscedasticity and were deemed to be appropriate for analysis as planned.

The variables at minimum have two quantifiable categories; for instance, gender has two categories. All variables were coded to, at minimum, have two categories, and the major
categories were at least interval data; for instance, the math test had a score from 0 to 20 points. There were no perfect linear relationships, and the data had variation with no predictor variations of zero. The data have a relatively normal distribution supported by the values (see Table 12) that have only one kurtotic values greater than absolute one (Neill, 2008). The data were reviewed and both tolerance and Variance Inflation Factor (VIF) are in the region of one, diminishing the probability of multicollinearity (Foster et al., 2006) (see Table 13). Scatter plots were examined to view data for possible curvilinear distributions (see Figure 6). None of the plots appear curvilinear. With low probability of multicollinearity and with these values of skewness and kurtosis, no transformations were deemed necessary.

Table 12

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Std. deviation</th>
<th>Variance</th>
<th>Skewness</th>
<th>Kurtosis</th>
<th>Std. error</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Std. error</td>
<td>Statistic</td>
<td>Statistic</td>
<td>Statistic</td>
<td>Statistic</td>
<td>Std. error</td>
</tr>
<tr>
<td>MAS</td>
<td>1.144</td>
<td>10.489</td>
<td>110.012</td>
<td>.182</td>
<td>.263</td>
<td>-.175</td>
</tr>
<tr>
<td>NSE-Math</td>
<td>1.558</td>
<td>14.277</td>
<td>203.832</td>
<td>-.715</td>
<td>.263</td>
<td>.474</td>
</tr>
<tr>
<td>BB</td>
<td>.257</td>
<td>2.356</td>
<td>5.553</td>
<td>-.487</td>
<td>.263</td>
<td>-.330</td>
</tr>
<tr>
<td>Hours Worked</td>
<td>.864</td>
<td>7.29</td>
<td>62.771</td>
<td>-.533</td>
<td>.263</td>
<td>2.229</td>
</tr>
</tbody>
</table>

MAS=Mathematics Anxiety Scale; NSE-Math=Nurse Self-Efficacy for Mathematics; BB=Bayne Bindler Medication Calculation Test

Table 13

<table>
<thead>
<tr>
<th>Model</th>
<th>Correlations</th>
<th>Collinearity statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Partial</td>
<td>Part</td>
</tr>
<tr>
<td>(Constant)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>MAS</td>
<td>-.196</td>
</tr>
<tr>
<td></td>
<td>NSE</td>
<td>.066</td>
</tr>
<tr>
<td></td>
<td>Hrs Worked</td>
<td>.229</td>
</tr>
</tbody>
</table>

Dependent Variable: Test Score; NSE-Math=Nurse Self-Efficacy for Mathematics; MAS=Mathematics Anxiety Scale
Figure 6. Scatter plot matrix between scores of variables.

Figure 7. Scatter plot of predicted values and residuals
Scatter plots of the residuals (see Figure 7), “the differences between the scores predicted by the multiple regression equation and the actual scores” (Foster et al., 2006, p. 38), were examined comparing each independent variable with the dependent variable to determine, normal distribution, linearity, and homoscedasticity. “If all three assumptions are met, the plot of the residuals against predicted scores will be roughly rectangular” (Foster et al., 2006, p. 38). Since scatter plot of residuals were basically rectangle-shaped, the assumptions were met for using data in the multiple regression equation.

The data were examined for outliers in data using frequency distributions. The outliers outside three standard deviations were examined compared to the normal curve. The family size of 15 was outside the normal curve, since this was not one of the variables studied the person was not deleted (See Figure 8).

*Figure 8. Histogram of persons living in home and normal curve overlay identifying outlier.*
Data Analysis

Mathematics anxiety and self-efficacy related to mathematics in nurses is related to performance of medication calculations. However, other factors such as work hours also influence mathematics calculation performance. For educators and mentors of nurses, there should be an awareness of the probability of medication calculation errors, which link to medication administration errors. Mathematics anxiety and self-efficacy regarding mathematics is an important area to explore related to how patient care safety can be improved before risky situations develop. The demographic items of Gender, Ethnicity, Nurse Type, Other degree, and Is English your native language did not have large enough groups to make any meaningful analysis (See Table 13). The demographic items, Age, How many years worked in a hospital and How many years have you been a nurse, were similar in distribution, and the tool should have had just one item instead of several; however, the items did not demonstrate a relationship to the other variables studied.

Table 14

Frequencies of Select Demographics

<table>
<thead>
<tr>
<th>Item</th>
<th>N</th>
<th>N Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nurse type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LVN</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>RN</td>
<td>77</td>
<td>92%</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>70</td>
<td>83%</td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Caucasian</td>
<td>75</td>
<td>89%</td>
</tr>
<tr>
<td>English first language</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>82</td>
<td>98%</td>
</tr>
<tr>
<td>Other degree than nursing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>71</td>
<td>84.5%</td>
</tr>
</tbody>
</table>

Results and Analysis for Each Hypothesis

A review of the possible relationships between MAS scores, NSE-Math scores, demographic items, and the BB medication calculation test was completed. The analysis revealed three significant variables related to medication calculation performance, MAS, NSE, Hours
worked. The sample did not yield a large enough group of LVNs to perform meaningful analysis on the variable type of nurse. Therefore, Research Question 2 and Hypotheses 4, 5, and 6 are not addressed.

Hypothesis 1. The perception of mathematics anxiety is negatively related to performance of medication calculations.

Using linear regression to assess the negative relationship of mathematics anxiety to performance of medication calculations, the $r$ value of -.269 resulted in a $p$ value of .007, which successfully yields a statistically significant result at $p < .05$. The hypothesis is supported as being true. The $R^2$ value of .131 and the adjusted $R^2$ value of .099 also support the hypothesis as being true. (See Figure 8)

Hypothesis 2. The perceptions of nurse self-efficacy for mathematics is positively related to performance on a medication calculation test.

Multiple linear regression was used to assess the positive relationship of nurse self-efficacy for mathematics to performance of medication calculations; the $r$ value of .225 resulted in a $p$ value of .020, which successfully yields a statistically significant result at $p < .05$. The hypothesis is supported as being true. The $R^2$ value of .131 and the adjusted $R^2$ value of .099 also support the hypothesis as being true. (See Figure 8)

Hypothesis 3. The perceptions of mathematics anxiety and the perceptions of nurse self-efficacy for mathematics are negatively related.

Using linear regression to assess the positive relationship of mathematics anxiety to nurse self-efficacy, the $r$ value of -.506 resulted in a $p$ value of <.001, which successfully yields a statistically significant result at $p < .05$. The hypothesis is supported as being true. The $R^2$ value of .131 and the adjusted $R^2$ value of .099 also support the hypothesis as being true.

Another variable emerged from the demographic data that had significant impact on the dependent variable of medication calculation performance. Hours worked was correlated to a
significant degree with medication calculations ($r = .250, p = .011$) and nurse self-efficacy for mathematics ($r = .185, p = .046$) but not with mathematics anxiety ($r = -.057, p = .303$). The relationship is not as strong with nurse self-efficacy as with the medication calculation performance. (See Figure 8)

Hypotheses 4, 5, and 6 cannot be tested because the sample failed to yield enough LVNs to sufficiently analyze the data.

Hypothesis 4. RNs will perform significantly better on a medication calculation test than LVNs.

Hypothesis 5. RNs will have less mathematics anxiety than LVNs.

Hypothesis 6. RNs will have more nurse self-efficacy for mathematics than LVNs.

\[ H_4 \text{ na} \]
\[ H_5 \text{ na} \]
\[ H_6 \text{ na} \]

\[ \text{Mathematic anxiety} \]
\[ \text{Mathematic self-efficacy} \]
\[ \text{Medication calculation} \]
\[ \text{Type of nurse} \]

Figure 9. Schematic model of relationships with regression values.

Assessing multiple variables simultaneously indicates the use of multiple regression techniques. The ANOVA summary table (see Table 14) is the output that the SPSS software generates to use in evaluation of the regression indicators of equality of means (Tabachnick, & Fidell, 2007). The regression coefficients and confidence intervals are listed in Table 15. and analyze the three variables on medication calculation performance. The $F$ value ($4.031, df = 3, 80$) yielded a statistically significantly result at alpha $< .05$ (0.010), thus rejects the null
hypothesis and accepts the alternative hypothesis. With an $R^2$ value of 0.131 adjusted to 0.099, collectively, the factors of mathematics anxiety and nurse self-efficacy for mathematics demonstrated a relationship to medication calculation performance.

The correlations among the variables explain that there are relationships but do explain the portions of the variance in medication calculation performance. Using commonality analysis as described by Nimon (2010) and Nimon and Reio (2011), a matrix was compiled using a script file (Nimon, 2010) in SPSS 19.0. The commonality matrix (see Tables 15 and 16) delineates the percentages that explain the variance of the seven combinations of variables. Mathematics anxiety alone explains 27% percent of the total effect to medication calculation performance, and hours worked explained 37%. Negative items on the commonality matrix confound the mix and some suggest that they should be reported as zero (Tabachnick & Fidell, 2007; Thompson, 2006). The one negative item is small (-2.6196) and does not detract from the analysis.

Table 15

**ANOVA Summary Table**

<table>
<thead>
<tr>
<th>Model</th>
<th>Sum of squares</th>
<th>df</th>
<th>Mean square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>60.526</td>
<td>3</td>
<td>20.175</td>
<td>4.031</td>
<td>.010</td>
</tr>
<tr>
<td>Residual</td>
<td>400.367</td>
<td>80</td>
<td>5.005</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>460.893</td>
<td>83</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Predictors: (Constant), Hrs Worked, MAS, NSE; Dependent Variable: BB Test Score.

Table 16

**Regression Results for Dataset**

<table>
<thead>
<tr>
<th>Predictor</th>
<th>R</th>
<th>R²</th>
<th>Adjusted R²</th>
<th>β</th>
<th>p</th>
<th>Unique</th>
<th>Common</th>
<th>Total</th>
<th>% of R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAS</td>
<td>.362</td>
<td>.131</td>
<td>.099</td>
<td>-.219</td>
<td>.074</td>
<td>0.0357</td>
<td>0.0364</td>
<td>0.0721</td>
<td></td>
</tr>
<tr>
<td>NSE</td>
<td>.072</td>
<td>.559</td>
<td>.0037</td>
<td>.072</td>
<td>.0034</td>
<td>0.0467</td>
<td>0.0467</td>
<td>0.0505</td>
<td></td>
</tr>
<tr>
<td>Hrs Worked</td>
<td>.225</td>
<td>.038</td>
<td>.0486</td>
<td>.225</td>
<td>.0627</td>
<td>0.0141</td>
<td>0.0141</td>
<td>0.0627</td>
<td></td>
</tr>
</tbody>
</table>

MAS=Mathematics Anxiety Scale; NSE=Nurse Self-Efficacy for Mathematics
Table 17

*Commonality Variance Coefficient Matrix*

<table>
<thead>
<tr>
<th>Variables</th>
<th>Coefficient</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Unique to MAS</td>
<td>0.0337</td>
<td>27.1942</td>
</tr>
<tr>
<td>B Unique to NSE</td>
<td>0.0037</td>
<td>2.8515</td>
</tr>
<tr>
<td>C Unique to Hours Worked</td>
<td>0.0486</td>
<td>36.9936</td>
</tr>
<tr>
<td>AB Common to MAS NSE</td>
<td>0.0291</td>
<td>22.1959</td>
</tr>
<tr>
<td>AC Common to MAS Hrs. Worked</td>
<td>-0.0034</td>
<td>-2.6196</td>
</tr>
<tr>
<td>BC Common to NSE Hrs. Worked</td>
<td>0.0069</td>
<td>5.2192</td>
</tr>
<tr>
<td>ABC Common to MAS NSE Hrs Worked</td>
<td>0.0107</td>
<td>8.1651</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>0.1313</strong></td>
<td><strong>100.0000</strong></td>
</tr>
</tbody>
</table>

**Summary**

The purpose of this study was to identify and analyze the relationships that exist between mathematics anxiety, nurse self-efficacy for mathematics, and medication calculation performance of acute care nurses. Each hypothesis was discussed to disseminate an understanding of the data analysis and results. The commonality matrix was added to give a fuller understanding of the relationships between the variables.

The original plan to differentiate between types of nurses failed to materialize, but the other variables, mathematics anxiety and nurse self-efficacy for mathematics, did have statistically significant relationships with medication calculations and each other. The demographic data added the variable of hours worked to the analysis and found a statistically significant relationship with medication calculations. The commonality matrix demonstrated that the large percentage of the medication calculation performance may be explained by hours worked alone. More research is necessary to further delineate the variables related to medication calculation performance.
Chapter 5 presents a discussion of the findings, conclusions, and recommendations for further research.
CHAPTER 5
SUMMARY OF FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

The purpose of this study was to identify and analyze the relationships that exist between mathematics anxiety, nurse self-efficacy for mathematics, and medication calculation performance of acute care nurses. This chapter includes the following sections: (a) Discussion of Findings, (b) Conclusions, (c) Recommendations for Further Research, (d) Summary. Each area is discussed in detail.

Discussion of Findings

The first goal of this study was to determine whether relationships exist that may explain why nurses have problems with medication calculations and to make suggestions about further research. For nurses to decrease medication errors they need to be aware of the problem and proactively seek solutions. Possible explanations as to why nurses are not good at medication calculations may stimulate further investigation into solutions to the problem. The health care environment is stressful and complex. Many layers of people in the organizations are involved in the medication administration process. The nurse, however, is usually the last line of defense prior to medication administration and has the vital responsibility to protect the patient. The nurse’s medication calculation skills are critical to the outcomes of patient care.

The demographics of levels of experience, type of degree, type of nurse, and nurse specialty did not demonstrate a relationship in this study, as found in other research (Cinar et al., 2006; McMullan et al., 2010, Wright, 2009), perhaps because the sample size was not large enough. Relationships between medication calculation performance, perceived mathematics anxiety, perceived nurse self-efficacy for mathematics, and how many hours a nurse works a week will add to evidence for improving education, ongoing competency training, and work
design. A second goal of this study was to provide evidence related to basic nursing skills (medication calculations) in order to reexamine how nursing instructors test and prepare new graduates for the work environment.

The stressful health care environment, especially that of nurses has challenges in regards to staffing, patient acuity, hours worked, an aging workforce, and multiple types of care providers. This study identified that mathematics anxiety, nurse self-efficacy for mathematics, and hours worked have a predictable relationship with medication calculation performance. The higher the mathematics anxiety, the lower the medication calculation score; the higher the mathematics anxiety, the lower the nurse self-efficacy for mathematics; and the more hours a nurse worked, the lower the score was on the medication calculation test. What this means is a need for further investigation. However, research that investigates interventions to decrease mathematics anxiety and/or increases nurse self-efficacy for mathematics, connecting them with medication calculation performance, would add to current evidence. Research investigating fatigue and hours worked needs to be developed to define parameters that promote optimum performance and decrease medication errors. The connection between attitudes, with both physical and emotional components, must be addressed in order to improve the health care environment to improve patient safety.

Nurses from one private suburban health care institution in Texas participated in this study. Pencil and paper instruments were used to gather data from the participants. Nurses, both RNs and LVNs, were encouraged to participate, and their anonymity was preserved in an effort to improve response rate. The managers who distributed the instruments demonstrated varying degrees of enthusiasm, and some units had smaller returns. The instruments consisted of three tools and demographic data. The MAS (Bai et al., 2009), which measured the nurses’ degree of
anxiety about mathematics and mathematic related situations, was used. The premise is if that persons are quite anxious about mathematics they will not do as well as those who are not as anxious on performance of mathematics problems. The NSE-Math (Andrew et al., 2009) is a 12-item instrument that measures nurse self-efficacy regarding mathematics. The premise that, if individuals feel better about their mathematics skill, they would do better on mathematic problems. The medication calculation test was updated from Bayne and Bindler’s test used in several studies (Bayne & Bindler, 1988, 1991, 1997; Serembus, 2001). The updates to the test were to clarify some of the abbreviations, remove apothecary measurements, and primarily use the metric system. The items on the test are typical dose forms, such as tablets, liquids, injections, and IV medications used in dosage situations encountered in everyday nursing practice in acute care. The score, performance on the BB medication calculation test, was used as the dependent variable for this study.

Results compiled from the instrument responses were used to address the following hypotheses, which are addressed in order.

Research Question 1. To what degree are the perceptions of mathematics anxiety or perceptions of nurse self-efficacy for mathematics related to performance on a medication calculation test by nurses.

Hypothesis 1. The perception of mathematics anxiety is negatively related to performance of medication calculations.

Mathematics anxiety is defined as “feelings of tension and anxiety that interfere with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations” (Richardson & Suinn, 1972, p. 551). As anxiety increases, the performance scores on a medication calculation test decreases. This study supported Hypothesis 1, and the null hypotheses is rejected. Mathematics anxiety had a statistically significant correlation with the score on the BB medication calculation test. This study agrees with Ashby
(1997), who reported that almost 60% of the nurses found medication calculations to be stress producing. Ashby also found that 56.4% of the nurses sampled could not pass the medication calculation test at 90%. She concluded that educators and trainers need to research ways to enhance the remediation process and find ways to improve nurses’ medication calculation ability. In the commonality analysis it was unique for 27% of the variance. There was overlap in variance with hours worked and NSE, for 27% of the variance. Therefore, mathematics anxiety was a factor influencing the medication calculation performance; however, the factor also shared a portion of the influence with the variables of nurse self-efficacy for mathematics and number of hours worked in a week.

Hypothesis 2. The perception of nurse self-efficacy for mathematics is positively related to performance on a medication calculation test.

Nurse self-efficacy for mathematics is defined as perceptions of one’s performance capabilities related to math problems, math tasks and math-related course work (Betz & Hackett, 1993). A nurse’s confidence in his/her mathematics performance may be related to prior experiences, successes, and/or failures. This study supported this hypothesis, and thus the null hypothesis is rejected. The relationship between nurse self-efficacy for mathematics and performance on the medication calculation test is statistically significant. This agrees with Bayne and Bindler (1991), who found a significant relationship with the same. However, the commonality analysis from this study reveals that the overlap with the other factors is larger than the unique characteristics. The NSE-math is unique for only 2.9% and shares almost 36% of the variance with the MAS and hours worked. This shared variance makes it difficult to attribute confidence in a predictive relationship regarding medication calculation performance.
Self-efficacy for mathematics may be important, but it may also be a sub-factor in other concepts, such as mathematics anxiety, fatigue level, stress levels, and other work environment issues regarding self-efficacy for other parts of job performance.

Hypothesis 3. The perceptions of mathematics anxiety and the perceptions of nurse self-efficacy for mathematics are negatively related.

There is, however, a statistically significant relationship between MAS and NSE (r = -0.506, p < 0.001); therefore, the null hypothesis is rejected. As explained above, there is overlap of mathematics anxiety and nurse self-efficacy for mathematics. The variance common to MAS and NSE combined is 23%, and the variance common to MAS, NSE, and Hours worked combined is 8% in relation to medication calculation performance. There needs to be further research to delineate the relationship of these two factors and medication calculation performance.

Research Question 2. To what degree are the type of nurse and the perceptions of mathematics anxiety or perceptions of nurse self-efficacy for mathematics related to performance on a medication calculation test.

Hypothesis 4. RNs will perform significantly better on a medication calculation test than LVNs.

Hypothesis 5. RNs will have less mathematics anxiety than LVNs.

Hypothesis 6. RNs will have more nurse self-efficacy for mathematics than LVNs.

Research Question 2 cannot be addressed because the sample of LVNs was too small to render meaningful results. A different sampling technique or different study design might elicit better data. There are several reasons for the small sample of LVNs. Perhaps the LVNs were reluctant to fill out the test because they did not feel comfortable doing mathematics in general. Or perhaps the LVNs did not believe they would do as well as the RNs. The many reasons concerning why the sample of LVNs was so small warrants further study.
The results are bound by limitations due to the small sample size being from one institution in Texas. The private suburban hospital may not be typical of a large urban medical center. The research institution and/or public facility may demonstrate different factors. The performance of medication calculations and the factors involved are multifaceted. The medication calculation test is not standardized and needs further development and testing.

Conclusions

Mathematics anxiety, nurse-self efficacy for mathematics, and the number of hours a nurse works a week do have a relationship to performance on a medication calculation test. Mathematics anxiety can be traced to childhood, and it can be influenced by teachers, peers, and family (Middleton & Spanias, 1999). Researchers studying other types of students agree that mathematics anxiety, self-esteem, and confidence are contributors to mathematic competence in students from middle school through college (Middleton & Spanias; Ho et al., 2000). Mathematics anxiety can be influenced by successes in mathematics performance, and this can be an avenue to improve nurse performance. This study found a significant relationship and significant overlap of the variables in the commonality analysis. Nurse-self efficacy for mathematics can be developed and improved in much the same way mathematics anxiety can be decreased. Middleton and Spanias concluded that educators need to help students be confident in their mathematic ability and find value in mathematics.

This study found a significant relationship between the number of hours worked and performance on the medication calculation test. The more hours worked, the lower the test score. More of the variance was unique to hours worked (37%) than was unique for the other variables. The number of hours nurses work and the length of shifts has been a growing concern. Working many hours consecutively, or taking enough time between shifts, were both linked to unsafe
working conditions (“Needlesticks,” 2008; Rogers et al., 2004; Trinkoff et al., 2006). Ulanimo et
al. (2007) found that one of the major nurse perceptions of causes of errors was fatigue and
nurses miscalculating doses. Nurses are more likely to make an error after working 12.5 hours or
more (Rogers et al., 2004). The transportation industry has strict guidelines regarding work
hours, shift length, consecutive hours worked, and time off before on duty again. Medical
residents and interns now have guidelines for programs. Fatigue is a factor, and work hours are
related. The IOM has guidelines for work hours.

If the calculation skills of this sample of acute care nurses are related to medication errors
there is reason to be concerned. Moyen et al. (2008) had several suggestions for simple strategies
to prevent medication errors (see Table 2), such as medication standardization, computerized IV
infusion devices, and avoiding excessive working hours. Each of these suggestions would
prevent some of the errors that may be committed by nurses who cannot successfully do
arithmetic. Since the most commonly missed calculation was a complex IV drip, the
computerized infusion device is strongly recommended for the complex critical IV drips used
with patients. The work hours, stress levels, and general working environment warrant careful
evaluation and system/process improvement. Polifroni et al. (2005) believe that the acute care
environment should promote regular practice sessions using mathematical skills and have clear
expectations of what is expected as the standard of practice regarding medication calculations.
Grandell-Neimi et al. (2001) and McMullan et al. (2010) found that nurses who did calculations
more often did better on their calculation tests.

Recommendations for Further Research

This study focused on mathematics anxiety and nurse self-efficacy related to performance
on a medication calculation test. The sample did not have enough LVNs to test the second
research question and further research needs to be done determining if there are reasons that the LVNs did not complete and return the survey. Another suggestion is to investigate the premise that the LVNs may not believe that they would do well on the test or LVNs avoid medication calculations and trust others to do the mathematics for them. Researching the population of LVNs specifically with these same tools would be interesting data.

The three instruments in this study need further evaluation for establishing validity and reliability in larger and varied samples from nursing, other health care professionals and students. Further research needs to determine which factors lead to high or low anxiety to promote strategies to decrease anxiety. The research can start with nursing students and continue on to practicing nurses. Establishing the importance of using the self-efficacy scale in conjunction with the mathematics anxiety scale also needs to be investigated.

The concept of mathematics anxiety and the relationship with mathematics performance can also be investigated in other groups of students, including children, adolescents and older adults. Nursing teachers need to evaluate their own mathematics anxiety, self-efficacy for mathematics and skill at medication calculations and learn better ways to teach their students. The concept of self-efficacy for mathematics needs to be investigated further to test the relationship strength with larger samples and in other situations to validate the instrument. The nurse self-efficacy for mathematics tool developed by Andrew et al. (2009) needs further evaluation of the two-factor format because this study found a small correlation with the factor of arithmetic concept.

The medication calculation test needs to be further validated using a collaborative effort with nursing teachers and health care educators to refine the instrument into a more standardized version to test students and nurses. The medication calculation test should investigate if there are
critical items or if certain types of questions, for instance intravenous or injections, may be more predictive of critical thinking abilities than calculating pills or tablets. Critical thinking skills and arithmetic skills measurement would improve planning for remediation and interventions for students struggling with mathematics.

Learning programs need to be evaluated to promote mastery of medication calculations that use authentic simulations, virtual or live. Authentic learning programs that promote mastery of medication calculations and other critical nursing competencies need to be instituted in both the nursing school setting and the practice environment. Medication calculation skills is a competency that needs to have ongoing evaluation. The acute care nurse who is administering medication should be able to perform medication calculation skills any time and not just for the occasional test.

The relationships between medication calculation performance, medication administration performance and other variables that increase or decrease error rates need to be investigated and more evidence to promote safe systems disseminated. Other variables may be a stressful environment, visual difficulties of the aging worker, many distractions when doing calculations, fatigue, fear of looking unprepared or incompetent, consequences of failure, unhealthy work environment, and many other factors affect medication administration. The demographic variables of family size, type of nurse, education level, ethnicity, gender, English as second language, and nursing as second career also need to be investigated. Best practices, performance improvement, and reliable evidence will lead to better patient safety and patient outcomes.

Another significant correlation was delineated from the demographics, as number of hours worked per week increased so did the medication errors. The other demographic variables
were not as specific to this study. However, the variables: number of hours worked, sleep issues, stress levels in the personal or work environment, and fatigue parameters warrant further evaluation. The demographic variables need to be investigated with the systems and processes surrounding the demographic item linked to the items. The systems/processes need improvement to have positive impact on patient outcomes and patient safety. Process improvement initiatives need to be implemented to improve medication calculation performance and decrease the chances of making medication error in the medication administration process.

Summary

The purpose of this study was to identify and analyze the relationships between mathematics anxiety, nurse self-efficacy for mathematics, and medication calculation performance of acute care nurses. The study focused on the perceived levels of mathematics anxiety, nurse self-efficacy for mathematics, and acute care nurses medication calculation skills. Statistically significant results supported the premise that mathematics anxiety is negatively related to performance on a medication calculation test, and mathematics anxiety is negatively related to nurse self-efficacy for mathematics. The significant correlation of number of hours worked by a nurse in 1 week the negative relationship to performance on the medication calculation test definitely needs further investigation.

Confidence in ability should decrease anxiety and this is demonstrated in this study. The medication calculation test was a typical test used for nursing students during their education. Acute care nurses should have been able to perform better on the test. Mathematics anxiety is a real phenomenon and needs to be investigated with interventions to alleviate. The results of the test provide a basis for comparison and should inspire nurses, educators, trainers, and administrators to look carefully at the education and training environment to improve process.
The variables have unique and common elements and can be investigated to more clearly delineate the unique properties. Studying interventions, process changes and fine tuning the instruments related to mathematics anxiety, fatigue, and medication calculation performance will improve patient safety and employee performance.
APPENDIX A

IRB APPROVAL FORM
Jeff Allen  
Department Learning Technologies  
University of North Texas  

Re: Human Subjects Application No. 11329

Dear Dr. Allen:

As permitted by federal law and regulations governing the use of human subjects in research projects (45 CFR 46), the UNT Institutional Review Board has reviewed your proposed project titled “Relationship among Mathematics Anxiety, Mathematics Self-Efficacy and Medication Calculation Performance in Licensed Vocational Nurses and Registered Nurses in a Suburban Hospital.” The risks inherent in this research are minimal, and the potential benefits to the subject outweigh those risks. The submitted protocol is hereby approved for the use of human subjects in this study. Federal Policy 45 CFR 46.109(e) stipulates that IRB approval is for one year only, July 28, 2011 to July 27, 2012.

Enclosed is the consent document with stamped IRB approval. Please copy and use this form only for your study subjects.

It is your responsibility according to U.S. Department of Health and Human Services regulations to submit annual and terminal progress reports to the IRB for this project. The IRB must also review this project prior to any modifications.

Please contact Shelia Bourns, Research Compliance Analyst, or Boyd Herndon, Director of Research Compliance, at extension 3940, if you wish to make changes or need additional information.

Sincerely,

[Signature]

Patricia L. Kaminski, Ph.D.  
Associate Professor  
Department of Psychology  
Chair, Institutional Review Board

PK sb
I am a doctoral student at the Department of Technology and Cognition at the University of North Texas. I am conducting a self-report survey and short math test to nurses. The purpose of this study is to identify and analyze the relationship among mathematics anxiety, mathematics self-efficacy, and mathematics performance in acute care nurses.

There are no foreseeable risks involved in this study because your name and anonymity will be protected and will not be included in the information collected or reported. The potential benefits will be a better appreciation for the complexity of safety in health care and an awareness of the need to improve processes. Results are expected to be used for improving nursing education and acute care nursing practice thus improving patient safety.

I invite you to assist me with this research project by completing the enclosed mathematics test and survey.

Approximately 40 minutes is required to complete the instruments and test.

Please remember:
- Your participation in this study is voluntary.
- All of your information will remain confidential.
- Please do not sign your name on the instrument.
- You may discontinue participation at any time without loss or penalty.

Instructions for completing the instruments:
1) Complete the questionnaire-Approximately 15 minutes
   *(Please answer ALL of the questions to the best of your knowledge.)*
2) Complete the 20 item medication calculation quiz-Approximately 25 minutes (you may use a calculator but, do not get help to do the test).
3) If you have any questions please contact, Joyce Melius or Dr. Jeff Allen
   *(contact information below)*

Dr. Jeff Allen  
University of North Texas at Denton  
Professor, graduate advisor  
jallen@unt.edu

Joyce Melius, MSN, RN, CCRN  
University of North Texas at Denton  
Graduate student, principal investigator

This research project has been reviewed and approved by the UNT Institutional Review Board (940) 565-3940. Contact the UNT IRB with any questions about your rights as a research subject.
Nursing Administrator:

I am a doctorate student at The University of North Texas at Denton. I am planning to conduct a questionnaire on mathematics anxiety and mathematics self-efficacy and also have participants complete a short medication calculation test. This research will aid me in completing my doctoral dissertation. I plan deliver the questionnaires and quizzes to staff nurses, RNs and LVNs.

I am requesting your approval to conduct my research within your institution. Please grant me permission and sign the bottom of this letter and contact me so I can pick up the original. I will need contact information: Name, email address, phone number and fax number, for the person I should work with. Let me know if you need more information.

If you are interested in the analysis of the results of my study, please indicate by checking the appropriate area of the letter.

I greatly appreciate your interest and assistance in this matter.

Sincerely,

Joyce Melius, MSN, RN, CCRN

PERMISSION TO CONDUCT RESEARCH

I, do hereby grant Joyce Melius RN

(Signature and title of Authorized Person) ______________

(Printed Name of Authorized Person) ______________

permission to conduct doctoral research at

(Official Name of Institution) ______________

[ ] Send me the results. Enclosed is information where to deliver document or email address.
APPENDIX B

SAMPLE OF INSTRUMENTS
**NURSING SURVEY**  
**Version I**

Directions: Calculate the following problems. Please do not get help with the test and do not use references. The test is anonymous and is not graded. You may use a calculator if you wish. There are 20 problems and it should not take more than 30 minutes to complete.

<table>
<thead>
<tr>
<th>Conversion Table</th>
<th>Intravenous Tubing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 kg = 2.2 lb</td>
<td>Abbott 15 gtt = 1 ml</td>
</tr>
<tr>
<td>1 tsp = 5 ml</td>
<td>AVI 20 gtt = 1 ml</td>
</tr>
<tr>
<td>1000 ml = 1 L</td>
<td>All companies 60 microgt = 1 ml</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question</th>
<th>Work Space</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>01. Ordered stat: 250 mg Amoxicillin oral. The Amoxicillin on hand contains 1 gram in each tablet. How many tablet(s) should the patient receive?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>02. Ordered stat: Lanoxin elixir 0.25 mg oral. The drug on hand is Lanoxin elixir 0.5 mg/ml. How many ml(s) should the patient receive?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>03. Ordered stat: Acetaminophen 1 1/2 tsp oral. The medication is available in a liquid of 500 mg/5 ml. How many ml(s) should the patient receive?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>04. The patient weighs 179 lbs. and is receiving Zofran. This drug's recommended dosage is 0.15 mg/kg IV. How much Zofran should be ordered for this patient?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>05. If a physician orders 10 ml of a certain oral medication to be given T.I.D. for 20 doses. How many ml(s) will be needed for a total of all doses?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>06. Ordered stat: Atropine 0.4 mg sc. The label on the bottle reads 0.2 mg Atropine per ml. How many ml(s) should be given?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>07. Ordered stat: 1 gram Carniprin oral. The drug is available in 400 mg tablets. How many tablets should be given to the patient?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>08. Ventiom syrup is available in a liquid form labeled 2mg/5ml. How much Ventiom is contained in each ml?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>09. Ordered: Cefdin 250 mg tablets B.I.D. X 10 days. How many doses will be taken by the patient by the end of 10 days?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. A cortisone acetate solution contains 25 mg in 1 ml. If 30 mg of the medication is ordered, how many ml(s) should be given?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
NURSING SURVEY
Version II

Anxiety and Self-Efficacy Regarding Medication Calculation in Nurses

Mathematics Anxiety Scale (MAS)

Directions: This survey is designed to find out how much anxiety you may have regarding mathematics. Please read each item carefully and circle the response from the following options that best represents your feelings about that item. Answer each question as appropriate. Select only one response for each question.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

01. I find mathematics interesting.
02. I get uptight during mathematics tests.
03. I think that I will use mathematics in the future.
04. My mind goes blank and I am unable to think clearly when doing my mathematics test.
05. Mathematics relates to my life.
06. I worry about my ability to solve mathematical problems.
07. I get a sinking feeling when I try to do mathematical problems.
08. I find mathematics challenging.
09. Mathematics makes me feel nervous.
10. I would like to take more mathematics classes.
11. Mathematics makes me feel uneasy.
12. Mathematics is one of my favorite subjects.
13. I enjoy learning with mathematics.
14. Mathematics makes me feel confused.

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

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

<table>
<thead>
<tr>
<th>No Confidence at all</th>
<th>Some Confidence</th>
<th>Complete Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

01. Compare two fractions and determine which one is larger (e.g., compare 5/8 with 2/3).
02. Add two large numbers (e.g., 90499 + 76582) without using a calculator.
03. Subtract two large numbers (e.g., 67225 - 23899) without using a calculator.
04. Multiply two large numbers (e.g., 5021 x 349) without using a calculator.
05. Divide one number with another (e.g., 1000 ÷ 9) without using a calculator.
06. Convert a drug dose from grams (g) to milligrams (mg).
REFERENCES


Needlesticks remain key concern , (2008, September 8). NurseWeek, September, 8, 41.


