

**A QUASI-EXPERIMENTAL STUDY MEASURING THE EFFECT OF
DIMENSIONAL ANALYSIS ON UNDERGRADUATE NURSES' LEVEL OF
SELF-EFFICACY IN MEDICATION CALCULATIONS**

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ABSTRACT

The instructional approach of dimensional analysis has been identified as an effective method for promoting conceptual understanding and decreasing calculation errors of nursing students. The purpose of this study was to determine the effectiveness of dimensional analysis in enhancing the mathematics self-efficacy levels of undergraduate nursing students. Using a quasi-experimental design, the Nursing Students Self-Efficacy for Mathematics tool was administered to 147 second-year nursing students enrolled in two different nursing programs in Alberta. One program used dimensional analysis, while the other program used the formula method to teach mathematical calculations. The findings demonstrate no difference in self-efficacy levels between the group being taught dimensional analysis and the group that was taught an alternative method. However, increased age, male gender, and higher grades received in high school mathematics contributed significantly to increased levels of self-efficacy. A discussion of the implications and recommendations for future research and nursing education conclude the thesis.

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CHAPTER ONE: INTRODUCTION

Medication calculation errors are common administration mistakes made in the field of nursing, as the ability to competently and accurately complete drug dosages is often lacking (Bayne & Bindler, 1988; Harne-Britner et al., 2006; Koohestani & Baghcheghi, 2009). Medication administration is a large part of providing patient care for both nursing students and registered nurses, and findings show that errors in administration make up 26-38% of all medication errors (Rice & Bell, 2005). It has been estimated that approximately one in every six medication errors is a result of miscalculations, and in 2003, the American Food and Drug Administration stated that approximately 41% of all medication errors were due to inappropriate drug calculations (Capriotti, 2004; Lesar, Briceland, & Stein, 1997; McMullan, Jones, & Lea, 2010). In comparison to other disciplines, such as medical doctors, pharmacists, and medical students, nurses are known to rank lowest on the scale of calculation proficiency (Oldridge, Gray, McDermott, & Kirkpatrick, 2004). According to Jukes and Gilchrist (2006), “This perceived lack of calculation ability amongst nurses has caused professional embarrassment” (p. 192).

Deficiencies in medication calculation abilities are generally classified as being mathematical, computational, or conceptual in nature, with conceptual incapacities generally causing the most difficulty (Blais & Bath, 1992; Segatore, Edge, & Miller, 1993; Wright, 2006b). Conceptual error is classified as incapacity to properly organize and setup the dosage calculation from the information given (Greenfield, Whelan, & Cohn, 2006). Other outlined barriers to accurate drug calculations in nursing students

include inconsistent teaching strategies (Elliott & Joyce, 2005; Rice & Bell, 2005; Røykenes & Larsen, 2010), inappropriate or inconsistent use of mathematical formulas (Segatore et al., 1993; Wright, 2008a, 2008b), and mathematics anxiety (Fulton & O'Neill, 1989; Pozehl, 1996; Walsh, 2008).

In response to these issues, educators and researchers have attempted to mitigate the problem by proposing and assessing the effectiveness of a number of different problem-solving strategies that strive to properly instruct nursing students on how to carry out medication calculations. These include methods such as the formula method, algorithmic-based instruction, the triangle technique, and dimensional analysis (Greenfield et al., 2006; Papastrat & Wallace, 2003; Sredl, 2006). Many of these studies show improvements in nursing students' calculation abilities when using each method; however, most educators cannot come to a consensus on which method is most appropriate for nursing education (Kohtz & Gowda, 2010; Wright, 2008a). In addition, educators have outlined other resources to help solve these drug calculation problems, including regular exposure to drug dosages in clinical practice, expanding numerical knowledge of dosages, understanding of proportions and factors, and the use of visual aids in the clinical setting such as syringes (Wright, 2006a, 2009a). Unfortunately, the problem still persists, and continued effort is required, as "investigation of strategies to combat calculation deficiency is warranted because proficiency in calculation is essential for safe medication administration" (Rice & Bell, 2005, p. 318).

Outlined Problem

These studies suggested that nursing students' level of medication calculation skill is problematic, and nursing students often struggle with a low sense of math self-

efficacy. Nursing programs play a large role in strategizing effective ways in ensuring that their students are able to accurately conceptualize and confidently carry out drug dosage calculations. This is especially significant since a main goal of nursing programs is to graduate nurses who are confident and competent in a variety of skill sets, including medication calculation (Elliot & Joyce, 2005). This is essential, as nursing students are the future workforce of the nursing profession and must be able to demonstrate competence in every aspect of their practice (College and Association of Registered Nurses of Alberta, 2013).

Purpose of the Research and Research Question

The purpose of this study was to evaluate the effects of dimensional analysis on the self-efficacy levels of second-year undergraduate nursing students, specifically in regards to their medication calculation abilities. The research question to be answered was: Is there a difference in the degree of self-efficacy with medication calculations between undergraduate nursing students who are taught dimensional analysis versus students who are not taught dimensional analysis?

Specifically, this project assessed the self-efficacy levels of nursing students who were taught medication calculations using the standardized method of dimensional analysis, and nursing students who were not being taught dimensional analysis.

Theoretical Framework

The theoretical structure for this research is based on the concept of self-efficacy. The concept originated within Bandura's (1977) social cognitive theory and was defined by Bandura (2006) as "people's beliefs in their capabilities to produce given attainments" (p. 307). Bandura (1977) proposed a theory of self-efficacy, which stated that an

individual's expectations of self-efficacy towards a task determined how much effort they would expend, how they would cope with their abilities, and how long they would persist in the face of difficulties, failures or obstacles. In his proposed model of self-efficacy, Bandura (1977) outlined four main sources from which individuals derive self-efficacy, which included performance accomplishments, vicarious experience, verbal persuasion, and emotional arousal. These four sources affect the strength of an individual's level of self-efficacy and contribute to their level of confidence in successfully completing difficult tasks. According to Zimmerman (2000), the concept of self-efficacy differed from other related concepts, such as self-esteem or self-concept, because it focused on task-specific performance capabilities and expectations rather than simply self-knowledge or evaluation. Therefore, self-efficacy beliefs are often predictive not only of academic success in students, but also effort and perseverance through challenging tasks (Bandura, 2006; Multon, Brown, & Lent, 1991; Zimmerman, 2000).

Self-efficacy is a concept often utilized in the field of nursing and nursing education as a means of better understanding how to promote confidence and competence and ensure patient safety. Self-efficacy plays a major role in the nursing student's capacity to accurately calculate medications (Walsh, 2008), as it is a "reliable predictor of whether or not they will attempt the task, the amount of effort they will expend, and their level of perseverance in the face of unforeseen difficulties" (Andrew, Salamonson, & Halcomb, 2008, p. 218). Nursing students have demonstrated that they often struggle with increased degrees of math anxiety and poor self-efficacy in relation to their medication calculation abilities (Hansen, 2004; Pozehl, 1996; Røykenes & Larsen, 2010). Even in comparison to students of other disciplines, nursing students often have much

poorer math skills and report higher levels of math anxiety (Pozehl, 1996). These findings suggest that interventions need to be implemented in nursing schools that promote the development of increased levels of self-efficacy in nursing students and further promote cultures of safety in nursing programs (Andrew et al., 2008; Hansen, 2004; Wright, 2006a).

In light of the available literature on the topic, in combination with the theory of self-efficacy as the guiding theoretical framework, the following independent and dependent variables were outlined for this study.

Independent Variable

- Use of dimensional analysis as a problem-solving method for medication calculations.

Dependent Variable

- Nursing students' self-reported feelings of self-efficacy in relation to their medication calculation abilities

Research Significance

Numerous studies have demonstrated that the lack of medication calculation abilities of nursing students is an ongoing issue in health care, and nursing schools have a responsibility to implement teaching strategies that attempt to mitigate the problem (Bayne & Bindler, 1988; Craig & Sellers, 1995; Raman, 2010). A number of different teaching methods exist for educating nursing students on how to accurately calculate medications, yet dimensional analysis has been shown to have distinct advantages. This method stimulates conceptual understanding of the problem, and when used as a standardized teaching technique, not only are improvements in dosage calculations seen,

but also sustained retention of learning (Craig & Sellars, 1995; Kohtz & Gowda, 2010; Koohestani & Baghcheghi, 2009). Self-efficacy, or one's belief in one's ability to successfully perform a task, is outlined as a predictor of performance in regards to medication calculations and mathematical performance (Røykenes & Larsen, 2010; Walsh, 2008). According to Zimmerman (2000), "Self-efficacious students participate more readily, work harder, persist longer, and have fewer adverse emotional reactions when they encounter difficulties than do those who doubt their capabilities" (p. 86). Therefore, it is imperative that nursing programs implement strategies that enable nursing students to develop and maintain confidence and proficiency in their drug calculations (McMullan, Jones, & Lea, 2012).

A number of studies demonstrated the value of dimensional analysis in improving the medication calculation abilities of nursing students (Cookson, 2013; Craig, 2013; Craig & Sellers, 1995; Greenfield et al., 2006; Koohestani & Baghcheghi, 2009; Rice & Bell, 2005). However, no study exists that examines the effectiveness of dimensional analysis in promoting self-efficacy for nursing students. Therefore, this quasi-experimental research study attempted to contribute to the knowledge base by assessing the effectiveness of dimensional analysis on undergraduate nurses' levels of self-efficacy in relation to their medication calculation abilities. In addition, the findings of this study might help inform nursing program curriculum decision makers and nurse educators on a strategy that has the ability to empower and enhance students' self-efficacy in relation to medication calculation abilities.

Outline of the Thesis

This thesis is comprised of five chapters. Chapter One is an introduction of the research problem, a summary of the available literature on the issue, the outlined research problem and research question, the theoretical framework guiding the research, and the specific variables being measured, as well as the significance of the study. Chapter Two outlines a review of the relevant literature associated with medication calculation errors made in practice by nurses and nursing students, the role of self-efficacy in promoting achievement in nursing students, and the use of dimensional analysis as a method for improving the calculation abilities of nursing students. Chapter Three provides the research methodology and data-collection procedures utilized for this project, while the data analysis results are presented in Chapter Four. Chapter Five includes a discussion of the findings, the conclusions made, limitations present in the study, and recommendations for future study.

CHAPTER TWO: LITERATURE REVIEW

The purpose of this literature review is to explore the topics of medication calculation errors in practice, the use of dimensional analysis as a standardized problem-solving method, and student nurses' levels of self-efficacy in regards to their medication calculation abilities. This chapter begins with a review of the relevant literature pertaining to the issue of errors made in nursing practice, followed by a review of the medication calculation errors made in practice by nursing students. This is followed by a review of the scholarly literature regarding the outlined independent variable, dimensional analysis, and its use as a problem-solving method for improving the medication calculation abilities of nursing students. A literature review on the role of self-efficacy, the outlined dependent variable, in medication calculations is presented. This is followed by a review of research linking the independent and dependent variables together. The chapter concludes with a summary of the reviewed literature.

Errors in Practice

In this section, literature pertaining to medical errors, medication errors, and errors made by nurses and nursing students during the medication administration phase will be presented. To conclude the section, literature pertaining specifically to drug dose calculation errors will be discussed.

Errors within Health Care

The unfortunate reality of any health care system is that errors are made on a daily basis, and subsequently, many patients' lives are put at risk (Institute of Medicine, 1999). The very nature of human beings demonstrates that they are unable to achieve perfection

(Wolf, 2007). Medical errors, in general, can be defined as “the failure of a planned action to be completed as intended or the use of a wrong plan to achieve an aim” (Institute of Medicine, 1999, p. 1), with the most-common medical errors being surgical, medication, or fluid-related incidences. According to the Canadian Institute for Health Information (2004), errors within the health care system are responsible for approximately 23,750 deaths per year in Canada. Additionally, medical errors account for approximately 1.1 million extra days spent in Canadian hospitals. Kondro (2004) stated that between 2000 and 2001, approximately 7.5% of Canadian patients admitted to hospital experienced an adverse event during their stay in hospital, with the two most common types of errors being surgical (34%), and fluid- or medication-related (24%). These errors result in roughly \$750 million in additional health-care expenditure.

In addition, it is estimated that patients who suffer from a medical error in health care are four to seven times more likely to die than those who do not (Elliott & Liu, 2010). Startling statistics from the United States reveal that medical errors are prevalent and deadly. In 1999, a report from two major studies, entitled *To Err is Human*, was released by the Institute of Medicine, which revealed that up to 98,000 Americans die every year due to avoidable mistakes made in hospitals, which cost their health care system between \$17 and \$29 billion per year. In this report, the Institute of Medicine outlined that all too often, errors were caused by flawed systems, methods, and health care environments that act to promote error instead of prevent it. In a more recent report, James (2013) estimated that more than 400,000 deaths per year could be attributed to preventable harm in hospitals, thereby making medical errors the third leading cause of death in the United States, behind heart disease and cancer. From 2009 to 2010, the

Canadian Institute for Health Information (2012a) estimated that avoidable medical errors in acute care facilities cost the Canadian health care system approximately \$397 million. O'Hagen, Mackinnon, Persaud, and Etchegary (2009) reported that approximately 4.2 million, or one in every six, Canadians revealed that they had experienced a medical error while being the recipient of health care in Canada in the previous two years.

Medication Errors

Medication errors are only one part of all medical mistakes made in health care, but they play a major role in contributing to the undermining of patient safety and patients' level of trust in health care. In order to distinguish from medical errors, medication errors are defined as "any preventable event that may cause or lead to inappropriate medication use or patient harm while the medication is in the control of health professional, patient or consumer" (Athanasakis, 2012, p. 774). Medication errors are also nearly unavoidable in health care, as the probability of committing a mistake increases with frequency of administration of medications (Wolf, 1989). Medication errors are very costly to health care systems worldwide, not only in monetary expenses, but also at the cost of human lives.

Wilkins and Shields (2008) completed a study on the frequency of medication errors made by Canadian nurses. They used data from the National Survey of the Work and Health of Nurses, which asked Canadian nurses to state how often one of their patients received a wrong medication in the last 12 months. The options for response were never, rarely, occasionally, or frequently. Two categories were created for the different responses: (a) either never or rarely and (b) occasionally or frequently. The results revealed that almost 19% (one-fifth) of the hospital Registered Nurses (RNs)

surveyed in Canada stated that medication errors had occurred with patients under their direct care occasionally or frequently.

In the United States, medication errors are the cause of approximately 7,000 (one-fifth) of the preventable deaths annually and cost the American health service approximately \$500 million per year (Athanasakis, 2012; Page & McKinney, 2007). In addition, estimates demonstrated that over eight million American families can expect one family member to experience severe adverse health effects due to medication errors made within health care (Hansen, 2004). Australian statistics show that errors in medication make up about 20% of all the errors made in hospital and cost their public health system approximately \$380 million per year (Eastwood, Boyle, Williams, & Fairhall, 2011). In Europe, medication errors were responsible for approximately one-fifth of all the preventable deaths due to adverse events within hospitals in 2001. In addition, these medication errors cost their National Health System £500 million per year and account for an average of 8.5 additional days spent in hospital (Page & McKinney, 2007).

The American Society of Hospital Pharmacists (1993) outlined 12 classifications of medication errors, which included “prescribing error, omission error, wrong time error, unauthorized drug error, improper dose error, wrong dosage-form error, wrong drug-preparation error, wrong administration-technique error, deteriorated drug error, monitoring error, compliance error and other medication error” (p. 223). Aronson (2009) outlined four types of medication errors from a psychological perspective, which include knowledge-based, rule-based, action-based, and memory-based errors (p. 603). Based on a literature review, O’Shea (1999) outlined a number of different contributing factors for

medication errors, including mathematical skills of nurses, knowledge of medications, years of nursing experience, length of work shifts, workload and staffing levels, delivery systems, policy and procedures, distractions and interruptions, and quality of prescriptions. Other identified causes included insufficient training, overload of information, lack of communication among health professionals, poor medication labeling, and deficient pharmacological knowledge of the medications (Elliott & Liu, 2010; Grandell-Niemi, Hupli, Leino-Kilpi, & Puukka, 2005; Harne-Britner et al., 2006).

According to Wolf (1989), a risk-reduction approach to medication error should include not only the identification and reduction of risks and causes associated with the error, but also the acknowledgement and reporting of error following the incident. Wolf, Serembus, Smetzer, Cohen, and Cohen (2000) examined the responses of a number of different nurses, pharmacists, and physicians to medication errors in practice. They found that most often medication errors go unreported because of feelings of guilt or shame because the health care provider fears for the health of their patient. The authors suggested that in order to increase the number of errors being reported, health care providers must feel support from colleagues and supervisors following an error, which could promote continued improvement and decrease the occurrence of system-based errors.

A study completed with a number of nursing students and experienced nurses demonstrated that increased exposure to medications and firsthand knowledge and experience in the clinical setting improve the clinical decision-making skills and clinical inference abilities of nurses. This often leads to a better understanding of the gravity of medication errors and appreciation for improved risk-reduction strategies (Wolf,

Ambrose, & Dreher, 1996). Wolf (2007) also emphasized that perfection in nursing practice is highly unlikely, but resources, such as technology and computer-assisted programs, could be utilized to assist in decreasing errors, improving therapies, and enhancing potential health outcomes for patients. Wolf emphasized that creating a culture of safety also required increased communication between health care providers, as “it is the human-machine and human-human connections that will lead to safer practice in the high-consequence systems of health care institutions” (p. 98).

These various factors demonstrate how medication errors are extremely multifaceted and multidisciplinary in nature. Health care professionals, including doctors, pharmacists, nurses, and nursing students, all play a role in contributing to the problem, as these errors can occur at any point, from prescribing and dispensing to administration and distribution (O’Shea, 1999; Wolf, 1989).

Medication Administration

Findings have shown that out of all medication errors, 26 to 38% occurred during the administration phase (Rice & Bell, 2005). Given that the administration of medication is a central activity in the provision of patient care, nurses are frequently the last link in the medication process chain. Consequently, it is believed that more than any other health care professional, nurses commit most of the medication errors (Davey, Britland, & Naylor, 2008). According to Bates (2007), nurses are responsible for 26 to 38% of all the medication errors that occur to hospitalized patients. In the UK, drug administration errors account for 25% of all reported errors within health care, with wrong drug or wrong calculation being the two most common errors made (McMullan et al., 2010). A retrospective case study completed by Wolf, Hicks, Altmiller, and Bicknell (2009)

examined all the errors committed by nursing students involving medications that were reported in the USP MEDMARX program. Their results found that wrong administration techniques, errors of omission, and improper quantity or dose of medication were the most common types of medication error for nursing students. Reports from a staff patient-safety survey found that most health care professionals attributed nursing as the profession with primary responsibility in regards to medication errors, even though they are only responsible for one part of the administration process (Hughes & Edgerton, 2005; Sulosaari, Suhonen, & Leino-Kilpi, 2010).

All the above examples and statistics demonstrate how prevalent and costly medication errors are to health care and how potentially disastrous they can be for patient safety. Nurses as well as nursing students play a pivotal role in the problem by being the administrators of the medications and the last person to check that the medications were prescribed and distributed correctly before administration (Elliott & Liu, 2008). All health care professionals must be made aware of the consequences their actions have on patients and families, and they must strive to take any necessary initiatives to decrease the level of medication errors in their practice and properly promote patient safety (Wolf, Hicks, & Serembus, 2006).

Calculation Errors of Registered Nurses

One crucial aspect for nurses in the safe administration of medications is the ability to properly calculate medications (Harne-Britner et al., 2006). It is estimated that approximately 7%, or one in every six, medication error is the result of miscalculation (Rainboth & DeMasi, 2006; Thomas, Holquist, & Phillips, 2001). In comparison to other health professionals, RNs often have much poorer medication calculation skills. Oldridge

et al. (2004) clearly demonstrated this in a pilot study in New Zealand, where a five-question drug calculation test was given to 111 health professionals, including 19 surgeons, 20 registrars, 22 medical students, 22 pharmacists, and 28 nurses. In total, all five problems were solved properly by 63% of the surgeons, 72% of the registrars, 46% of the medical students, 71% of the pharmacists, and only 24% of the nurses. According to Capriotti (2004), “fifty-six percent of nurses could not calculate medication dosages to a 90% proficiency rate” (p. 245). These findings only further support that nurses and student nurses alike must be suitably educated and able to retain medication knowledge in order to administer medications properly and safely.

Various studies have sought to designate and outline the different categories of calculation errors made by nurses. In general, three main categories of calculation errors have been discussed in the literature: arithmetical, mathematical, and conceptual errors (Bliss-Holtz, 1994; Worrell & Hodson, 1989). Arithmetical or measurement errors transpire when someone is unable to carry out the calculation properly (Wright, 2004). Mathematical errors are classified as a lack of understanding of basic mathematical concepts or principles, such as the simple math functions of multiplication and division (Blais & Bath, 1992; Wright, 2006a, 2006b). Conceptual errors are most prevalent in the literature, and are classified as the inability to properly create the mathematical equation from the information given (Eastwood et al., 2011).

Bliss-Holtz (1994) conducted a study to determine if allowing nurses the use of calculators would decrease arithmetical errors. A sample of 51 nurses was given a written calculation test to complete, initially with a calculator and then without. The results showed that using a calculator did improve the calculation results; however, over 65% of

the participants using a calculator were still unable to achieve a 90% score or higher on the test. These results suggested that calculators assisted nurses in reducing arithmetical errors, but did not adequately address the issue of nurses' lack of understanding of the mathematical concepts associated with medication calculations (Bliss-Holtz, 1994; Wright, 2006a, 2006b). Correct calculations cannot be carried out using a calculator if nurses lack the understanding of different math functions such as multiplication and division, as this affects how they input their numbers into the calculator and, subsequently, how they interpret their results (Haylock, 2010).

Bayne and Bindler (1988) identified that medication errors in nursing are often attributed to nurse's lack of medication calculation skills. In their exploratory study, they made note of the fact that this problem is very multi-faceted. They created a 20-item medication calculation test to answer the study questions, which they gave to a sample of 62 nurses (29 RNs and 33 graduate nurses) attained from two larger hospitals in Eastern Washington. The test was reported to have a high level of reliability (.82), and validity was obtained by examining pharmacology and nursing texts and consulting nursing experts. A questionnaire was included to provide the researchers with some background information of the participants, such as educational levels, practice settings, years of practice, and medication administration responsibilities. The participants were also asked to self-rate their overall level of skill and comfort with carrying out medication calculations. The findings showed that the nurses' test scores ranged between 20% and 100%, with a large concern being that only 35% scored higher than 90%. The most significant finding of the study was the nurses' self-rating of their level of calculation skills as average, above average, or below average corresponded highly with their test

scores. The authors concluded that difficulties nurses have with calculations was not a new problem and was not improving. The authors recommended that due to the low levels of medication calculation ability and mathematical skill, periodic testing of nurses in education and in practice needed to be implemented in order to correctly evaluate their dosage calculation abilities. Limitations of this study were the small sample size and non-random sampling, possibly making the results less generalizable to the greater nursing population.

In their subsequent study, Bindler and Bayne (1991) showed that out of the 110 RNs involved in that study, 81% scored below the 90% mark, and approximately 43% of the nurses scored below 70% on a written calculation exam. Interestingly, a majority of the RNs in the study rated their medication calculation skills as average. Bindler and Bayne found this concerning because these nurses were administering medications regularly, knowing full well that their calculation skills were lacking.

Calculation Errors of Nursing Students

Numerous studies have shown that student nurses also struggle in their calculation abilities and often lack the capabilities to safely administer medications (Bayne & Bindler, 1988; McMullan, Jones, & Lea, 2009; Rainboth & DeMasi, 2006; Wright, 2006a, 2006b). Even though it has been estimated that the calculations involved in completing medication problems are situated around a seventh-grade mathematics level or below, studies reveal that students still struggle with basic math abilities, such as division, use of formulas, and multiplying fractions (Rainboth & DeMasi, 2006). This lack of calculation ability has been outlined as an international problem not limited to North America. Jukes and Gilchrist (2006) stated that nursing students and staff in the

UK, US, Australia, Canada, Finland, and Sweden all struggle with their ability to properly perform medication calculations, and this lack of ability not only poses a threat to patient safety, but to the credibility of the nursing profession as well.

Nursing students also seem to struggle with the same three types of errors that cause issues for practicing nurses, as outlined above. In a Swedish study completed by Kapborg (1995), the author examined the mathematical understanding and abilities of nursing students. The results showed that common mathematical errors made by the students included difficulty with conversions and fractions and the misplacement of decimals. In addition, a variety of literature identified conceptual errors as the most common error for nursing students, resulting from an inability to accurately create the mathematical question from the information given (Blais & Bath, 1992; Grandell-Niemi, Hupli, & Leino-Kilpi, 2001; Wright, 2008a, 2008b). According to Wright (2004), nursing students must be able to conceptualize the information present in the clinical setting in order to properly create and set up the calculation formula to be solved.

In the following section, studies addressing the issue of calculation errors and nursing students are discussed. These studies are international in nature, but are applicable and relevant since this problem has been identified as a nursing issue on a global scale, which also has implications for Canadian nursing students.

In their study, Grandell-Niemi et al. (2001) sought to understand the learning experiences of graduating nursing students with medication calculations. This descriptive study had a sample of 204 graduating nursing students who were enlisted from eight different colleges in Finland. The authors used a specifically designed questionnaire as their data-collection method, which was divided into five sections, to gain a broad range

of information. A calculation instructor and additional researcher deemed the questionnaire to have adequate content validity. The findings revealed over half of the participants stated that they found math easy. Over 70% stated that they felt they had adequate medication calculation skills, with only a small number stating they did not comprehend the problems. Yet, the majority of the students struggled in solving the calculation problems, with one-third of the students making basic arithmetic mistakes, and one-fifth of the sample completing the dosage calculations incorrectly. Interestingly, the findings showed a strong relationship between the participants' self-predictions of their mathematical skills and their actual dosage calculations. The authors concluded from this study that many nursing students have difficulty with their mathematical proficiency, as established in numerous other studies (Bindler & Bayne, 1991; Blais & Bath, 1992; Craig & Sellers, 1995). Grandell-Niemi et al. suggested that nursing programs increase time and effort in creating new teaching strategies to properly educate students and evaluate their dosage calculation skills on a regular basis to determine if they are fit for practice or require additional help. Limitations outlined by the authors included the small sample size and convenience sampling which created threats to validity and generalizability.

Rainboth and DeMasi (2006) conducted a mixed-method study of 99 second-year nursing students to determine if mandatory weekly classes and calculation assignments using one standardized calculation method would improve students' performances over a period of three months. Using a pre-test, post-test intervention followed by a 4-point Likert survey, they found that the intervention group scored significantly higher on the 14 multiple-choice questions post-test than the pre-test ($p < 0.0001$). After three months, the

intervention group also scored significantly higher on the exam compared to the control group, showing a higher level of retention among the intervention group. The survey also revealed numerous themes, with the most prominent theme being “the majority of students felt that knowledge of one medication calculation method was more useful and less confusing than multiple methods” (p. 660). The authors proposed that nursing education should place increased emphasis on reviewing basic math skills with students and consistently teach one method of problem solving to reduce student confusion and mathematical anxiety. Limitations arose due to the convenience sampling and that all the participants came from one educational setting and were predominantly female and Caucasian.

Galligan (2001) conducted a qualitative study on the cognitive and metacognitive processes utilized by nursing students who struggle with medication calculations. The sample included 13 nursing students from the University of Queensland. Participation was solely based on volunteers. Ten group interviews were conducted. The questions on the interview were based on the thought processes used when completing calculations. Students were asked a series of questions before starting the calculation (i.e., How much do you like or dislike this type of question and why?) and following (i.e., Did you get stumped? Why or why not?). After each question, the interviewer prompted a discussion. The findings revealed a number of different emerging themes from the student participants, including problems in comprehending the calculation question, transformation errors in misusing a standard formula, and difficulty with division and decimals leading to process errors. Galligan postulated that by using qualitative methods like this alongside the more traditional quantitative approach, more insight into nursing

students' math struggles would result, and teachers would be exposed to better strategies for giving support to their students.

More recently, Eastwood et al. (2011) conducted a study to determine if second-year nursing students were able to correctly complete drug dosages and properly perform basic math calculations. Their sample included 52 Australian nursing students, and the instrument used was a descriptive survey to collect demographic data of the participants, attitudes surrounding drug calculations, along with some basic drug and mathematical calculations. The results showed that only 56.1% of the questions were answered correctly, while interestingly enough, 63.5% of the participants stated they had no problems with drug calculations. The majority of the errors fell into the arithmetical category (38.9%), followed closely by conceptual errors (36.0%), with computational errors coming in last (25.1%). The authors viewed the average test score of 56.1% as a dangerous and unacceptable level of mathematical skill and accurateness. They recommended that an increase in qualitative studies was needed to properly understand the reasons behind the poor mathematical performance and identify possible solutions to the problem. Generalizability of the results was limited due to the specific sample and location on one Victoria, Australia campus,

Summary

In summary, the above studies established and demonstrated the prevalence and gravity of the medication calculation errors made by nursing students and nurses globally. In the following section, I will discuss the relevant literature pertaining to the outlined independent variable, dimensional analysis. This mathematical problem-solving method will be studied in further detail and compared to other learning strategies in order

to be demonstrated as an appropriate tool for improving the medication calculation abilities of nursing students.

Independent Variable: Dimensional Analysis

Included in this section is an introduction to the independent variable of dimensional analysis. I begin this section by outlining a number of mathematical problem-solving methods often used for instructing nursing students. These methods include the formula method, algorithmic-based instruction, the triangle technique, and multiple methods. I conclude the section with a discussion of the relevant literature associated with the problem-solving method of dimensional analysis

Mathematical Problem-Solving Methods

The lack of medication calculation abilities of nurses has significantly contributed to the number of medication errors happening daily in health care. As stated previously, approximately one in six of all medication errors are linked to miscalculations (Lesar et al., 1997). These deficiencies have been attributed to a number of different factors, such as “poor basic mathematical skills, inconsistent teaching methods, inconsistent or incorrect use of mathematical formulas, and reliance on the formula method” (Koohestani & Baghcheghi, 2009, p. 233). In order to address some of these issues, a number of different problem-solving strategies have been identified to promote the development of drug calculation skills in nursing.

Formula method. Nurses are most commonly taught medication calculations using the formula method. This method uses the formula: “what you want, over what you have, multiplied by what it’s in” (Wright, 2008a, p. 40). This method has historically been portrayed as very simple, logical, and easy to use (see Figure 1).

<p>A patient requires 250 mg Amoxicillin orally The elixir available is 125 mg/mL How much do you administer?</p>
<p>Formula: $\frac{\textit{What you want}}{\textit{What you have}} \times \textit{What it's in} = \frac{250}{125} \times 1 = 2mL$</p>

Figure 1. Example of formula use and the required translation from number back to clinical practice.

However, critics have suggested that the formula method poses problems because the numbers have to be taken out of the clinical context, thereby making the focus of the method all about the mathematical skill of the student. In addition, the formula method forces students to rely simply on the structured process of the formula and their memory, creating a lack of conceptual understanding and decreasing the level of critical thinking of the nursing student (Wright, 2008a).

Algorithmic-based instruction. This instructional teaching method utilizes algorithms as a simple way to break problems down into definite yes or no stages. This is helpful because it saves time; the individual only has to read what is relevant, and the instructor has to define clearly what operations are needed to find the solution. In their study, Connor and Tillman (1990) compared algorithmic-based instruction of dosage calculations and teacher-directed instruction to determine their effects on the medication calculation abilities of nursing students. The teacher-directed instruction treatment group utilized lectures as their mode of instruction, followed by written exercises dosage calculations, while the algorithmic-based instruction cohort relied on a study guide with

explanations and demonstrations of algorithms used for solving dosage calculations. This experimental design used an initial post-test to evaluate preliminary learning combined with a second post-test to assess students' levels of retention. The author suggested that this method also enables students to develop a much higher level of decision making, with a proven degree of reliability, although the comparison yielded no significant statistical differences. However, both methods were found to be effective in helping increase student's initial learning and levels of retention. Connor and Tillman proposed that because algorithmic-based instruction was found to save faculty time and enhance the performance of students, it might be a more viable option for instruction than the traditional methods or lectures.

The triangle technique. This method was developed to assist nursing students in their medication calculations and decrease their mathematics anxiety. The goal of the triangle technique is to accommodate the different learning styles of students by encompassing all three learning styles in its conceptual plan: visual, auditory, and kinesthetic (Sredl, 2006). Sredl (2006) proposed that nursing students would have an increase in understanding calculations after undergoing instruction with the triangle technique. Using a pre-test/post-test design, the data showed a high correlation in the accuracy of calculations following the educational instruction of this technique. Sredl felt that this logical, simple, and adaptable technique could become a helpful tool for students to perform calculation problems accurately, as it "incorporates principles of adult learning-it surprises, delights, and, once comprehended and used successfully, enhances self-esteem" (p. 87). However, this relatively new instructional method is rarely cited in the literature as an effective teaching method.

Multiple methods. Wright (2004) used a qualitative design to investigate whether multiple strategies were helpful in improving nursing students' math skills. The results showed that an assortment of strategies were effective in enhancing the confidence and perceived math skills of students. In a subsequent study, Wright (2006b) utilized a quasi-experimental approach to determine if the implementation of multiple instructional methods, with the focus on conceptual and mathematical skills, was successful in improving dosage calculations. The results showed that strategies focused on these two developmental areas helped to notably improve the medication calculation abilities of nurses. Wright (2008a) completed a two-part critique of the traditional drug calculation formula taught in nursing schools. In part one of the study, Wright found that this method is often complex, illogical, and unrelated to practice. Evidence also suggested that often nurses do not even utilize the formula in practice (Wright, 2008a).

In part two, Wright (2008b) offered a variety of evidence-based alternatives to the traditional formula, including techniques like compensating, the use of building blocks, and proportional reasoning. Wright (2008b) argued that whereas the formula method is often confusing and not relevant to practice, these methods allow the nursing student to visualize and conceptually understand the calculation. Wright (2009a) then completed a three-part series to again examine nursing students' drug calculation abilities. She offered additional methods appropriate for supporting enhanced learning and noted that often the choice of method depends solely on the nurse and the problem needing to be solved. She proposed four different resources essential for supporting the drug calculation skills of nursing students: clinical practice, numeracy knowledge, proportions and factors, and clinical tools such as syringes (Wright, 2009b). She clearly stressed that consistent

exposure in clinical practice was the most essential resource in creating and sustaining drug calculation skills and promoting conceptualization of the problems involved.

Dimensional Analysis

Dimensional analysis is based on the premise that utilizing one consistent formula during the entire nursing curriculum helps decrease students' level of confusion and prevents mathematical mistakes (Rainboth & DeMasi, 2006). In a study utilizing dimensional analysis, Craig and Sellers (1995) demonstrated that students who were taught only one problem-solving technique expressed less frustration and committed fewer errors than those taught multiple or inconsistent strategies. Craig (2013) also noted that educational systems that use inconsistent and multiple formulas add to students' confusion in conceptualizing medication calculations. Dimensional analysis has been utilized in the chemistry field for a number of years and is otherwise referred to as factor-label method, conversion-factor method, unit analysis, or quantity calculus (Rice & Bell, 2005). This method operates under the premise that any expression or number multiplied by one does not change the value of that number. Therefore, conversion factors can be created from two units that demonstrate equal amounts. For example, a commonly known conversion factor is the measurement between kilograms and pounds: $\frac{1 \text{ lb}}{0.45 \text{ kg}}$ or $\frac{1 \text{ kg}}{2.21 \text{ lbs}}$. Therefore, dimensional analysis can be used when two measurements are directly proportionate to each other by utilizing the appropriate conversion factor (Craig, 2013). This method is described as a logical, systematic approach applicable to all types of medication calculations and does not involve memorizing numerous formulas (Rice & Bell, 2005).

According to Greenfield et al. (2006), dimensional analysis “is a mathematical calculation method in which the units on the medication package are systematically converted to the units of the drug ordered” (p. 92). As noted earlier, one of the biggest problems in medication calculations is the ability to properly conceptualize, the problem (O’Shea, 1999), so this standardized conceptual model provides students with one method for solving each and every medication calculation by removing formulas and reducing the number of steps required to complete the problem (Greenfield et al., 2006). According to Craig (2013), regardless of what type of medication calculation is required, in dimensional analysis, the same five steps apply (see Figure 2).

Administer PO Advil (ibuprofen) 400 mg every 6 hours for arthritis.
The dosage on hand is 200 mg/tablet

1. Identify the *given quantity* of the problem
 $400 \text{ mg} =$
2. Identify the *wanted quantity* of the problem
 $400 \text{ mg} = \text{tablets}$
3. Establish the *unit path* from the given quantity to the wanted quantity using equivalents as conversion factors.
 $400 \text{ mg} \times \frac{\text{tablet}}{200 \text{ mg}} = \text{tablets}$
4. Set up the *conversion factors* to permit cancellation of unwanted units. Carefully choose each conversion factor and ensure that it is correctly placed in the numerator or denominator portion of the problem to allow the unwanted units to be canceled from the problem.
 $400 \text{ mg} \times \frac{\text{tablet}}{200 \text{ mg}} = \text{tablets}$
5. Multiply the numerators, multiply the denominators, and divide the product of the numerators by the product of the denominators to provide the numerical value of the wanted quantity.
 $400 \text{ mg} \times \frac{\text{tablet}}{200 \text{ mg}} \times \frac{400}{200} = 2 \text{ tablets}$

Figure 2. One factor medication problem.

Compiled from Craig (2013).

A number of studies that have explored the effectiveness of using dimensional analysis for teaching medication calculation have shown interesting results. Craig and Sellers (1995) conducted a study using a quasi-experimental design to test the effects of dimensional analysis on the medication calculation abilities of second-year nursing students in Iowa. Using a pre-test/post-test data collection method, the results showed that students in the experimental group displayed a significant improvement from their pre-test to post-test score ($p = 0.00001$). Greenfield et al. (2006) completed a pilot project, also using a quasi-experimental design, to determine if dimensional analysis was useful in reducing drug calculation errors. After an analysis of the data was collected and computed with a t -test, the results showed that the experimental group, who were taught dimensional analysis, completed calculations with greater accuracy ($p = 0.05$) on the drug calculation test than those in the control group, who were taught traditional formula.

More recently, an experimental study was conducted by Koohestani and Baghcheghi (2009) to compare the traditional formula method with dimensional analysis and determine its effects on the development and retention of learning in nursing students. Interestingly enough, the results showed that improvements in the learning rate increased significantly in both groups, but the rate of retention of learning was significantly higher in dimensional analysis over the traditional formula group. Therefore, the authors recommended the use of dimensional analysis as an educational tool over the traditional method. The main limitations inherent in these studies regarding dimensional analysis were their small sample size, sampling strategy (i.e., non-random, convenience), and that they were usually delegated to only one university campus, which made their results less generalizable. Another noted gap revolved around addressing student

satisfaction in using dimensional analysis. Only one study incorporated a qualitative component to address this concept (Rice & Bell, 2005).

Summary

In summary, a number of different strategies and methods have been proposed and studied over the years in an attempt to address the medication calculation errors made by nursing students, and many of these methods have shown promising results. However, the studies reviewed have provided inconsistent results and recommendations pertaining to the most effective method in teaching medication calculations. Therefore, regardless of the outlined benefits of several other problem-solving strategies, for the purpose of this study, dimensional analysis was examined to determine its effectiveness in promoting self-efficacy for nursing students when it is utilized as a standardized teaching method for medication calculations.

Dependent Variable: Self-Efficacy

The dependent variable, self-efficacy, is discussed in the following section. The review will begin with discussing the theoretical concept of self-efficacy, followed by the role of self-efficacy in academic performance and achievement, and conclude with the effect self-efficacy has on the mathematical performance of nursing students when completing medication calculations.

The Concept of Self-Efficacy

Self-efficacy makes up a part of social cognitive theory, which proposes that success is dependent on the interactions between an individual's behaviours, personal dynamics such as thoughts and beliefs, and conditions of their environment (Schunk, 2003). Bandura (1977), often considered the father of self-efficacy, created a theoretical

framework to determine how an individual's psychological process alters his or her rate and degree of self-efficacy. In his model of self-efficacy, Bandura suggested four main sources: performance accomplishments, vicarious experience, verbal persuasion, and physiological states. He accredited the process by which people develop confidence in their abilities as multi-faceted, including personal experiences, learning from others' experiences (i.e., vicarious), what a person is told about his/her abilities, and how these experiences have affected the person emotionally. Karabacak, Serbest, Kan Öntürk, Eti Aslan, and Olgun, (2013) reiterated that these four basic factors play a large role in education and building self-efficacy in students. They stated that the first factor of personal experience is based on the idea that self-efficacy increases upon success and decreases upon failure. Secondly, observing successful performances of others may increase one's level of self-efficacy (i.e., "If he can do it, so can I"), but watching failed attempts may decrease it. Thirdly, students who receive positive verbal support while performing required tasks experience increased levels of self-efficacy, while the fourth and final method is how the ability of students to control their psychological reactions in different emotional states may indicate their level of self-efficacy in a given situation.

Bandura (1977) stated that often, "efficacy expectations determine how much effort people will expend and how long they will persist in the face of obstacles and aversive experiences" (p. 194). Bandura (2006) stated that distinction has to be made between self-efficacy and other related concepts, such as self-esteem, locus of control, and outcome expectancies. Self-efficacy is a measure of capability, whereas self-esteem is a measurement of self-worth. A high locus of control (i.e., strong belief about outcome possibilities) does not necessarily indicate a strong sense of security and enablement if

someone believes he or she lacks the level of efficacy needed to carry out challenging tasks. The third distinction concerns outcome expectations. Whereas self-efficacy measures a person's perceived capability to carry out specific tasks, outcome expectations judge the outcomes that arise from those performances. Although all three concepts are similar, distinctions must be made, as the constructs have conceptual and empirical differences that cannot be overlooked (Bandura, 2006).

Self-Efficacy and Academic Performance

Theorists have discussed the important role of self-efficacy in academic achievement and outcomes (Schunk & Rice, 1987). Schunk (1990) stated that students initially have varying levels of efficacy based on their differing academic abilities, attitudes, and previous experience, such as their previous successes and failures in academics. In addition, personal influences such as students' ability to process information, set goals, and the environmental factors they encounter, such as receiving rewards or feedback from instructors, all indicate to students how they are learning. Students then use these signals to develop a level of self-efficacy, which they then utilize during future learning (Schunk, 1990).

Zimmerman (2000) acknowledged that students with higher levels of self-efficacy, "participate more readily, work harder, persist longer and have fewer adverse emotional reactions when they encounter difficulties than do those who doubt their capabilities" (p. 86). In essence, perceived levels of self-efficacy influence a student's approach to learning along with his/her motivation to succeed. According to Schunk (1991), motivation is improved when students recognize that they are progressing in their learning, and as they continue to practice and become more proficient in their skills, their

sense of self-efficacy is maintained. According to Margolis (2005), because self-efficacy affects motivation so strongly and motivation plays such a powerful role in learning and performance, educators must be equipped with the appropriate strategies to “help struggling learners transform weak into strong self-efficacy” (p. 223).

Multon et al. (1991) conducted a quantitative meta-analysis of self-efficacy literature across various samples, designs, and methodologies to better understand the role self-efficacy played in academic performance and persistence. Their results revealed positive, statistically significant relationships, as the estimates of effect size in both meta-analyses were .38 for performance and .34 for performance. These findings suggest that self-efficacy accounted for 14% of the variance in academic performance and about 12% in academic persistence. Multon et al. concluded from their results that self-efficacy positively influenced both educational performance and diligence, regardless of students’ actual academic abilities.

Self-Efficacy and Mathematical Ability

As highlighted in the previous discussion, self-efficacy plays a major role in the academic achievement outcomes of students in general. In addition, self-efficacy has a significant effect on the mathematical ability of students. The purpose of a study completed by Pajares and Kranzler (1995) was to determine the role self-efficacy and general mental ability played in the mathematical problem-solving skills of 329 high school students in the Southern United States. Path analysis was utilized to test the impact of variables, such as math self-efficacy, general mental ability, math anxiety, and gender, on mathematical functioning. The results showed that self-efficacy as a dependent variable accounted for 27% of the variance. This showed that students’ beliefs

of self-efficacy regarding their mathematical capabilities were significantly related with their levels of math anxiety and accuracy of math calculations. Pajares and Kranzler realized that the confidence students possess greatly affects their performance along with their willingness to engage in difficult tasks and persevere in challenging times.

Other characteristics of individuals, such as their levels of math anxiety, attitudes regarding mathematics, age, and gender, also seem to play a role in determining students' levels of self-efficacy. Akin and Kurbanoglu (2011) completed a study whereby they sought to study the relationships between self-efficacy, math anxiety, and math attitudes. Their sample consisted of 372 students enrolled in a Turkish university. Using correlation analysis, their results demonstrated significant correlations between math anxiety, math attitudes, and self-efficacy. They further discussed how math anxiety can be considered a result of low self-efficacy, and an individual's positive or negative attitude regarding mathematics is highly correlated with self-efficacy. For example, students who had high levels of self-efficacy often developed positive attitudes toward mathematics, while those with low self-efficacy often developed negative attitudes.

Jameson and Fusco (2014) conducted an exploratory study with 226 undergraduate students to determine if self-efficacy and math anxiety levels differed between traditional undergraduate students (aged 18 to 22) and adult learners (i.e., students older than 22 years). Their results demonstrated that adult learners experienced higher levels of math anxiety and reported lower levels of math self-efficacy as compared to the traditional undergraduate students. The relationship between age and attitudes regarding math demonstrated the correlation that as age increased, math self-efficacy diminished and math anxiety increased. In addition, other studies have shown that

females tend to exhibit more feelings of mathematics anxiety as compared to their male counterparts, and older women experience greater feelings of anxiety than younger women (Betz, 1978; Fulton & O'Neill, 1989). Educators must take into account all the different factors that affect students' self-efficacy levels in order to properly empower students who struggle with low levels of self-efficacy and assist them in their academic performance (Schunk, 1990).

Self-Efficacy and Nursing Students

The purpose of nursing education is to graduate proficient and competent nurses. This includes assisting nursing students in gaining confidence, not only in their psychomotor skills, but also in the cognitive and affective aspects of the nursing profession (Karabacak et al., 2013; Lauder et al., 2007). Self-efficacy becomes the “theoretical basis for skills development in students, which leads to increased motivation and confidence to provide patient care in complex situations” (Karabacak et al., 2013, p. 125). According to McLaughlin, Moutray, and Muldoon (2007), self-efficacy not only affects nursing students' academic successes, but also serves as a useful tool for identifying at-risk students who may be on the brink of academic failure. In addition, self-efficacy is often a predictor of nursing students' retention and progress in nursing programs. Harvey and McMurray (1994) used two self-efficacy scales: one to measure student nurses' academic self-efficacy and another to measure their clinical self-efficacy. Their findings revealed that academic self-efficacy was predictive of students withdrawing from a course, but clinical self-efficacy was not, as students with decreased academic self-efficacy were more likely to leave the nursing program than those students with higher levels of academic self-efficacy. In addition, Laschinger (1996) maintained

that because of the positive correlations between self-efficacy and achievement, students with higher levels of self-efficacy who face difficulties in their nursing education will persist longer and expend more effort in overcoming the problem than those students who do not trust their abilities. Lauder et al. (2007) also found that the more support nursing students received from their instructors and their nursing program, the greater their self-efficacy.

As described, the medication calculation skills of nurses and student nurses alike are often sorely lacking, leading to the potential for medication errors and possible harm to patients. A number of studies suggested that nursing students struggle with mathematics self-efficacy and anxiety, and in comparison to other collegiate students, nursing students report higher levels of mathematics anxiety and score much lower on mathematical skills tests than non-nursing students (Fulton & O'Neill, 1989; Pozehl, 1996; Røykenes & Larsen, 2010). Pozehl (1996) demonstrated this phenomenon with a comparative, descriptive design, in which the mathematical calculation abilities of 56 nursing students were compared with 56 students in non-nursing majors. The findings revealed that only about 18% of the nursing group received over a 70% passing grade on the algebra test, while approximately 71% of the non-nursing group scored 70% or higher. This further suggests that math skills are lacking in student nurses, and nursing education must make appropriate improvements in order to enhance nursing students' mathematical skills.

Based on his mixed-method study completed in 2008, Walsh revealed that mathematics anxiety correlated significantly with beliefs about mathematics and students' levels of confidence in completing difficult mathematical calculations. The r^2

value revealed that 7% of the variance in math anxiety was correlated with a student's beliefs about mathematics. Walsh's findings suggested that enhanced calculation strategies must be implemented early on in nursing programs, and consistently emphasized for the duration of the program, to promote the proper learning and retention of these skills. The author outlined that a qualitative aspect to the study was important because there is often very little insight into the underlying reasons why nursing students experience such high levels of mathematics anxiety. Emphasis was also placed on how math educators must take into consideration the affective factors in mathematical research.

Andrew et al. (2008) administered a survey to second-year nursing students, which included the newly created nursing students' self-efficacy for mathematics (NSE-Math) instrument. This instrument was designed to determine levels of students' confidence in both their arithmetical skills and abilities to calculate medication dosages. Face validity of the instrument was established by a number of experienced nursing educators responsible for teaching medication calculation, and the construct validity of the instrument was calculated using factor analysis. The internal consistency of the entire instrument was calculated, with a resulting Cronbach's alpha score of 0.88. The results found that students with a low NSE-Math score performed lower on their calculation exam than those with a high NSE-Math score. The authors believed this tool was important for establishing the mathematical areas in which nursing students have the least amount of confidence, in order to promote the creation of appropriate teaching interventions to support these students. This is essential, as a frequently noted gap in the literature was that nursing programs and instructors often do not take into account the

impact of self-efficacy on students' mathematical abilities and, therefore, are not tailoring their curriculum and teaching strategies to properly enhance this learning

In a study completed in the UK, the researchers sought to compare the effectiveness of the conventional route of teaching (i.e., handout) to a self-taught e-learning module on the calculation abilities and degree of self-efficacy in nursing students (McMullan et al., 2010). Using a randomized control trial design to avoid corruption of results between the experimental and control group, they conducted their work with a fall cohort ($N = 137$) and a winter group ($N = 92$). Their results showed that students who were taught using e-learning were more adept at completing the calculation exam than those receiving the handout, and they were more confident in completing their calculations ($p = 0.022$).

Summary

As outlined in this section, self-efficacy plays a significant role in the beliefs nursing students have in regards to their medication calculation abilities and, subsequently, their ability to correctly calculate those dosages. As a few authors have mentioned, a straightforward, consistent mathematical teaching method introduced early on and utilized for the duration of a nursing program could lead to the stimulation and retention of learning and increase the self-efficacy levels of students (Blais & Bath, 1992; Craig & Sellers, 1995). Therefore, the intent of this study was to determine the effectiveness of dimensional analysis on the self-efficacy levels of nursing students. The following section is a brief review of the scholarly literature that directly relates the independent and dependent variables of the proposed study in order to outline the existing literature and need for additional research on the topic.

Intersection of Variables

Very little research has been conducted that directly measures the effectiveness of dimensional analysis in promoting self-efficacy or confidence levels of nursing students. In their study, Rice and Bell (2005) sought to determine if dimensional analysis would decrease the rate of medication errors and increase confidence in the calculation abilities of nursing students. This pilot study used a pre-test/post-test design followed by a questionnaire at the end of the semester, and the results showed that dimensional analysis was an effective strategy for improving medication calculation abilities. This was confirmed by the decrease in number of medication errors made by nursing students, and of the errors made, most were computational rather than conceptual or conversion errors. The results on self-perceived levels of confidence also showed a statistically significant increase ($p = 0.000$) by the end of the semester after being taught dimensional analysis.

According to Rice and Bell (2005), the results from this study were an encouraging report on the effectiveness and usefulness of using dimensional analysis as a calculation teaching method for nursing students. However, due to the limitations of convenience sampling from one educational site, they outlined that more investigation of dimensional analysis as a teaching method is needed. They concluded that “because confidence and accuracy in drug dosage calculation continues to be a problem for nursing students, an effort should be made to implement and evaluate strategies that could eliminate this deficiency” (p. 317). Therefore, the purpose of this study was to add to the existing knowledge base regarding the effectiveness of dimensional analysis in enhancing the self-efficacy levels of nursing students, specifically in regards to how they calculate medications.

Chapter Summary

Medication calculation errors are a serious problem in the nursing profession, and they pose a major risk to patient safety. A large amount of research has been completed outlining the prevalence and cost of medication calculation errors on health care systems, and many studies frequently outlined the inability of RNs to accurately and consistently complete medication calculations. This problem also greatly affects nursing students, which lays a responsibility on nursing programs, as graduating nurses are expected to be both proficient and competent in all aspects of the nursing profession, including the large responsibility of properly administering medications. As outlined by a number of studies, a large majority of calculation errors are due to an inability of nursing students to properly conceptualize the problem or set-up the question from the information presented, and therefore, any proposed strategy must be able to address the conceptual errors that students so often struggle with.

Dimensional analysis has been shown to be an effective method for improving these conceptual errors and increasing the accuracy of students' medication calculation abilities. Only a few studies have been conducted on the effectiveness of dimensional analysis as a medication calculation teaching method, but they all described dimensional analysis as a very simple, straightforward method that addresses the conceptual errors that students often make, and it aids in decreasing error rates. In addition, self-efficacy, or confidence in one's ability, is often shown to have a direct effect on students' calculation performances and levels of mathematics anxiety. Generally, those who experience higher levels of self-efficacy perform better, persist longer through adversity, and have increased motivation to succeed as compared to those who report lower levels of self-efficacy. Only

one study has been conducted that specifically addresses the usefulness of dimensional analysis in promoting confidence for nursing students. Therefore, the aim of this study was to examine if dimensional analysis is effective in enhancing feelings of self-efficacy for nursing students in regards to their medication calculation abilities.

The procedures and methodology used for collecting and analysing the data for this study are presented in Chapter Three. A discussion of the outlined research design is included, along with a description of the sample population. The chapter concludes with a discussion of all the ethical considerations present in the study, along with details pertaining to the instrument and the method used for data collection.

CHAPTER THREE: RESEARCH DESIGN

The purpose of this chapter is to outline the research objective, review the research question and variables, and discuss the rationale behind the chosen research design. The strengths and weaknesses of the research design will be examined along with an introduction to the sample population, data collection procedures, and analysis. An outline of the ethical considerations maintained for this study is presented as the conclusion to this chapter.

Research Objective

The purpose of this research was to assess the effects of dimensional analysis on the self-efficacy levels of undergraduate nursing students, in regards to their medication calculation abilities. In addition, this study sought to determine if dimensional analysis is superior to an alternative teaching method in promoting self-efficacy levels in nursing students. Previous literature demonstrated that when dimensional analysis was utilized as a medication calculation teaching method for nursing students, the rate of calculation errors decreased (Cookson, 2013; Craig, 2013; Greenfield et al., 2006; Rice & Bell, 2005). Only one study revealed that dimensional analysis did actually boost the confidence levels of nursing students (Rice & Bell, 2005).

There has been no study completed that specifically addressed the effects of dimensional analysis on self-efficacy levels of nursing students. Therefore, the research question for this study was: Is there a difference in the degree of self-efficacy with medication calculations between undergraduate nursing students who are taught dimensional analysis versus nursing students who are not taught dimensional analysis?

The independent and dependent variables were:

- **Independent Variable:** Dimensional analysis as a problem-solving method for medication calculations.
- **Dependent Variable:** Nursing students' self-reported feelings of self-efficacy in relation to their medication calculation abilities.

Research Design, Advantages and Limitations

This quantitative, comparative research study was carried out using a quasi-experimental non-equivalent (pre-test, post-test) control group model (Creswell, 2009), or otherwise referred to as a controlled before-and-after study (Grimshaw, Campbell, Eccles, & Steen, 2000). In this type of study, a control group with comparable characteristics and functioning to the experimental group is selected. Data collection is conducted in similar ways in both populations before and after the intervention is administered to the experimental group. The analysis compares the performances between the control and experimental groups using a between-group data analysis, and any noted changes are attributed to be a result of the intervention (Grimshaw et al., 2000).

Although randomized control trials are often viewed as the gold standard for many types of research, there are times when the conditions of this type of design cannot be met, and a quasi-experimental design is a preferred alternative (Panko, Curtis, Gorrall, & Little, 2015). Advantages of this type of design are that it is an effective way to investigate relationships in naturally occurring settings where certain necessities of a true experiment, such as control and manipulation, are not met (Behi & Nolan, 1996). In addition, quasi-experiments prove very useful “where there are practical and ethical barriers to conducting randomized control trials” (Grimshaw et al., 2000, p. S11). The

main limitation of a controlled before-and-after quasi-experimental study is the non-randomization of participants, often making it difficult to confidently attribute any noted differences as a result of the intervention (p. S11).

A quasi-experimental design using a convenience sample was used for this study. This type of design is appropriate because the control and manipulation requirements of a true experiment could not be carried out with these groups of naturally formed nursing students. Therefore, a quasi-experiment was an appropriate alternative for making inferences about the groups. Program A was designated the experimental group, as it was already teaching medication calculations using the dimensional analysis approach. A comparable control group was chosen (Program B) because of its similar characteristics and the fact that it did not utilize the teaching method of dimensional analysis for medication calculations. These population characteristics and a description of the teaching methods and interventions specific to each program are outlined in further detail in the Population and Sample section of this chapter. In addition, the data-collection procedure was carried out using the same questionnaire and was administered as closely as possible between both groups, depending on the scheduling and availability of students at each facility. The exact data-collection procedures are also outlined in the Data Collection section of this chapter. In addition, a between and within group analysis was conducted during the data analysis to determine if differences between the groups could be attributed to the intervention of dimensional analysis. The results of the analysis are presented in detail in Chapter Four.

Population and Sample

Using convenience sampling, the entire second-year undergraduate nursing student populations from two southern Alberta schools of nursing were recruited to participate in this study. In this type of study, a control group with comparable characteristics to the experimental group must be chosen in order to increase homogeneity between groups and improve the generalizability of the results. Although some differences existed between the programs in regards to scheduling and teaching approaches of the medication calculations, both Program A and B offered similar clinical rotations during second year that their students could be assigned to. These included medical, surgical, post-partum, labour and delivery, or pediatric nursing clinical rotations. These types of clinical rotations were appropriate, as a majority of medication calculation practice occurs during these clinical rotations. In addition, both programs had a comparable number of clinical hours per week of approximately two shifts per week. Both programs included a mandatory medication calculation exam to be completed at the beginning of the semester. Additional detailed demographic information for both groups will be discussed further in Chapter Four to further demonstrate the homogeneity between groups.

The entire population of second year nursing students from each site were eligible to participate in the study ($N = 210$), with more students derived from Program A ($n = 118$) than from Program B ($n = 92$). To promote homogeneity between groups, only students enrolled in the 4-year Bachelor of Nursing program were recruited to participate. Therefore, students enrolled in an after-degree Bachelor of Nursing program were not recruited to participate. Following administration of the post-test questionnaire, the final

sample of students who participated for the length of the entire study consisted of Program A ($n = 75$) and Program B ($n = 72$), making the total number of participants ($N = 147$).

Intervention

Dimensional analysis was taught throughout the entire Fall 2015 semester to all the second-year nursing students at Program A. This program begins teaching basic dimensional analysis in first year, using the first five chapters of the textbook *Clinical Calculations Made Easy: Solving Problems Using Dimensional Analysis* (Craig, 2013). Beginning in second year prior to the mandatory exam, students complete a 1.5 hour teaching session on dimensional analysis, taught by the nursing course lead who had completed an in-depth literature review on dimensional analysis. For the remainder of the semester, students utilized dimensional analysis in the clinical setting with their clinical instructors, who were also instructed in dimensional analysis. In addition, they continued to work through the rest of Craig's (2013) textbook for the remainder of the semester. Students did not complete a subsequent calculation exam at the end of the semester, but were provided with opportunities to practice the calculations in their clinical rotations, and clinical instructors were expected to continually assess students' medication calculation abilities throughout the semester.

The faculty at Program B did not use one particular method to teach medication calculations. Their teaching resources consisted of a generalized dosage calculation textbook entitled *Dosage Calculations* written by Pickar, Pickar-Abernathy, Swart, Swedish, and Graham (2014). This text teaches the three-step approach for calculating dosages: (a) Convert measurements to the same unit, (b) Consider what dosage is

reasonable, and (c) Calculate using the formula method. In addition, students worked through a free online resource for medication calculations on a weekly basis as part of the course requirements for their theory course. The online resource was created by the nursing faculty in 2003 and consists of four modules that address different aspects of medication calculations, including basic math, metric system, fluid balance, administration of oral and injectable medications, and the management and administration of IV medications. Program B also reinforced medication calculation instruction throughout the entire Fall 2015 semester during the students' clinical rotations. Students were expected to practice their medication calculations and demonstrate competence to their clinical instructors as part of their program requirements, which entailed completing their necessary calculations with accuracy as part of their passing grade during their clinical rotation.

Data Collection

The data-collection process is further outlined in this discussion. I begin with a discussion of the questionnaire design used to collect the data, including the design's advantages and limitations. This is followed by an outline of the data-collection process used for this study.

Survey Design

A survey design was utilized for collecting data, due to its effectiveness in gathering large amounts of information from a target sample in order to make inferences about the entire population (Reitz & Anderson, 2013). The survey, which included the NSE-Math questionnaire and collection of demographic data, was administered to the participants using the more traditional, paper-and-pencil approach, as face-face

administration could promote increased participation. However, some literature argued that a limitation to using a traditional paper-and-pencil survey collection method over web-based collection is that it is often more expensive and time-consuming and often involves the researcher having to travel long distances to ensure that data collection is conducted appropriately (Lefever, Dal, & Matthíasdóttir, 2007).

A low response rate may also pose a problem to the survey design, as decreased levels of participation make it more difficult to generalize the findings to the entire target population (Fowler, 2002). However, a number of strategies were used in this study to decrease non-response rates. Keeping the questionnaire anonymous, self-completed, and paper-based helped to alleviate the potential fear of being identified. In addition, administering the questionnaire during mandatory class times when students were required to meet allowed every student the opportunity to participate if they chose to. A five dollar Tim Hortons gift card was given as a small incentive following the pre-test questionnaire to encourage student participation. As a result, the response rate across both programs for the pre-test questionnaire was approximately 80% of all second-year nursing students, followed by a response rate of approximately 70% of all students for the post-test questionnaire. Response rates specific to each participating nursing program will be further discussed and outlined in the beginning of Chapter Four.

Process of Data Collection

Data were collected at both sites at the beginning of the Fall 2015 semester. Classroom presentations were utilized to introduce the purpose of the research and the details of the study at both sites. For Program A, this was completed during a mandatory orientation session. Due to the lack of available time during the orientation session, the

classroom presentation had to be conducted a week prior to the administration of the questionnaire. Administration of the pre-test questionnaire took place on September 11 and 14, 2015, directly following their mandatory calculation exam. Students who chose to participate came directly from their exam to a nearby table to complete the questionnaire. Students who chose to participate were given the complete questionnaire, with a detailed information sheet attached to the front. Consent was implied when students returned the completed questionnaire. Administration of the post-test occurred on December 1, 3, and 4, 2015, during a final mandatory pharmacology session, wherein the classroom instructor allotted the study approximately 20 minutes of class time. Another brief presentation of the study was given to remind students of the nature and purpose of the research, followed by administration of the post-test questionnaire.

Students at Program B were recruited for the pre-test questionnaire in classroom presentations during a nursing theory course. The mandatory medication calculation exam was written on September 17, 2015, with recruitment and administration of the questionnaire occurring on September 22 and 25, 2015. Classroom presentations were again used to outline the research goals and nature of the research, followed directly by administration of the questionnaire to any student who wished to participate. The post-test questionnaire was administered during one of the final nursing theory classes of the semester on November 24 and 27, 2015. The process for recruitment and administration of the post-test questionnaire was identical to the pre-test questionnaire.

Instrument

The self-efficacy questionnaire (Appendix A) consisted of the NSE-Math instrument created by Andrew et al. (2008). Demographic data, including age, gender,

math grade in high school, high school math course taken, any additional post-secondary math courses taken, and the grade students received on their mandatory medication calculation exam, were also collected. The NSE-Math instrument consisted of 12 items that are used to measure the confidence level of nursing students in completing a variety of different math skills in relation to medication calculations. Responses were measured on a 10-point Likert scale (0-3 = no confidence, 4-7 = some confidence, 8-10 = complete confidence). Responses are summed up at the end to receive the total instrument score (Andrew et al., 2008). Face validity was established by a “panel of experienced nurse academics who were involved in teaching medication calculation computation to nursing students” (p. 219). Construct validity was calculated using factor analysis, resulting in two factors being extracted from the tool. Factor one was labeled “*Confidence in application of mathematic concepts to nursing practice,*” which had a resulting Cronbach’s alpha score of 0.90, and factor two was labeled “*Confidence in arithmetic concepts,*” also with a score of 0.87 (p. 220). Reliability of the full instrument was calculated and deemed appropriate, with a resulting Cronbach’s alpha score of 0.88. Acceptable Cronbach’s alpha values often differ in the literature, but most often range between 0.70 and 0.95 (Tavakol & Dennick, 2011), and therefore, each Cronbach’s alpha score for the NSE-math instrument was deemed acceptable.

Data Entry and Cleaning

The IBM Statistical Package for the Social Sciences (SPSSTM) version 22 was used. Due to the nature of the repeated measures analysis, participants who had completed the pre-test questionnaire and not the post-test questionnaire were left out of the data analysis ($n = 27$). The dependent variable and continuous variables were checked

for normality and transformations were not performed in order to preserve the interpretability of the results. A mixed-design repeated measures ANCOVA was utilized to assess the relationships between the variables. Statistical significance was set at an Alpha level of 0.05, and each statistical test was presumed to be two-tailed. Findings from these statistical tests are further outlined in Chapter Four.

Ethical Considerations

Ethics approval was granted from the University of Lethbridge Human Subject Research Committee as well as the research ethic boards of both Program A and Program B. Written confirmation was received from the chair of the nursing program at each facility providing access to conduct a research study with the second-year nursing students.

Prior to the administration of the questionnaire, all prospective participants were informed of the details of the research project. This included a brief discussion of the purpose of the research, amount of time required to complete the questionnaire, and an explanation of the rights of the participants, including an emphasis on voluntary participation and withdrawal at any point in the study. The noted harms and benefits associated with participating were also outlined. A detailed cover letter was attached to the front of each questionnaire, providing participants with all the necessary information to make an informed decision (Appendix B). Consent was implied by voluntary completion and return of the questionnaire.

Anonymity was maintained by not collecting any personal identifying information from participants. Participants were asked to assign themselves a code number, which consisted of the first three letters of their first name, first three letters of their last name,

and their date of birth. This allowed the researcher to track the data across the pre- and post-tests. The names of participating universities were also left out of the write up of the results and were coded either Program A or B to further promote anonymity.

Confidentiality was maintained by keeping all data on a password-protected laptop, with all paper copies of the questionnaires and code numbers being kept in a locked filing cabinet in a locked office in at the University of Lethbridge. Only my thesis supervisor and I had access to the data. All hard copies of the questionnaires and code numbers will be placed in confidential bins for document disposal after five years. All data and study documents will be deleted from my personal computer after five years.

Chapter Summary

A quasi-experimental research design was utilized for this study, as it allowed the researcher to assess the outlined dependent and independent variables and attempt to answer the proposed research question. In this chapter, I outlined in further detail the process used to carry out this research study, including the sampling strategy, intervention, data-collection procedures, and analysis followed by the pertinent ethical considerations. The NSE-Math instrument created by Andrew et al. (2008) was demonstrated as a valid and reliable tool for examining nursing students' self-efficacy for mathematics. The data collected with this questionnaire were entered and analyzed using the SPSSTM software package version 22, and the results of that analysis are outlined in Chapter Four.

CHAPTER FOUR: FINDINGS

Outlined in this chapter are the findings that resulted from the statistical data analyses carried out to answer the following research question: Is there a difference in the degree of self-efficacy with medication calculations between undergraduate nursing students who are taught dimensional analysis versus nursing students who are not taught dimensional analysis?

The following independent and dependent variables helped to guide the analyses:

- **Independent Variable:** Dimensional analysis as a problem-solving method for medication calculations. The level of measurement for this variable was deemed nominal or categorical, as students were either exposed to dimensional analysis or they were not exposed.
- **Dependent Variable:** Nursing students' self-reported feelings of self-efficacy in relation to their medication calculation abilities. The level of measurement for this variable was labeled as scale or continuous, as students reported their levels of self-efficacy on a Likert scale, and responses were summed to give a total instrument score.

I present a brief review of the instrument used to collect the data, followed by a presentation of the response rates of each participating program. A comparison of the demographic data between the two programs and descriptive statistics of the independent and dependent variables is outlined, followed by the results of the statistical tests applied to assess the research question.

Instrument

Data collection was completed at two participating schools of nursing in southern Alberta, with the participants completing the NSE-Math instrument (see Appendix A). The reliability of the full instrument, and for each factor, was calculated using Cronbach's alpha. The Cronbach's alpha score for the full instrument was 0.88, while the result for the "*Confidence in application of mathematic concepts to nursing practice*" factor was 0.90, and for the "*Confidence in arithmetic concepts*" factor, the resulting score was 0.87.

Response Rates

A total population size of 210 second-year nursing students were eligible and recruited to participate in the study at the pre-test and post-test phase. The distribution of response rates for each nursing program is presented in Table 1.

Table 1. *Distribution of Response Rates by Program*

Program	<i>N</i>	<i>n</i> (Response Rate) Pre-test	<i>n</i> (Response Rate) Post-test
A	118	91 (77%)	75 (64%)
B	92	82 (77%)	72 (67%)
Total	210	173 (77%)	147 (67%)

Using the G-Power statistical software version 3.1.9.2 and taking into account the total population size of 210, an appropriate sample size was estimated prior to the study. Assuming the alpha level a priori is set at .05, the level of acceptable error is 5%, the effect size is moderate at 0.5, and with the actual power rating set at 0.90, the

recommended sample size generated was 140. In addition, the recommended sample size for each group was 70 (see Appendix C). Therefore, the resulting sample from this study was considered acceptable at 147 participants, with 75 participants from Program A and 72 participants from Program B.

Demographic Data

The descriptive statistics completed for the entire sample as well as the descriptive statistics for each participating program are presented in this section. Normality was assessed for each continuous variable in the study: namely, the dependent variable as well as the variables of age, high school math grade, and students' grades on the mandatory medication calculation exam. Skewness was noted in each of the above-mentioned continuous variables; however, they were not transformed in order to preserve the interpretability of the results. A Chi-square test was conducted for nominal variables, and the Mann Whitney U test was used to examine the differences for the continuous variables because of the failure in the assumption of normality.

Descriptive Statistics

The overall mean age of the participants was 22.35 years ($SD = 5.46$), with ages ranging from 18 to 45 years. For Program A, the mean age of participants was 21.53 years ($SD = 5.20$), with a range of ages from 18 to 43 years, while the mean age of participants from Program B was 23.21 ($SD = 5.63$), with ages ranging from 19 to 45 years. A Mann-Whitney U test was conducted to determine if the ages and grades received on the medication calculation exam differed significantly between programs. The mean rank of Program B was found to be significantly higher than Program A, Standardized Test Statistic = -3.854 ($U = 1,722.0$), $p < .001$ (2-tailed), indicating that

students from Program B were significantly older than students from Program A. The overall gender distribution showed that there were 132 (89.8%) female and 15 (10.2%) male participants respectively for the study. Program A had 66 female participants and nine male participants, while Program B had 66 female and only six male participants.

In regards to high school math courses taken, 51.7% of all the students had taken Pure Mathematics 30, 18.4% had taken Applied Mathematics 30-2, and 17.0% had taken both Pure Mathematics 30 and Applied Mathematics 30-2. Only 12.9% of students had not taken either Pure or Applied Mathematics in high school, as these students did not take high school mathematics in Alberta, but completed a comparable high school mathematics course outside of Alberta. Descriptives were also collected on whether or not students had taken any additional post-secondary mathematics courses.

Approximately 46.3% of all the students claimed they had taken additional courses, 50.3% of students stated they had not taken any additional courses, while the remaining 3.4% of the students did not respond to the question. Students were asked to specify which additional courses had been taken. Not every student specified which courses had been taken, although a number outlined “Calculus, Statistics, or Bio Statistics” as examples. The frequencies of the high school math courses taken and any additional post-secondary courses taken between programs are outlined in Table 2.

In addition, a Chi-square test was completed to determine whether a significant difference existed between programs in the frequency of other post-secondary math courses students had taken. A significant Chi-square statistic was obtained: $\chi^2_{(1, N=142)} = 25.275, p < .001$, demonstrating that a significantly higher number of students from Program B had taken other post-secondary math courses in comparison to Program A.

Table 2. *Frequencies of High School Math Courses Taken*

Math Courses		Program A	Program B
High School	Applied	14	13
	Pure	39	37
	Both	10	15
	Other	12	7
Any Other Post-Secondary	Yes	20	48
	No	53	21

Students were also asked to share their final grade for high school mathematics.

The grade distribution of participants is shown in Table 3.

Table 3. *Distribution of Final Grades in High School Math*

High School Math Grade	Program A	Program B	Total
A (86–100%)	37	43	80
B (73–85%)	30	15	45
C (67–72%)	5	6	11
D (60–66%)	1	7	8
E (50–59%)	2	1	3

A Chi-square test was conducted to evaluate whether students' final math grades differed significantly between programs. A significant Chi-square statistic was obtained $\chi^2_{(4, N=147)} = 10.317, p = .035$. Follow-up comparisons using the *z*-Test of Column Proportions were conducted, and the results are provided in Table 4. The results demonstrated that Program A (experimental group) had a significantly higher number of

students with a final grade of 73–85% in high school math, and Program B (control group) had a significantly higher number of students with a final high school math grade of 60–66%.

Table 4. *Comparisons of Column Proportions*

Final Grade in High School Math	Group	
	Program (A)	Program (B)
A (86–100%)		
B (73–85%)	B	
C (67–72%)		
D (60–66%)		A
E (50–59%)		
F (0–49%)		

Results are based on two-sided tests with significance level .05. For each significant pair, the key of the category with the smaller column proportion appears under the category with the larger column proportion.

In addition, students were asked to reveal the grade received on their mandatory medication calculation exam taken at the beginning of the semester. The mean grade received on the exam for the entire sample was 94.40% ($SD = 6.35$), with grades ranging from 70 to 100. For each program, the distributions of grades received on the mandatory medication calculation exam are presented in Table 5.

Table 5. *Comparison of Medication Calculation Grades between Programs*

Program	Mean	SD	Range
A	94.46	7.19	70–100
B	94.33	5.40	77–100

Mixed-Design ANCOVA

A mixed-design analysis of covariance, or ANCOVA, was chosen to analyze the data collected in this study, as this method is effective for testing the differences between two independent groups, while also exposing subjects to repeated measures (Green & Salkind, 2011). In addition, ANCOVA also controls for the effects of other continuous variables, called covariates, that are not of primary interest in the study. Therefore, ANCOVA breaks down the variance of the dependent variable into variance explained by the covariates and the categorical independent variable.

In this type of mixed-effect design, there is a between-subjects variable and a within-subjects variable followed by a repeated measures design. This allows the researcher to measure multiple independent variables found in the data. According to Howell (2010), the following assumptions are inherent to this type of statistical design: (a) change scores for each condition are normally distributed around the mean; (b) the sphericity, or difference score, variances are equal across all levels and are evaluated by the Mauchly's Test; and (c) the homogeneity of variance, or error variance, is the same across each population.

In regards to this study, the time-to-time collection of data using the pre- and post-questionnaire was designated as the within-subjects factor in the mixed-design

ANCOVA. The experimental and control groups were outlined as the between-subjects factor. The continuous variables of age and high school math grade were significant contributors to the model, but were not of primary interest in the study; therefore, they were deemed as covariates in order to statistically control for their effects on the analysis. The results from the analysis are outlined in the following section.

Results

A mixed-design, repeated measures ANCOVA was used to assess the effectiveness of dimensional analysis on the reported self-efficacy levels of nursing students between Program A and Program B. The average NSE-Math Score for both Program A and Program B for the pre- to post-test questionnaire are presented in Table 6.

Table 6. *Means and Standard Deviations of NSE-Math Scores for Program A and Program B from Pre to Post-Test Questionnaire*

NSE-Math	Group	Mean	SD
Pre-Test	Program A	86.4	13.1
	Program B	89.9	14.2
Post-Test	Program A	89.0	12.8
	Program B	91.9	14.8

The means demonstrate that overall, students from Program B (control) reported higher levels of self-efficacy at both the pre- and post-test phase as compared to Program A (experimental).

The main effects and interaction effects are displayed in Table 7. As can be seen, a non-significant main effect was obtained for Time, indicating that the overall self-

efficacy for mathematics scores did not significantly increase from the pre- to post-test questionnaire. In addition, a non-significant main effect was found overall per group, demonstrating that there was no significant difference between Program A (experimental group) and Program B (control group) in students' reported self-efficacy scores.

Table 7. *Main Effects and Interaction Effects in the Mixed-Design ANCOVA*

Variable	ANCOVA Test Result	Partial Eta Squared
Time	$F(1, 140) = 1.72, p = .192$	Partial $\eta^2 = .012$
Group	$F(1, 140) = 2.50, p = .116$	Partial $\eta^2 = .018$
Gender	$F(1, 140) = 6.08, p = .015^*$	Partial $\eta^2 = .042$
Age	$F(1, 140) = 7.32, p = .008^*$	Partial $\eta^2 = .050$
High School Math Grade	$F(1, 140) = 8.42, p = .004^*$	Partial $\eta^2 = .057$
Time x Group	$F(1, 140) = 0.54, p = .463$	Partial $\eta^2 = .004$
Time x Gender	$F(1, 140) = 0.13, p = .715$	Partial $\eta^2 = .001$
Time x Age	$F(1, 140) = .145, p = .231$	Partial $\eta^2 = .010$
Time x High School Math Grade	$F(1, 140) = 0.44, p = .508$	Partial $\eta^2 = .003$
Time x High School Math Grade x Gender	$F(1, 140) = 0.53, p = .467$	Partial $\eta^2 = .004$

Note: * $p < .05$

Finally, no significant interaction effects were obtained between Time x Group, Time x Gender, Time x Age, Time x High School Math Grade, and Time x High School Math Grade x Gender. This indicates that each teaching method utilized at each nursing program has equivalent efficiency in improving the self-efficacy levels of nursing students. These combined results demonstrated that in this particular study, dimensional

analysis was, in fact, not any more effective in enhancing the self-efficacy levels of nursing students at Program A as compared to the alternative teaching method used by Program B.

A number of significant main effects are noted in Table 7. As can be seen, a significant main effect was obtained for Gender, indicating that overall, men reported greater levels of self-efficacy as compared to the women. It should be noted that the overall percentage of male participants in this study (10.2%) was greater than the national proportion of male RNs employed in Canada (6.4%) (Canadian Institute for Health Information, 2012b). However, from a statistical perspective, due to the large gender imbalance in the population, these results must be viewed with caution.

In addition, a number of significant main effects were noted for the covariates: namely, age and high school math grade. These effects suggest that both age and previous math grades in high school were important confounders between the groups and contributed significantly to the model. A multiple regression was performed to examine the correlations between these two significant covariates and the dependent variable. Reported level of self-efficacy was designated as the dependent variable, and age and previous high school math grade were designated as the independent variables. Entry of the variables was simultaneous. Displayed in Table 8 are the unstandardized regression coefficients (B); the standardized regression coefficients (β); the semi-partial correlations (sr_i^2), and adjusted R^2 .

Table 8. *Multiple Regression Results*

Independent Variables	Regression Coefficients (<i>B</i>)	Standardized Regression Coefficients (β)	Squared Semi-Partial Correlations (sr_i^2)
Age	.42*	.17	.03
High School Math Grade	2.94*	.21	.04
Constant	86.16**		

$R = .26^*$; adjusted $R^2 = .056$; * $p \leq .05$; ** $p < .001$

R was significantly different from zero, $F(2, 146) = 5.29, p = .006$. Both variables of age ($sr_i^2 = .03$) and previous grade in high school math ($sr_i^2 = .04$) contributed significantly to the prediction of increased self-efficacy ratings. Altogether, only 5.6% of the variability in students' self-efficacy ratings was predicted by knowing the scores on the two independent variables of age and previous high school math grade. Therefore, these positive significant correlations could indicate that older age and higher math grades received in high school are associated with increased levels of reported self-efficacy.

Chapter Summary

In this chapter, the results of the statistical analyses were presented. These findings demonstrated that the teaching method of dimensional analysis did not have any statistical impact on the self-efficacy levels of nursing students. However, other factors such as the age, gender, and previous high school math grades of the nursing students significantly affected their reported levels of self-efficacy in regards to their medication

calculation abilities. The discussion of these findings is discussed in Chapter 5, along with any drawn conclusions from the findings. The limitations of the research study are outlined along with the implications that the research findings have for nursing education. I conclude Chapter 5 with an outline of recommendations for future research.

CHAPTER FIVE: DISCUSSION

This chapter begins with a reiteration of the purpose of the research and the research question. An interpretation of the results of the data analysis and a discussion of the research findings in light of previous literature are presented. The implications for nursing education, research limitations, and recommendations for future research are also included. The plans for the dissemination of the results of this study conclude the chapter.

Purpose of the Research

The ability to calculate medications both competently and confidently is an integral aspect of patient safety and an essential skill required of nursing students (Bayne & Bindler, 1988; Rainboth & DeMasi, 2006). However, medication calculation errors are a common occurrence in nursing, as completing drug dosages is challenging for nursing students and often triggers anxiety and confusion (Walsh, 2008). The ability to calculate medication doses correctly is also greatly influenced by the degree of self-efficacy that nursing students possess (Hansen, 2004; McMullan et al., 2011). Studies have demonstrated that nursing students often have difficulty with self-efficacy in regards to mathematics, experience higher levels of math anxiety, and score much lower on math skills tests than students from other disciplines (Pozehl, 1996; Røykenes & Larsen, 2010).

According to the entry-to-practice standards of the College and Association of Registered Nurses of Alberta (2013), nursing students must demonstrate responsibility and accountability for all areas of their practice, including the safe administration of medications to the patients they are actively caring for during their clinical rotations.

Therefore, it is imperative that nursing students fully understand the implications of medication calculation errors to patient safety, and they must seek to make every effort to prevent such errors in their practice. Since undergraduate nursing education programs in Alberta are charged with preparing graduates able to achieve entry-to-practice competencies (College and Association of Registered Nurses of Alberta, 2013), they play a vital role in ensuring that students are provided with resources to practice both competently and confidently.

The purpose of this study was to examine the effectiveness of dimensional analysis in improving the self-efficacy levels of nursing students in regards to their medication calculation abilities. An additional objective was to provide useful information for the enhancement of nursing curriculum in the area of mathematics self-efficacy and medication calculation abilities. Utilizing the theory of self-efficacy as a theoretical framework, the following research question was developed:

- Is there a difference in the degree of self-efficacy with medication calculations between undergraduate nursing students who are taught dimensional analysis versus nursing students who are not taught dimensional analysis?

Discussion of the Findings

An initial hypothesis I made was that dimensional analysis would enhance nursing students' level of self-efficacy for medication calculations. However, this hypothesis was rejected based on the results of this study. The findings of this study demonstrated that dimensional analysis, the teaching method used at Program A (experimental group) was not any more effective in increasing the nursing students' self-efficacy levels in regards to their medication calculation abilities in comparison to

nursing students' self-efficacy levels in Program B (control group). In addition, no statistically significant increases in self-efficacy levels were seen over time for either the experimental or control group.

Although one study in the literature demonstrated an increase in perceived levels of confidence (Rice & Bell, 2005), the findings of this study are congruent with the results from a number of other studies, which have demonstrated no statistical differences between a variety of different instructional approaches on nursing students' calculation competency and confidence (Connor & Tillman, 1990; Glaister, 2005; Koohestani & Baghcheghi, 2009). Teaching methods such as the formula method, algorithmic-based instruction, the triangle technique, multiple methods, ratio-proportion method and dimensional analysis have all been outlined as effective tools for improving dosage calculation abilities of nursing students (Connor & Tillman, 1990; Fulton & O'Neill, 1989; Glaister, 2005; Hunter Revell & McCurry, 2012; Sredl, 2006; Wright, 2004, 2008a). The findings of this study are in keeping with the findings of other studies, which claim that there is inconclusive evidence as to which method is most appropriate for improving the skills of nursing students.

Despite the lack of a statistically significant increase in self-efficacy, there was however, a mean improvement in self-efficacy over time across both groups participating in the study. The average NSE-Math Scores for both Program A and Program B demonstrated that overall, students from Program B reported higher levels of self-efficacy at both the pre (Mean: 89.9) and post-test (Mean: 91.9) phase as compared to Program A (Pre: 86.4, Post-test: 89.0). In addition, the program that utilized dimensional analysis (Program A) had a slightly greater increase in reported self-efficacy levels

compared to Program B. This finding could be explained by the conceptual nature of dimensional analysis and is consistent with a variety of literature, which claimed that this method promotes enhanced conceptualization of the material and increased retention of learning (Craig & Sellers, 1995; Greenfield et al., 2006; Koohestani & Baghcheghi, 2009). This result demonstrated clinical significance for supporting dimensional analysis as an effective instructional approach for medication calculations.

During the analysis, a number of other variables were identified as having a significant impact on the students' reported levels of mathematics self-efficacy. These included gender, age, and high school grades in mathematics, which will be discussed in further detail in the following sections.

Gender

Approximately 90-95% of nursing students are female; therefore, understanding the effect gender has on mathematical competency and self-efficacy in nursing students is of vital importance (Hodge, 1997). The gender distribution for the participants in this study showed that there were 132 (89.8%) female and 15 (10.2%) male participants respectively. A larger number of male participants participated in this study than what is typically found in the RN population. The most recent update from the Canadian Institute for Health Information (2012b) report entitled *Regulated Nurse: Canadian Trends, 2007 to 2011* stated that the national proportion of male RNs makes up only 6.4% of all RNs employed in Canada. Therefore, the gender distribution found in this study represented a higher proportion of male nurses than what is found in other studies, making the findings generalizable.

Gender differences and mathematics self-efficacy. The results from this study demonstrated that overall, the male participants reported higher levels of mathematics self-efficacy than the female participants. The male participants scored higher on their mathematical self-efficacy ratings for both the pre-test questionnaire (Mean: 96.14) and the post-test questionnaire (Mean: 97.51) as compared to the females (Pre-test mean: 87.3; Post-test mean: 89.67). The female participants saw a slightly larger increase in self-efficacy levels across the study than the males, but the males continually scored much higher than the females across the study. The slight increase in self-efficacy over time for the female participants might be reflective of their perceived success in being able to administer medications accurately and safely during their clinical course. This was in keeping with Stage and Kloosterman's (1995) findings that self-efficacy was significantly related to the final course grades of the female participants, but not the male participants. Indeed, female students often outperform their male counterparts in the classroom by receiving higher grades (Kenney-Benson, Pomerantz, Ryan, & Patrick, 2006), which could have been a factor in enhancing their feelings of self-efficacy for mathematics over the course of this study.

In keeping with Fennema and Sherman (1977) and Hackett (1985), where men consistently scored higher levels of confidence as compared to women, the male participants in this study rated their confidence levels with mathematics consistently higher than the female participants. It may be that the effects of sex role socialization or the method of learning the social expectations and values linked with one's sex to mathematics-related behaviour influences attitudes towards mathematics and choices of math courses taken in high school (Davies, Spencer, & Gerhardstein, 2002; Eccles, 1984;

Hackett, 1985). In addition, the low expectancy pattern that many females often display in regards to mathematics, often a result of long-held gender role stereotypes that display women as less intellectually competent than men, could assist in explaining the results of this study (Betz & Hackett, 1983; Eccles, 1984; Franceschini, Galli, Chiesi, & Primi, 2014).

Relevance to nursing students. As noted previously, the large majority (approximately 90%) of nursing students are female. Yet, even with conducting an exhaustive search, little literature was found that pertained to the effect that gender has on mathematics self-efficacy levels and mathematical competency specific to nursing students. Within the literature that was retrieved, some authors believed that female nursing students have social and cultural predeterminants, such as the effect of sex-role socialization and gender stereotypes, which impair their computational abilities in mathematics (Fulton & O'Neill, 1989). The finding of this study could be explained by the continual view permeating many nursing students and the public alike, that educational areas such as the health sciences and literature are deeply associated with human concerns while mathematics is only a concern for other more mechanical and scientific disciplines (Hodge, 1997). Another noted issue, which could potentially explain the results of this study, has demonstrated that nursing students often choose to enrol in nursing school because they enjoy science, dislike mathematics, and feel that proficiency in mathematics is not a necessary skill required in nursing (Fulton & O'Neill, 1989). However, the low levels of reported self-efficacy by female participants noted in this study and the high frequency of medication calculation errors recorded in the literature clearly disqualify this notion (Oldridge et al., 2004; Rainboth & DeMasi, 2006; Thomas

et al., 2001; Wright, 2004). Therefore, this deep-rooted notion that mathematics is often disconnected from women continues to affect how women view their mathematical abilities and, subsequently, how they rate their levels of self-efficacy in relation to mathematics.

This finding suggests that there is a continual need for all nursing students, regardless of gender, to be suitably educated to develop a strong sense of self-efficacy in their mathematical abilities in order to administer medications properly and safely. Hence, gaining a broader understanding of the issues surrounding gender and mathematical competency is an essential concept for nursing education.

Age

Another major finding in this study indicated that older students reported higher levels of self-efficacy than younger students. The overall mean age of the participants was 22.35 years, with ages ranging from 18 to 45 years. For Program A, the mean age of participants was 21.53 years, with a range of 18 to 43 years old, while the mean age of participants from Program B was 23.21, with ages ranging from 19 to 45 years. The positive significant correlation obtained between age and self-efficacy ratings using multiple regression demonstrated that as the age of the student increased, so did their self-efficacy rating. This finding is important to note, as trends in enrolment have shown that an increased number of mature students (not new high school graduates) are entering nursing programs (Moyer & Wittmann-Price, 2008).

Studies that specifically addressed the relationship between age and self-efficacy were limited. However, a number of studies were found that examined the relationship between age and *academic performance*, or achievement levels, of students. In the

literature, academic performance was often measured using the grade point average of students or their level of success on a particular assignment or examination. A close connection exists between the concepts of academic performance and self-efficacy, as self-efficacy is often a significant predictor of achievement (Motlagh, Amrai, Yazdani, Abderahim, & Souri, 2011). Some authors have even noted self-efficacy as “the strongest cause of the respondents’ academic achievement” (Yusuf, 2011, p. 2625). Therefore, the findings from this study were consistent with the results from a number of studies in other areas of education, despite the fact that they specifically addressed the relationship between age and performance levels rather than self-efficacy. The relevance of these studies in supporting the findings of this particular study cannot be overlooked and will be explored more fully in the following paragraphs.

Age and performance levels. The results of this study demonstrated increased age is significantly associated with higher levels of self-efficacy. Age is often a significant predictor of increased performance levels. Mature students, who have prior life experience and did not enter post-secondary education directly out of high school, seem to consistently demonstrate higher academic performance levels and display greater depth and quality in their learning approaches in comparison to their younger classmates (Clutts, 2010; Richardson, 1995). A select few authors noted that age was not significantly associated with either the performance or self-efficacy levels of undergraduate students (Clutts, 2010; Ebenuwa-Okoh, 2010); rather, their improved performance was often associated with their approach to learning. Consequently, it is possible that the more mature students in this study expressed higher levels of self-efficacy because they engaged in different approaches to learning. According to Sadler-

Smith (1996), mature business students (> 23 years) reported using a “deeper” approach to learning that included a critical examination of the literature, broad application to a variety of contexts, and use of reasoning and logic. In contrast, the non-mature students (\leq 23 years) used more of a surface approach to learning. These students seemed to rely on routine memorization of material, accepted ideas without complete understanding, and demonstrated difficulty in applying the material to a wider context.

Relevance to nursing students. Specifically, in regards to nursing students, increased age also seemed to significantly affect their academic performance levels. Older nursing students often achieve better results in their academic performance in their coursework and obtain higher grades than their younger counterparts (Salamonson & Andrew, 2006; van Rooyen, Dixon, Dixon, & Wells, 2006). Ofori (2000) reiterated the findings of this study by demonstrating that age significantly predicted the overall performance of nursing students in their nursing module assessments. Ofori’s findings suggested that “non-mature” students (< 20 years) were classified as being at-risk in terms of their academic performance as compared to the “very-mature” students (> 34 years). In addition, the mature nursing students could have been more intrinsically motivated in their academic performance as a result of their prior life experience, and they may have utilized a deeper approach to studying because they perceived their schooling as a final opportunity for developing a sustainable career (Ofori, 2000; van Rooyen et al., 2006).

Therefore, according to this study, increased age is correlated with increased levels of mathematics self-efficacy in nursing students. This finding was supported by other literature that suggested increased age significantly affects the academic

performance levels of students. However, because pertinent literature rarely addressed nursing students' self-efficacy levels for medication calculations specifically, it is unclear how age directly affects the mathematics self-efficacy levels of nursing students. The findings from this study support the need for further investigation.

Previous Math Grades in High School

The third, and final, major finding from this study demonstrated that previous high school math grades contributed significantly to the participants' level of mathematics self-efficacy. The positive significant correlation between grades and self-efficacy indicated that higher math grades received in high school were associated with increased levels of reported mathematics self-efficacy.

This finding was supported in the literature by a number of different researchers. Bandura (1977) outlined four main sources of self-efficacy, with the most important factor being the interpretation of previous accomplishments or "mastery experience". In accordance with social cognitive theory, previous academic accomplishments provide this type of mastery experience, which allows for the creation and fostering of positive self-efficacy beliefs (Pajares & Graham, 1999). In keeping with Karabacak, Serbest, Kan Öntürk, Eti Aslan, and Olgun's (2013) findings, the participants in this study who experienced higher levels of self-efficacy may have had personal experiences of success and, therefore, were more likely to score higher on their self-efficacy. These incidents of success often proved to be the most consistent source of students' self-efficacy throughout all domains of academics, as "successful performance in a domain can have lasting effects on one's self-efficacy" (Usher & Pajares, 2008, p. 89).

Indeed, previous mathematics performance is strongly associated with self-efficacy (Stage & Kloosterman, 1995). So while one study found that math grades were not significantly correlated to students' self-efficacy levels (Clutts, 2010), the majority of the literature supported the finding from this study. Students with increased overall achievement in mathematics are generally the students who are more likely to report increased feelings of confidence in their abilities and self-efficacy towards mathematics (OECD, 2013). In addition, age and mathematics grade self-efficacy often conjointly predict students' mathematics performance levels (Spence & Usher, 2007). Therefore, based on the results of the current study and previous research, it is concluded that previous success in mathematics plays a significant role in the development of the mathematics self-efficacy levels of nursing students. The implications of this finding for nursing education will be discussed further in the following section.

Implications for Nursing Education

Results from this study have implications relevant to nursing education. The identification of certain factors that contribute to poor mathematics self-efficacy in nursing students and subsequent poor performance in calculating drug dosages is an important priority of nursing education. Since age, gender, and previous math grade in high school have been identified as contributors to students' levels of self-efficacy in regards to their medication calculation abilities, at-risk students could be identified before beginning their nursing program. For example, the finding from this study, which demonstrated that previous high school mathematical grades contributed to students' self-efficacy levels, supports the current idea of retaining math grades as a defining criterion for admission into nursing programs. According to van Rooyen et al. (2006), excellent

academic performance in high school predicts enhanced results in nursing course grades and performance. In a study exploring the medication calculations of newly entering nursing students, Hutton (1998) also demonstrated that students with higher mathematics grades in previous courses taken completed their calculations more accurately than those who had lower previous math grades. Therefore, creating and utilizing appropriate admission criteria in order to admit the most suitable nursing students continues to play a major role for nursing programs (Shulruf, Wang, Zhao, & Baker, 2010).

Thus, this information could benefit nursing programs by guiding admission committees in the selection of appropriate potential students. Schools of nursing have both an ethical and professional responsibility to graduate nurses who are skilled and possess the knowledge and competency to provide safe and appropriate patient care. Utilizing dependable, evidence-based indicators to guide the admission process assists nursing programs in ensuring that they admit students with the highest potential to succeed on both the academic and clinical front (Ali & Naylor, 2010). For example, a math test could be developed for use in the admission process for educators to obtain a baseline level of the mathematical abilities of their potential students and identify any at-risk students prior to admission. In addition, a brief self-efficacy questionnaire for mathematics could be developed to assess the level of confidence that students have prior to entry into nursing school. Confirming that prospective students have a solid mathematical knowledge base prior to admission could save nursing programs future time and energy in ensuring that their students are adequately prepared to complete medication calculations correctly and confidently.

Nursing educators also need to be aware of indicators like age, gender, and previous math grades as precursors to self-efficacy levels, as they may need to “tailor their instructional strategies and counseling practices in ways most supportive both of their students’ self-efficacy and, subsequently, of their achievement” (Usher & Pajares, 2008, p. 92). Such guidance and resources could include self-study workbooks, computerized teaching modules and tutoring, and additional time in the practice lab to assist students with conceptualization of the information. Consistent encouragement from both teachers and peers is an example of the third source of self-efficacy according to Bandura (1977). These types of supportive messages can boost students’ confidence in their mathematical abilities and increase their level of effort and perseverance when they are struggling. Naturally, then, it is imperative that nursing instructors are conscious of the factors that help to generate and maintain the self-efficacy beliefs of their students.

However, in order to provide the appropriate guidance and encouragement to students who are struggling with medication calculations, nursing educators must also be thoroughly equipped with the knowledge and properly taught how to apply the instructional strategy to their own medication calculation abilities. This may require nursing programs to increase faculty support to include enhanced educational sessions for instructors on how to properly teach medication calculations. Because only when nursing instructors feel confident in teaching the method and applying it to their own practice will they be able to properly support their students and provide resources to boost their confidence and improve their calculation abilities.

Despite the lack of statistical significance in this current study for supporting dimensional analysis as an effective method for promoting mathematics self-efficacy in

nursing students, its clinical significance for enhancing the calculation abilities of nursing students cannot be overlooked. As mentioned earlier, a variety of available literature demonstrated no statistical significance between different learning approaches for medication calculations, as each method seemed to have advantages and disadvantages. Some literature determined that a variety of teaching methods should be readily available for the calculation instruction of nursing students to meet the variety of learning needs of nursing students (Wright 2008a, 2008b). However, additional research outlined that in order to promote consistency and greater retention of learning, educators must decide on one approach to utilize exclusively across the entire nursing curriculum (Blais & Bath, 1992; Craig & Sellers, 1995; Hunter Revell & McCurry, 2012). In order to address the different learning styles of students, this single standardized approach must also “integrate various teaching strategies, including the use of technology to complement the learning styles of students” (Hunter Revell & McCurry, 2012, p. 1355).

Additional innovative strategies, such as self-study workbooks, computerized modules, and increased availability of practice time in the simulation lab, could also promote enhanced conceptualization of the material, leading to an enhanced development of students’ self-efficacy levels. The feasibility of using one approach across the curriculum would also be improved, as each instructor would be educated in the teaching method and better equipped to answer the potential questions that arise from the nursing students. Therefore, a continual need remains for nursing education to evaluate and develop their dosage calculation teaching strategies in order to properly teach mathematics to nursing students and enhance students’ self-efficacy levels.

Research Limitations

A number of research limitations were present in this study and could have had potential implications for the results. This study was completed at only two institutions using convenience sampling for recruitment of participants, therefore possibly making the results less generalizable to other undergraduate nursing programs. Another noted limitation was that students from Program A had been previously exposed to the teaching method of dimensional analysis in year one of their nursing program. This pre-exposure to dimensional analysis could possibly explain why there was no significant increase in self-efficacy levels from students at Program A during the time of the study. In addition, the time frame for this study may have been negatively influenced by the limitations enforced by the nursing students' academic program. The study was completed over only one semester of study, which may not have been an adequate amount of time for dimensional analysis to be properly learned and conceptualized by students. The effectiveness of dimensional analysis may have been diminished because of the time restraints of this particular study, as "additional expenditure of time and effort for automaticity to occur was not possible" (Glaister, 2005, p. 10). An additional limitation for this study was the use of self-reporting for data collection. Self-reporting is often subject to different biases, and its credibility is questioned, as participants often exaggerate their abilities for reasons of self-enhancement and presentation, self-deception, and memory (Paulhus & Vazire, 2007).

Recommendations for Future Research

Subsequent research on this topic could address one of the limitations of this study by recruiting participants from more than just two schools of nursing. Such a study

could also incorporate more than just second-year nursing students in their target population. Alternatively, a longitudinal study could address this study's limitations by introducing the study prior to any teaching of dimensional analysis. This would enable the researcher to receive proper baseline values of students' reported self-efficacy levels. The researcher could then follow students through their entire undergraduate nursing education and possibly one year into their RN practice, to observe any changes in their mathematics self-efficacy, which could be directly associated to dimensional analysis. Similar additional studies will need to be initiated in order to offer added insights into the question of mathematics self-efficacy and its effects on the medication calculations abilities of nursing students.

Dissemination of Results

This study will serve as an important piece of information for nursing educators to take into account when evaluating and enhancing their medication calculation curriculum and teaching strategies. The aggregate results of this study will be presented to both of the participating schools of nursing to inform them of the effectiveness of their individual teaching strategies and places for improvement. Additional dissemination will occur through possible presentations at conferences, such as nursing education and nursing research conferences, and through an article published in a peer-reviewed nursing journal.

Conclusions

This research offers insight into the complex nature of the mathematics self-efficacy of nursing students in regards to their calculation abilities and the difficulty nursing educators face in attempting to foster these feelings of self-efficacy in nursing

students. Although dimensional analysis had support from previous literature and was expected to be an effective method for teaching medication calculations and enhancing self-efficacy, the results of this study did not provide any statistical support for those expectations. However, the results suggested that dimensional analysis might still have clinical significance as a teaching method if it is utilized in conjunction with innovative teaching strategies. In addition, gender, age, and previous grades in high school mathematics are important factors for nursing educators to take into consideration when developing nursing curriculum that seeks to promote the self-efficacy levels of nursing students in regards to their medication calculation abilities. According to Hodge (1997), “identifying these factors will advance our understanding of the under-achievement in mathematics of nursing students and leads to ways of providing intervention and remediation” (p. 27). These types of interventions in nursing education will help to ensure that nursing students develop a greater sense of self-efficacy for medication calculations, leading to a reduced rate of medication calculation errors and ultimately improving patient safety outcomes.

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APPENDIX A: SELF-EFFICACY QUESTIONNAIRE

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

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

1. Compare 2 fractions and determine when one is larger (e.g. compare $\frac{5}{8}$ with $\frac{2}{3}$).

No confidence at all

Some confidence

Complete confidence

0 1 2 3 4 5 6 7 8 9 10

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

No confidence at all

Some confidence

Complete confidence

0 1 2 3 4 5 6 7 8 9 10

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

No confidence at all

Some confidence

Complete confidence

0 1 2 3 4 5 6 7 8 9 10

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

No confidence at all

Some confidence

Complete confidence

0 1 2 3 4 5 6 7 8 9 10

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

No confidence at all

Some confidence

Complete confidence

0 1 2 3 4 5 6 7 8 9 10

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

No confidence at all

Some confidence

Complete confidence

0 1 2 3 4 5 6 7 8 9 10

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

No confidence at all

Some confidence

Complete confidence

0 1 2 3 4 5 6 7 8 9 10

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

No confidence at all

Some confidence

Complete confidence

0 1 2 3 4 5 6 7 8 9 10

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

No confidence at all

Some confidence

Complete confidence

0 1 2 3 4 5 6 7 8 9 10

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

No confidence at all

Some confidence

Complete confidence

0 1 2 3 4 5 6 7 8 9 10

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

No confidence at all

Some confidence

Complete confidence

0 1 2 3 4 5 6 7 8 9 10

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

No confidence at all

Some confidence

Complete confidence

0 1 2 3 4 5 6 7 8 9 10

Reference:

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

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Permission is granted for research and educational use of the scale.

APPENDIX B: INFORMED CONSENT COVER LETTER

September 15, 2015

Dear Potential Research Participant:

You are being invited to participate in a research study on the self-efficacy of nursing students in regards to their medication calculation abilities. In particular, we are interested in better understanding if a certain medication calculation teaching method, dimensional analysis, is effective in increasing the self-efficacy, or confidence levels of nursing students.

Completing the questionnaire will take about 10 minutes. Completing both questionnaires (one now and one in December) will require about a total of 20 minutes of your time. Each questionnaire is comprised of 12 medication calculation related questions. On the first questionnaire a number of demographic related questions (i.e. age, gender, math grade in high school etc.) are also asked.

While there are no anticipated physical or emotional harms expected as a result of participating in this study, some students may become uncomfortable in answering questions about medication administration. Should you feel anxious or concern during the completion of the questionnaire, please stop answering the questions and hand the questionnaire back to me. I would also encourage you to either speak to one of your nursing instructors or school counselor about your feelings.

There are no direct benefits to you for participating in the study. However, nursing instructors may benefit from the study by gaining a deeper understanding of the self-efficacy of nursing students in relation to their medication calculation abilities.

Several steps will be taken to protect your anonymity and identity. I will be creating a list of participant names and I will assign you a code number that will be placed on the questionnaire you complete. No personal identifying information will be collected on the questionnaire. The list of participant names and code numbers and the questionnaires will be kept in a locked filing cabinet at the University of Lethbridge. Only I will have access to the list of participant names and code numbers. Only my thesis

supervisor and I will have access to the data. All information will be destroyed in a confidential manner after 5 years' time.

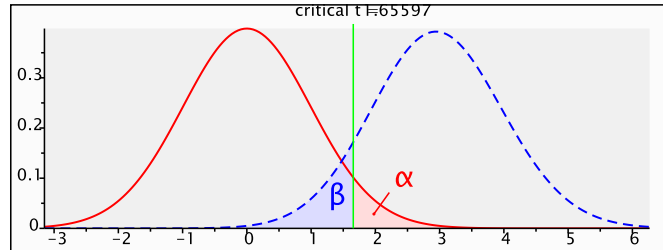
Your participation in this research is completely voluntary. If you decide to participate, you will receive a \$5 Tim Hortons gift card for your time and trouble before you start the first questionnaire. You may withdraw from the study at any time and for any reason. Withdrawing from the study will have absolutely no effect on your course mark or progress in the nursing program. If you do this, all information from you will be destroyed up to the point where I will be conducting data analysis.

The results from this study will be presented in writing in a Master`s thesis which will be made publicly available, and read by a thesis committee. The results may also be presented in person to groups of nursing instructors, nursing students, and other health care professionals. At no time, however, will your name be used or any identifying information revealed. If you wish to receive a copy of the results from this study, you may contact me at the email address [\[email address\]](#).

If you require any information about this study, or would like to speak to me, please email Kim Veldman at [\[email address\]](#). If you have any questions regarding your rights as a participant in this research, you may contact the Office of Research Services at the University of Lethbridge at [\[phone #\]](#) or [\[email address\]](#).

APPENDIX C: SAMPLE SIZE ESTIMATION

G*Power 3.1.9.2



t tests - Means: Difference between two independent means (two groups)

Analysis: A priori: Compute required sample size

Input:	Tail(s)	=	One
	Effect size d	=	0.5
	α err prob	=	0.05
	Power (1- β err prob)	=	0.90
	Allocation ratio N2/N1	=	1
Output:	Noncentrality parameter δ	=	2.9580399
	Critical t	=	1.6559704
	Df	=	138
	Sample size group 1	=	70
	Sample size group 2	=	70
	Total sample size	=	140
	Actual power	=	0.9029656