ISSN 2475-529X

Research Article

Journal of Nursing & Healthcare

Use of Dimensional Analysis in an Associate Degree Nursing Program

Bridget Maley[1], Patricia Ford Garofalo[2]*

[1]*Assistant Professor, New York City College of Technology, Brooklyn, New York, 11201, USA.*

[2]*Adjunct Faculty, Adelphi University, College of Nursing and Public Health, Garden City, New York 11530, USA.*

***Corresponding author**
Patricia Ford Garofalo, Adjunct Faculty, Adelphi University, College of Nursing and Public Health, Garden City, New York 11530, USA, E-Mail: pgarofalo@adelphi.edu.

Submitted: 22 Dec 2016; **Accepted**: 21 Apr 2017; **Published**: 25 Apr 2017

Abstract

The aim of this retrospective study was to show the use of dimensional analysis increased associate degree nursing students' mathematical computation competency and may reduce nursing medication errors in practice.

A recent report compiled by Mackary and Daniel from John Hopkins, stated that medical error is the third leading cause of death in the United States [1]. The most commonly cited estimate of annual deaths from medical error in the United States is a 1999 Institute of Medicine (IOM) report which is possibly limited and now outdated [2]. Medication errors contribute to patients' deaths, whereas nurses administer either incorrect medication, or incorrect doses of medication. Human error is inevitable, however designing safer systems to administer medication such as the use of a bar code system, and the standardization of academic medication calculation teaching may decrease these errors.

According to a report from a major insurance company that insures a large percentage of nurses, malpractice claims in nursing is on the rise [3]. Claim settlements and court judgments for 2015 against nurses include: failure to communicate, medication errors, charting by exception, and legal risks. Medication calculation errors can be one of three categories, conceptual, mathematical, and measurement, with conceptual errors (setup of the calculation equation) accounting for 68% of all errors [4].

Nursing textbook publications teaching dose calculation often use multiple methods: ratio-proportion, "desired over have", and various formulas to calculate medication dosage. Students then need to use the appropriate formula to solve the problem with fractions often leading to miscalculations with added or dropped zeroes.

The use of dimensional analysis (DA) only requires the student to use a single equation, and learn one calculation process, rather than several steps required by other methods or even memorization of multiple formulas [5].

Background

Medication dosage calculation has always been identified as a challenge for nursing students. As faculty in an associate degree nursing program, the researchers identified that students were experiencing difficulty passing the medication calculation course and identified the problem as lack of a unified method of medication calculation. The researchers introduced the use of dimensional analysis as the sole method for medication calculation. The researchers were introduced to dimensional analysis through previous work experience and exposure to Greenfield, Whalen, & Cohen's study which included teaching dimensional analysis to baccalaureate nursing students [6]. Dimensional analysis is a method of calculating medication dosages based on cognitive learning theory [5]. Accurate dosage calculation is not just basic math skills, but is also an introduction to the professional context of drug administration [7]. Craig identified that the use of dimensional analysis as the one method of problem-solving reduces confusion encountered by nursing students when multiple methodologies are used [5]. Nursing students need to be able to conceptualize the medication calculation process.

Medication errors are one of the most common and costly errors in healthcare [8]. These costs can be significant to healthcare institutions as each error is estimated to cost between 2,000 and 8,750 dollars [9]. Nurses intercept 50% to 86% of medication errors before these errors reach the patient, however the errors that nurses make are more likely to adversely affect the patient [9]. Medication administration is a major component of the nurses' role within the clinical setting and is considered a high risk task requiring a consistently safe and accurate approach [10]. Accurate dosage calculation and administration of medication is the responsibility of the registered nurse; therefore nursing students need to have a strong understanding and ability to properly calculate dosages to ensure the safe administration of medication to clients in the clinical setting.

Literature Review

Each year in the United States, preventable medication errors occur in 3.8 million inpatient admissions. Furthermore, costs associated with inpatient preventable medication errors cost $16.4 billion annually [11]. Analysis of student errors in medication dose calculations uncovered that conceptual (lack of understanding) and procedural (division and multiplication of fractions) errors occurred most commonly. These findings also found that medication errors occurred due to numerical inability (basic functions such as multiplication and division) or the inability of the nursing student to conceptually extract the correct information to set up the problem. Conceptual errors were the most common error in medication calculation 68% and as high as 91% among sophomore nursing students [12, 13]. Memorizing formulas without understanding the concept will not aide nurses in times of urgency [14].

Bliss-Holtz hypothesized that if nurses were allowed to use calculators then this would reduce the commonly occurring arithmetic errors [15]. Using two groups of nurses (n=51), one group used a calculator and one group did not. The results indicated that although the group with the calculator scored higher than the non-calculator group, 65.3% of the nurses were still unable to obtain the required score of 90% even with the use of a calculator. This indicates a 1 in 10 error while administering medications. Although calculators can help with mathematical abilities they do not help with the conceptual abilities, students still need to know how to input the data. The authors argue that calculators are present in the clinical area and may help to reduce errors. Kohtz & Gowda, found that although all of the groups were allowed to use calculators, numerous math errors occurred (45.5%) [4]. It is unclear if this was due to the lack of attention taken by students or faulty cognitive processes in entering the correct numbers and decimals.

Faculty need to consistently begin at the basic math level and progress to a higher level of computation. Coyne, Needham, & Rands' study duplicated previous findings of errors in conceptualization (specifically intravenous calculation formulas based on weight), basic math skills related to division and multiplication [16]. Furthermore, visualization of the medication dose and side effects through the use of case studies were found to improve students' conceptualization of the dosage problem. Analysis of medication errors suggest that these errors are the result of multiple individual errors that occur in a system. Kohtz and Gowda, compared two different methods for teaching nursing students medication calculation, dimensional analysis (DA) or conventional methods (desired over have, and ratio/proportion) [4]. The purpose of their study was to evaluate which of the two teaching approaches would best reduce medication calculation errors among their nursing students. Although these authors' findings were inconclusive, both groups of students continued to struggle with conceptual errors. These findings are inconsistent with other studies demonstrating better performance for students using DA.

Wright states that nurses and nursing students need to have the mathematical and conceptual skills necessary to accurately calculate drug calculations to administer medications safely [17-19]. Some nurses and nursing students are lacking in some of these basic math skills. Using a quasi-experimental approach and a pre and posttest design. A convenience sample of 71 second year nursing students, the students were given a 30 question drug calculation exam on the first day of class, the exam was reviewed by an expert panel to access validity. After the review of the exam, strategies were put in place to improve upon the weaknesses of the students. These strategies included online math sessions reviewing simple math concepts identified as weaknesses, a 2 hour lecture explaining the formulas, a drug calculations workbook was distributed to the students, and a practice lab for students was created. The students were then retested 7 months after the initial exam. Only 44 students took the second exam because of moving out of this specific class. All post-tests showed a significant improvement over the pre-test although results on the exam were still poor only 32% (n=14) students received an 83%, and 32% (n=14) calculated more than a third of the answers incorrectly. The intervention helped improve the students' ability but fell short of the accuracy necessary to obtain the 100% required as the acceptable margin for error. This study indicated that math ability as well conceptual abilities need to be addressed by nursing students in their medication calculation courses.

McMullan, Jones, & Lea studies have shown that 30-40% of medication errors are related to drug calculation errors, and this might be an underestimate [14]. These errors occur due the deficiency in mathematical ability of the person performing the calculations. Many studies indicated that students have a weakness in basic numeracy test (addition, subtraction, multiplication of whole numbers, decimals, and fractions [3, 20, 21]. A convenience sample of 2 cohorts of second year diploma students (n=229) and a convenience sample of 44 Registered Nurses were used for this study. A correlational cross sectional study design was used to conduct this study. Participants were not allowed to use a calculator for the exam but were allowed to use paper and pencil. The registered nurses scored statistically significantly higher than the student nurses on the exams, both groups performed poorly. Both groups' numerical skills were poor with on average 55% of the nursing students and 45% of the registered nurses failing a basic ability test. The drug calculations ability were similar with 99% of the students and 95% of the nurses receiving less than 80% and 92% of the students and 89% of the nurses failing to reach the 60% level. There is a need for nurses to practice their math skills and medication calculations even while in practice and nursing students need to gain competence in their basic math skills.

Dimensional analysis has a noted advantage as there is only a single equation rather than several steps required by other approaches such as desired over have or ratio and proportion [4]. Dimensional analysis has been used in nursing for over 30 years although it has not been embraced by nursing education. A comparison study was performed with nursing students, data was collected over 4 semesters (2 years) with a final sample size of 79 students. The experimental group (n=36) was taught dimensional analysis and the control group (n=43) was taught conventional methods. All students had previously taken a medication calculation course in their first semester of junior year. The hypothesis that dimensional analysis would provide better outcomes was not supported (Polfroni et al, 1993).

Method

Design and Sample

This was a retrospective comparative study using two groups of

associate degree nursing students. The purpose of the study was to examine whether the use of dimensional analysis would improve the medication dosage calculation abilities of associate degree nursing students.

Associate degree nursing students in an urban public northeastern college served as the sample. A total of 353 nursing students were enrolled in a pre-dimensional analysis medication calculation course utilizing three different methods of calculation, ratio/proportion, desired/have, and dimensional analysis allowing the students to choose a preferred method of calculation. The post dimensional analysis group (n=348) was introduced to dimensional analysis as the sole method of medication calculation.

Procedure

Application to the researchers' college Institutional Review Board (IRB) was made. The IRB granted that this research protocol met the conditions for exemption. All students were enrolled in a required one credit medication calculation course. Students enrolled from fall 2011 through fall 2013 (n=353) took the course utilizing three different calculation methods and were not permitted to use a calculator. Students enrolled from spring 2014 through spring 2016 (n=348) utilized dimensional analysis as the sole method of medication calculation and the use of a basic calculator was permitted. All students followed the same course syllabus, and took three required semester exams and a cumulative final exam.

Instrument

Three semester examinations and a cumulative final exam required students to convert units and calculate dosages for oral, intramuscular, and intravenous medications based on body weight. All exams were taken in a controlled environment, students were instructed to answer questions and show all calculations.

Data Analysis

Data were entered using the Statistical Package for the Social Sciences (SPSS) version 22. Pearson's Chi Square test utilizing the total number of students who took the course, the number of students who withdrew and the number who failed pre-dimensional analysis and post dimensional analysis.

Results

Demographics

Demographic data were not collected. Nursing students in these groups are homogenous; all nursing students pass an entrance exam and have the required GPA for entrance into the nursing program.

	Students	Passed	Failed	Withdrew
Pre-dimensional analysis	n=353	248	76	29
Post dimensional analysis	n=348	337	0	11

Medication Calculation Course Results

The pre-dimensional analysis group n=353, 76 students failed the course with a score of less than 75%, 29 withdrew from the course, and 248 passed with a grade of 75% or greater. The post dimensional analysis group n=348, 0 students failed the course, 11 students withdrew from the course, and 337 students passed the course with a grade of 75% or greater.

Analysis of Collected Data

The sample of this study consisted of 701 students, and analysis of collected data, calculated using Pearson's Chi Square revealed statistically significant results. $x^2 = (2248); 97.609; df2; p<.001$. The results were statistically significant ($p<.001$) that the post dimensional analysis group scored with greater accuracy than the pre-dimensional analysis group.

Limitations and Suggestions for Future Research

Although this was a relatively large sample size it was limited to one school of nursing. There is still debate in the nursing academic community about the use of a calculator for medication calculation. Review of the literature states that use of a calculator may enhance students' math abilities but they still must understand the conceptual aspect of what a question is asking to correctly set up and solve the math equation [6, 15].

Conclusion

Basic math and conceptual abilities are necessary to understand nursing medication calculation problems. This is the basis for safe medication administration and is critical to safe nursing practice. Students still need these basic math calculation competencies despite the introduction of unit dose medication packages. Conceptual errors continue to account for the majority of calculation errors. This study's findings suggest that the use of dimensional analysis should be the method of choice for nursing programs. Statistically significant results were noted when using dimensional analysis as the sole method of medication calculation as compared with multiple methods of medication dosage calculation. With the advance of unit dosing, bar coding, and high alert IV medications together with the use of dimensional analysis future nurses may have the ability to practice safe medication administration [22].

References

1. Mackary M, Daniel M (2016) Study Suggests Medical Errors Now Third Leading Cause of Death in the U.S. http://www.hopkinsmedicine.org/news/media/releases/study_suggests_medical_errors_now_third_leading_cause_of_death_in_the_us.
2. Institute of Medicine (2000) To err is human: Building a safer health system. Washington, D.C.: National Academy Press.
3. Brown L (2016) Medical Malpractice Claims against Nurses.
4. Kohtz C, Gowda C (2010) Teaching drug calculation in nursing education: A comparison study. Nurse Educator 35: 83-86.
5. Craig G, Sellers S (1995) The effects of dimensional analysis on the medication dosage calculation abilities of nursing students. Nurse Educator 20: 14-18.
6. Greenfield S, Whelan B, Cohn E (2006) Use of Dimensional analysis to reduce medication errors. Journal of Nursing Education 45: 2.
7. Olsen, Giangrasso, Shrimpton (2012) Medical Dosage Calculations: A Dimensional Analysis Approach, 11th Edition. Upper Saddle River, New Jersey: Pearson.
8. AHRQ (2015) Medications errors. https://psnet.ahrq.gov/primers/primer/23/medication-errors.
9. Anderson P, Townsend T (2015) Preventing high alert medication errors in hospital patients. American Nurse Today 10: 18-23.
10. Levette-Jones T, Bourgeois S (2011) The Clinical Placement, 3rd Edition An Essential Guide for Nursing Students. St. Louis,

MO: Elsevier.
11. Network for Excellence in Health innovation (2013) Annual Meeting Report.
12. Blais K, Bath J (1992) Drug Calculation Errors of Baccalaureate Nursing Students. Nurse Educator 17: 12-15.
13. Segatore M, Edge D, Miller M (1993) Posology errors by sophomore nursing students. Nursing Outlook 41: 160-165.
14. McMullan M, Jones R, Lea S (2010) Patient safety: numerical skills and drug calculation abilities of nursing students and registered nurses. Journal of Advanced Nursing 66: 891-899.
15. Bliss-Holtz J (1994) Discriminating types of medication calculation errors in nursing practice. Nursing Research 43: 373-375.
16. Coyne E, Needham J, Rands H (2013) Enhancing student nurses' medication calculation knowledge; integrating theoretical knowledge into practice. Nurse Education Today 33: 1014-1019.
17. Wright K (2007) Student nurses need more than math to improve their drug calculating skills. Nurse Education Today 27: 278-285.
18. Wright K (2009) The assessment and development of drug calculation skills in nurse education; a critical debate. Nurse Education Today 29: 544-548.
19. Wright K (2010) Do calculation errors by nurses cause medication errors in clinical practice? A literature review. Nurse Education Today 30: 85-97.
20. Gillham D, Chu S (1995) An analysis of student nurses' medication calculation errors. Contemporary Nurse 4: 61-64.
21. Lerwill C (1999) Ability and attitudes to mathematics of post-registration health-care professionals. Nurse Education Today 19: 319-322.
22. Bush P, Hueckel R, Robinson D, Seelinger, Molloy M (2015) Cultivating a Culture of Medication Safety in Prelicensure Nursing Students. Nurse Educator 40: 169-173.