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Mathematical Calculations Ability of Registered Nurses

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MATHEMATICAL CALCULATION ABILITY OF REGISTERED NURSES

by

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ABSTRACT

MEDICATION CALCULATION ABILITY
OF REGISTERED NURSES

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Medication errors occur throughout health care settings. These errors can be caused by a multitude of factors, one of the most important being mathematical calculation. The purpose of this study was to replicate an earlier study by Bindler and Bayne (1991) examining the mathematical calculation ability of registered nurses. Utilizing a model of skill acquisition suggested by Dreyfus and Dreyfus (1980) and applied to nursing by Benner (1986), it was hypothesized that years of experience and frequency of calculation would have a significant interactive effect on the score of a medication calculation test.

A descriptive correlational design was utilized. A convenience sample of registered nurses (n=92) was tested. The hypothesis was not supported as being statistically significant.

Dedication

Dedicated to my husband Vince,

for his constant

love and support.

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CHAPTER 1

INTRODUCTION

The nursing role encompasses a wide range of responsibilities dependent on scope and area of practice and occupational expectations. While it is difficult to identify a single skill which all nurses, regardless of practice area, must be able to perform competently, most nurses would agree that medication administration is universal. Affiliated with administration is the task of dosage calculation to ensure proper medication amounts for patient requirements. Many clinical settings have made a transition to unit dose packaging (Koska, 1989), thus significantly reducing the need for medication dosage calculation ability but obviously not eliminating it.

The necessity for accurate medication calculation is readily apparent. Inaccurate calculations can complicate medical care, increase patient length of stay, prolong patient illness, and in some cases, cause death (Koska, 1989). Beyond the cost to the patient's recovery and well-being, each of the above has potential economic costs. Analysis of some hospital records indicate medication errors to be one of the most frequent initiators of nursing

malpractice cases (Luquire, 1989).

The Michigan Hospital Association identified medication administration errors as the second most frequently reported incident in forty Michigan hospitals (Brown, 1979). A 1981 hospital study indicated that approximately 75% of medication errors are undetected and/or unreported (Fuqua & Stevens, 1988). The American Society of Hospital Pharmacists estimates the national medication error rate at greater than twenty percent of total medications administered (Koska, 1989). A final study estimates error rates as high as 38% of all medications given (Scholz, 1990). The wide variance results from an unclear definition of what constitutes a medication error. Medication errors encompass the following situations: wrong patient, omission of a dose, wrong time, incorrect drug, extra or unordered drug, improper route of administration, wrong rate, or wrong dose (Fuqua, & Stevens, 1988; Scholz, 1990).

Several studies have reported wrong dose to be the most frequently occurring error (Brown, 1979; Scholz, 1990). Incorrect dose has been associated with increased cost to hospital and patient due to cost of incident report completion, cost of additional hospital services including increased length of stay, and cost of injuries related to drug treatment (Brown, 1979). Incorrect doses of medication can be due to a multitude of causes: lack of time to accurately complete calculations, distractions surrounding the nurse trying to calculate the correct dose,

overconfidence in familiarity with medications, and inability to perform the correct mathematical calculations to name a few. This study will focus on incorrect dose related to mathematical calculation ability as a source of medication errors.

Calculation skills rely heavily on the mathematics ability of nurses. According to Benner (1984), skill acquisition is attained by passing through several levels of proficiency from novice to expert. Using this model, the more experience a nurse has in calculating medication dosages, the more accurate the nurse should be. Therefore, nurses with more experience should have fewer medication calculation errors than novice nurses.

The purpose of this study is to consider the relationship between nurse achievement on a medication calculation test and years of experience as a practicing nurse. This work purports to replicate results of previous studies by Bindler and Bayne (1988, 1991) concerning medication calculation abilities of registered nurses.

CHAPTER 2

LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

Literature Review

Actual research on medication errors' cause and frequency was not available earlier than 1968 (Francis, 1980), and research focusing on these issues has not received considerable attention to this day. Considerable literature pertaining to medication errors consists of editorial opinions focusing on reporting and tracking occurrences in hospital settings (Betz & Levy, 1985; Brandt, Deml, Gerke, & Lee, 1988; Byrd, 1984; Conklin, MacFarland, Kinnie-Steeves, & Chenger, 1990; Davis & Cohen, 1987; Del Bueno, 1972; McGovern, 1987; Pierce, 1984; Rheinstein, & McGinnis, 1992) and research related to medication error tool tracking development (Cobb, 1986; Hodgin, 1984; McNeilly, 1987; and Sherman, & Clinefelter, 1989). Other articles highlighting appropriate disciplinary actions and consequences of medication errors are found (Graham & McMahon, 1989; Harnden, 1988; Johnson, 1987; Killian, 1991; Long, 1992; Luquire, 1989; McNeilly, 1987; and Schwartz & Lowe, 1989). Other articles are related to medication errors and how-not-to articles aimed at the beginning nurse

and emphasizing basic procedures and examples of error occurrence (Cohen, 1992; Cushing, 1984; Davis & Cohen, 1987; McGovern, 1987; and Pierce, 1984; Rheinstein & McGinnis, 1992). This literature review will outline articles concerning the reported frequency, under-reporting of medication errors and review the most common medication error classifications, including errors in dosage calculation. Finally, studies examining cause of dosage error calculation will be evaluated.

Reported frequency of errors. Several studies have shown that medication errors are the highest cause of incident reports in hospital settings (Long, 1982; Francis, 1980). Additional studies place medication errors as the second most common cause of reporting (Koska, 1989; Worrell & Hodson, 1989). A study in which nurses were observed preparing and administering medications reported that medication error rates ranged from seven to thirty percent (Bindler & Bayne, 1991). Up to 29% of the nurses in this study frequently failed to report their errors.

While researchers may not agree on the actual frequency, it is the general consensus that under-reporting is common.

> "Whenever data are presented, authors acknowledge that only a fraction of the true incidence of errors is known because of underdetection and under-reporting" (Fuqua & Stevens, 1988).

Fuqua and Stevens (1988) estimate that only 25% of

medication errors that occur are actually reported. Another researcher compared physician' comments concerning nursing questions related to necessity of filling out incident report with actual number of reports filled out and concluded errors are frequently not recorded (McNeilly, 1987). Reasons for under-reporting occurrence of medication errors has been attributed to two primary factors: 1) people not knowing an error has been committed and 2) people choosing to not report an error (Scholz, 1990). A study by Francis (1980) in which anonymously reported medication errors were compared to officially reported medication errors concluded that nurses made ten times more anonymously reported errors than were officially reported. Due to the self-reporting nature of this study, the number of errors which the nurse was unaware of committing were not included.

Upon review of the literature related to reporting of errors, it is apparent medication errors happen and are written up as incident reports. Furthermore, a great deal more errors occur than are actually discovered or reported.

Types of medication errors. The most commonly reported medication errors include: omission of an ordered dose, administration of an incorrect dose or drug, administration of a dose at an incorrect time or by an incorrect route, administration of a dose to the incorrect patient, and other miscellaneous errors. Many studies consider drug omission, incorrect dose, and incorrect drug to be the most commonly occurring reported medication errors (Brown, 1979; Francis,

1980; Fuqua & Stevens, 1988; Long, 1982; Poster & Pelletier, 1988).

From a risk management perspective, Brown (1979) described a hospital based tracking program to determine where medication errors occur, the type of medication errors, and who makes the errors. Brown concluded that the majority of errors (82%) were made by the nursing staff on nursing units. The most frequent medication error was incorrect dose and/or rate (33%). This was followed by incorrect drug (17%), omission (15%), incorrect route (11%), and incorrect time (11%). Another study (Long, 1982) tracked reported medications errors over a twelve month period in forty hospitals. The most frequently reported error was omission (28%). This was followed by incorrect dose (17%), incorrect drug (15%), and miscellaneous. Long compared number of medication errors reported using unit doses versus floor stock and prescription methods and found no significant difference.

A different study (Poster & Pelletier, 1988) considered types of medication errors in different nursing care delivery systems over a twelve month period in a psychiatric hospital. Findings showed omission to be the most frequently occurring error. This was followed by incorrect dose. Other medication errors such as incorrect patient, incorrect route, incorrect time, repeat dosage given, and unordered medication were reported less frequently. The authors note that in a psychiatric setting, unlike in other

medical settings, the need to divide dosages and perform dosage calculations is infrequent. Poster and Pelletier, (1988) described this as a potential explanation for the high rate of incorrect dose but suggested no explanation for the omission errors.

Fuqua and Stevens (1988), in a compilation of three separate studies related to medication errors, reported incorrect dose to be the most frequent error from 18% - 33% of the time. Other frequently reported errors were omission, incorrect drug, and unordered drug.

Francis (1980) compared nursing perceptions of medication errors committed and reported anonymously to officially reported medication errors. Nurses anonymously reported 538 medication errors over a 57 day period while officially reporting 53 errors during the same time period. It was not clear in the literature whether officially reported errors were included in the anonymous reporting. The study found anonymously reported medication errors to be incorrect time (73%), not charted (11%), omission (6%), incorrect dose (6%), incorrect patient (1%), and incorrect route (1%). Official incident reports consisted of the following: incorrect dose (32%), incorrect drug (25%), omission (25%), incorrect patient (9%), incorrect time (6%), incorrect route (4%), and not charted (0%). Nurses' explanations on anonymous reports for cause of medication errors included: situational factors (47%) such as nurse being too busy, competing activities of greater priority and

nurse fatigue; patient access factors (21%) such as patient not being physically available to nurse at designated time; no reason given (15%); incorrect procedural factors (14%); miscellaneous (3%). The primary official cause was incorrect procedural factors (92%) followed by patient access facts (5%). Francis explained the discrepancy between official and anonymous reports on timing and charting errors to be related to increased nursing autonomy: nurses decide that exact time of medication administration and charting is not critical and routinely does not warrant an official report. The three most common officially reported errors are omission, incorrect dose, and incorrect drug (85% combined). These errors were viewed as having greater potential for harm and were officially reported more consistently.

The self-reporting nature of the Francis study can only consider those medication errors that nurses are aware of committing. Nurses will be more aware of certain medication errors than others. For example, omission of a drug is readily apparent because of the obvious incomplete nature of the medication chart. Whereas an error involving incorrect dose is difficult to identify unless the dosage and calculations were verified by a source other than the nurse performing the initial calculations. An earlier study regarding nursing ability to compute drug doses for infants concluded that even when dosage calculations were wrong, experienced nurses (one or more years of practice) had a

greater tendency to be confident in their calculation ability. Therefore, they would be more likely to administer an incorrect dose (Perlstein, Callison, White, Barnes & Edwards, 1979).

The literature review related to occurrence of medication errors strongly indicates errors in dosage and omission of medications are a primary concern. With the exception of Francis (1980), no study defined the cause of these medication errors. Frequently errors in omission relate to factors beyond the scope of nursing such as medication missing or unavailable, patient not physically available, and/or patient refusing to take the medication.

Cause of dosage errors. While omitting medication can be problematic, an extra dose or an additional amount can be administered when the error is recognized. Incorrect dose is a prominent issue for the nursing profession as it is generally directly under nursing control. Incorrect dose could be due to misreading the prescription, misreading the actual medication label or incorrect mathematical calculations but all of these fall strictly under the domain of nursing. For this reason it is important to examine causes of errors in medication dose which is an area over which nursing does have control. Much of the literature connects incorrect dose medication errors to nursing calculation abilities (Bayne & Bindler, 1988; Bindler & Bayne, 1981; Conti & Beare, 1988; Markowitz, Pearson, Kay, & Loewenstein, 1981; Perlstein, et al., 1979).

Markowitz, et al. (1981) administered a twenty-five question exam on the hazards of medication to nurses, physicians, and pharmacists at one hospital. The hazards of medications considered were drug dose and administered, drug interaction, adverse drug reaction, interpretation of clinical data, drug indications and contraindications, and drug actions. The mean score of 100 nurses was significantly lower than pharmacists and physicians. While the administered test encompasses a wide range of knowledge, relevant to this study is the information obtained concerning years of experience related to test scores on knowledge of hazards of medication. Markowitz, et al. found no significant difference in test results between nurses of varying years of experience. This study concluded that years of experience in nursing is not a factor in drug knowledge which includes dosage calculations. However, the researchers recommend further study with larger samples.

Another study (Perlstein, et al., 1979) tested 95 nurses in a newborn intensive care setting on their ability to correctly compute drug doses. Researchers found that one of every twelve (8.3%) doses computed were at least ten times greater or lower than the required dose. The study also found no significant difference in error rate between experienced versus inexperienced nurses (Perlstein, et al., 1979). However, researchers defined experienced nurses to be those who were tested one or more years after graduation from nursing school. This does not consider length of

licensure or years of practice.

A related study tested the dosage calculating abilities of fifty-five newly hired nurses and compared scores to years of nursing experience. A follow-up portion of the study related test scores to documented dosage calculating errors from incident reports obtained over the following twelve month period (Conti & Beare, 1988). The authors categorized nursing experience into the following: 0-1 month experience, 1-36 months, and greater than 36 months. They found no significant difference in test scores among these categories. Additionally, they found no statistically significant correlation between test scores and subjects' likelihood of making documented dosage administration errors within the subsequent twelve month period. This indicates test scores may not be an accurate predictor of a nurse's propensity for making future dosage errors.

In summary, according to the literature review, no statistically significant correlation has been established between a nurse's years of experience and calculation ability. There has been no set definition used to categorize nurses as experienced versus nonexperienced.

Studies by Bayne and Bindler (1984, 1988, & 1991) form the foundation for this study. Bayne and Bindler (1984) originally studied seven hundred nursing students at a west coast school for nursing. They tested basic mathematical skills of the students-addition, subtraction, multiplication, division, and use of fractions, decimals,

and percents. They determined up to 38% of each student group were unable to achieve a score of at least 70%. This study raised concerns that if students performed poorly, some practicing nurses might also lack the mathematical skills need for safe medication calculations.

A second study was conducted on sixty-two nurses from two large western hospitals. The sample consisted of twenty-nine registered nurses and thirty-three graduate nurses waiting for licensure. The testing was done during hospital orientation and looked at a variety of factors pertaining to nursing calculation ability. These factors included: 1) number of nurses able to achieve 90% on a medication calculation exam; 2) occurrence of errors related to type of calculation needed ie: intravenous calculations, conversions required, multiple calculations and inclusion of fractions or decimals; 3) years of experience; 4) educational preparation; 5) frequency of medication administration in job setting; 6) nursing perception of ability to calculate medications; 7) stress associated with medication calculation; and 8) type of medication errors occurring (Bayne & Bindler, 1988).

The investigators developed a twenty-item medication calculation examination to answer the study questions. The exam was normed on forty senior baccalaureate nursing students just prior to graduation. The exam was modified after the norm to assure items actually measured calculation ability and not judgement skills. A conversion table was

included providing conversions easily found on a nursing unit to ensure testing of calculation abilities and not memory of conversion factors. The reliability factor of the test was found to be 0.82 with an odd-even split half reliability test. Content validity was established by a review of nursing and pharmacology textbooks and use of a panel of nursing experts (Bayne and Bindler, 1988).

The investigators found test scores ranging from 20% to 100% with only 35% of the nurses attaining a score of 90%. Significantly more errors were made with intravenous medication calculations that with oral, subcutaneous or intramuscular dosages. There was no significant error increase related to use of conversions, number of calculations, or use of decimals, fractions or percents. The study found no significant differences between nurses with < 1 year, 1 - 3 years, 3 - 5 years or > 5 years experience or in educational preparation. Additionally, amount of experience in medication administration was not found to have any significant effect on medication error rate. They did find nurses accurately correlated their comfort and skill level with ability to calculate correctly.

Bayne and Bindler (1988) concluded that many nurses lack the mathematical calculation ability to safely administer medications. The authors inferred years of experience had no significant relationship to calculation skills, but they utilized a relatively small sample size with a disproportionately large number of graduate nurses.

In their third study, Bindler and Bayne (1991) utilized a similar format. This study looked at nurse achievement on a medication calculation exam, types of computations which are most difficult for nurses, relationships between nurse demographics and test scores, and the relationship between nurse self-rating of skills and comfort with test scores. They tested 110 nurses from four medical centers in the western states. Some nurses completed the test as a portion of hospital orientation and some nurses volunteered to be tested. One hundred and five subjects were registered nurses, with four graduate nurses and one nurse whose status was unstated. Confidentiality was maintained by use of an identification number to return test results. The authors utilized the same medication calculation examination piloted in their earlier study and similar results were obtained. Test scores ranged from 20% to 100% correct with 29% of the nurses attaining 90%. Again, significantly more errors were made with intravenous calculations than other types. Test scores were not significantly correlated with type of educational program, years of practice or amount of experience in medication administration. As in the previous study, nurses were found to positively correlate their accuracy and comfort with higher test scores. The one difference this study demonstrated over the previous study was to indicate which computations were most difficult for nurses. This study found nurses had significantly more errors when multiple calculations were required and

conversions were necessary to complete the question (Bindler and Bayne, 1991). The study recommended continued testing of nurses' calculation ability and implementation of strategies to improve mathematical skills.

When analyzing the calculation ability of nurses, certain testing issues must be considered. The amount of stress experienced in a pencil and paper test may be significantly less than nurses experience on a busy floor. Fewer distractors are present to compete for the nurse's attention. The actual time allotment for each question on the medication calculation examination is most likely longer than the nurse allots for calculations of a similar nature on the patient care unit. Additionally, test-takers are influenced by a desire to perform better because of the attention generated by taking a test as demonstrated by the Hawthorne effect (Polit & Hungler, 1987).

> The recorded [medication] error rate is probably a minimal estimate of the true frequency of medication errors. It is likely that the nurses performed better on the test than they do during day-to-day nursing care. That the test situation can maximize performance was recently demonstrated ... (Bleyer & Koup, 1979).

Summary of Literature Review. In conclusion, a thorough review of the literature indicates the quantity of reported medication errors is a problem and that number is likely only the tip of the iceberg in relation to actual frequency of occurrences. Many studies suggest that years of experience is not an accurate predictor in determining probability of medication error occurrence but "years of experience" has not been defined consistently. One report classified "experienced" nurses as those nurses who have graduated from nursing school more than one year ago (Perlstein, et al. 1979) with no indication of whether the nurse actually worked in that time frame. Another author defined "experienced" as longer than three years work experience (Conti & Beare, 1988). Bayne and Bindler (1988, 1991) indicate experienced nurses to be those nurses who have practiced longer than five years. It is reasonable to hypothesize, however, that expert nurses with more experience, when truly separated from less experienced novice nurses, will score higher on a medication calculation examination. Finally, no literature was available that examined frequency of medication calculation.

Conceptual Framework

The conceptual framework utilized for the present study supports the idea that skill acquisition improves with years of experience and frequency of exposure to a skill. Benner (1984) bases her writings on nursing skill acquisition on previous work by Dreyfus and Dreyfus (1980) involving

airline pilots and chess players. Dreyfus and Dreyfus (1980) indicate that during the acquisition and development of a skill, a learner passed through five levels of accomplishment: novice, advanced beginner, competent, proficient, and expert. Benner applies Dreyfus' stages to nursing skill acquisition.

The skill acquisition of nurses has been conceptualized as progressing through several distinct stages. Benner hypothesizes that skill acquisition is a linear phenomena with a certain amount of time in a similar situation required to progress from stage to stage (Benner & Tanner, 1987). Stages are not mutually exclusive: when an expert nurse encounters a new situation, she may function at a lower level but previous experience should enhance progression through the remaining stages at an accelerated rate.

The novice nurse is considered a beginner with no experience of the situation presented. Nursing students are considered to be novices. Additionally, any nurse entering a clinical setting where they have had no previous experience with the particular patient population may function at the novice level.

The next stage is advanced beginner. Advanced beginners are generally considered to have marginally acceptable performance and have some real situational experience (Benner, 1984). An advanced beginner is commonly considered to have up to six months work experience (Benner,

Tanner, & Chesla, 1992).

A competent nurse is at the next progressive level and considered to have been in the same or similar work settings for two or three years (Benner, 1986). A competent nurse tends to have a feeling of mastery and ability to cope with the many demands of nursing.

The final stages are proficient and expert. Nurses at both levels have a high degree of skill and operate from a deep understanding of the situation (Benner, 1986). The distinction separating the proficient nurse from the expert is not clearly defined. The proficient nurse is considered able to formulate a picture of how patient care should occur and able to recognize when the normal or ideal picture does not occur (Benner, 1986). A proficient nurse is considered by Benner (1986), to have worked with a similar population group for three to five years whereas an expert is considered to have at least five years of experience. An expert nurse is one who has been recognized by peers and supervisors as an expert practitioner (Benner, et al., 1992, Corcoran, 1986). Expert nurses have a large background of experience to draw on and develop an almost intuitive grasp of a situation.

Various nursing research studies have analyzed skill acquisition utilizing the Benner framework. Holden and Klinger (1988) compared the diagnostic patterns of novice and expert nurses in explaining infant crying. The authors concluded that expert nurses scored significantly different

from novice nurses in all measurements. The expert nurse was most efficient at diagnosing why the infant was crying and eliciting information about the infant's crying. One of the conclusions of this study was that "important cognitive changes occur with clinical experience" (Holden & Klinger, 1988).

A different study compared the clinical judgement process of registered nurses (experts in their field) with student nurses (considered to be beginners) (Itano, 1989). The researcher concluded the expert nurse was more likely to elicit more cues, be more efficient with cues obtained and obtain cues which were more useful than the novice nurse. This supports Benners' model of skill acquisition.

A final study examined the planning process utilized by expert and novice nurses in a hospice setting (Corcoran, 1986). This study also concluded expert nurses demonstrated a different skill level than novices. The expert nurse was more likely to generate more options for care plans and described the plans in greater detail than the novice nurse.

The above studies look at highly abstract nursing skills. Each of them clearly demonstrates a strong relationship between years of experience (an expert nurse) and increased skill acquisition. It is reasonable to assume Benners' model could be applied to the skill of medication dose calculation.

Benner (1986) correlates actual years of experience with skill acquisition. This is presuming the nurse would

have adequate opportunity to practice the skill during the intervening years. Benner points out that even an expert nurse may function at a novice level when confronted with a situation in which they have no previous experience (Benner, 1986). It is important, therefore, to examine not only years of experience but frequency of opportunity to calculate medication also.

Definition of terms

For purposes of this study, the following definitions from the literature review and conceptual framework will be used. Wrong dose is defined as a dosage of medication different than ordered wherein the difference is a direct result of an error in calculation made by the nurse. Nursing experience is defined with years of experience in a situation being the primary indicator. The novice nurse will be defined by combining Benner's (1986) stages of novice, advanced beginner and competent practitioner. Therefore, the novice nurse will be defined as a nurse with less than three years experience as a registered nurse performing medication calculations. Expert nurses will be defined by merging Benner's proficient and expert classification of a practitioner. An expert nurse will be considered to have longer than three years experience performing medication calculations. Frequency of calculation is a measurement of the opportunity to engage in the targeted clinical skill of medication calculation during a professional setting.

Research Question

The question being posed in this study is: How do frequency of calculation and years of experience influence score on a medication calculation test? It is hypothesized that years of experience as a practicing nurse and frequency of dosage calculation have a significant interactive effect on the score of a medication calculation test.

CHAPTER 3

METHODOLOGY

Research Design

This study utilized a descriptive correlational design to examine the relationship of nurses' years of experience and frequency of opportunity for dose calculation to score on a medication dose calculation exam. Nurses were asked to complete a short demographic questionnaire followed by the medication calculation exam. This study utilized a test developed by Bayne and Bindler (1988, 1991) and replicated a portion of their research.

The design of the study was selected to eliminate external variables where possible. The test was given in a cross-sectional method utilizing a short time span of two weeks on each unit to eliminate contamination by nurses discussing the test with other nurses. Constancy in communication was maintained by utilizing a preset cover sheet (Appendix A) with each test and a prewritten script (Appendix B) to introduce the study to nurses. Unfortunately, self-selection for study inclusion was a problem. Nurses who are less comfortable with their math skills could have chosen to not return the exam, leaving a

skewed sample of only those who feel comfortable with their calculation ability. Reduction of this factor was attempted by deleting any chance of later identification means with the test: by keeping test results and reporting anonymous, it was hoped that nurses would view the test as less threatening. Additionally, many people have an innate curiosity related to self-testing. It was anticipated that these two factors, guaranteed anonymity and curiosity, would eliminate some fear nurses might feel. One final threat was the possibility that subjects would utilize resources other than a calculator and the listed conversions to complete the test. It was hoped that the low threat associated with the test design would encourage nurses to be honest about the testing situation.

The major threat to the internal validity of the study lay in controlling intrinsic variables. Analysis of variance was used to control extraneous variables of education level of the nurse and frequency of medication administration.

Population and Sample

This study was conducted at a midwest, 425 bed hospital with a convenience sample of nurses in a staff nurse position on various patient care units. Criterion for inclusion in the study were: currently employed as a staff nurse working eight or more hours per week, performing medication calculation at work weekly, and licensure as a registered nurse. Respondents who did not meet all criteria

were excluded. The study was introduced to prospective subjects at a routine staff meeting. The questionnaire (Appendix C & D) was distributed to all eligible nurses and they chose to participate or not. All eligible nurses were sent a reminder letter (Appendix E) within one week encouraging them to complete the test. The nurses implied their consent by returning the completed calculation exam within two weeks of receiving the test. Approval to conduct this study was obtained from the Human Subject Review Committee at Grand Valley State University and Bronson Nursing Research Committee. Opportunity for anonymous participation removed the only possibility of subject risk.

Instrument

The instrument used in this study was a 20 item, fill-in-the-blank medication calculation examination that measured the nurse's ability to accurately calculate medication dosages (Appendix C). This tool was developed by Bayne and Bindler (1988) and used for this study with their permission (Appendix F). The examination was norm referenced on a group of baccalaureate nursing students prior to graduation, modified and piloted on a sample of 62 nurses and graduate nurses (Bayne & Bindler, 1988). The odd-even split half test of reliability was 0.82 and content validity of the test was established by a panel of three nursing experts and a thorough review of pharmacology and nursing literature (Bayne & Bindler, 1988).

Additional information was obtained related to years of

nursing experience, educational background, medication administration activities and demographic information (Appendix D).

Procedure

The test was introduced and distributed to eligible nurses at a routine staff meeting. Instructions were given and nurses were given the test to complete independently. Nurses not in attendance at the staff meeting were given a test packet in their individual in-house mailbox with the introductory script included. Test packets were distributed with all information enclosed in a blank manilla envelope to maintain subject confidentiality.

Participants were requested to fill out the test using only a calculator and a conversion card (Appendix G). The conversion card was provided with the test. Subjects were asked to seal their completed test in a furnished envelope and return the test within two weeks through interhospital mail. Each nurse was sent a reminder letter (Appendix E) one week after original test distribution to assist in completing the test. Each test had a card with an identification number matching the test identification number. Nurses were asked to remove the attached card and reserve this number to identify their score on the test. Nurses were requested to complete the test with the assistance of a calculator and/or pencil and paper, and the provided conversion card only. Tests were scored and results posted by listing the identification number and the

score for each subject in an appropriate place identified by each nursing unit manager. The test number was known only to the nurse taking the test, thereby guaranteeing anonymous results. The demographic questionnaire (Appendix D) had a section for subjects to indicate if they choose to not have their score posted.

CHAPTER 4

DATA ANALYSIS

Medication errors occur in health care settings at a significant rate. While multiple issues are involved in the administration of medication, current literature identifies dose calculation as a significant, specific cause for error occurrence. It would be beneficial if there were a method to anticipate which nurse might be prone to medication calculation errors to enhance their calculation skills. The novice to expert model (Benner, 1986) supports the relationship between skill acquisition and years of experience. This model implies the more experience a person has with a task, the better they should perform this task. It is worthwhile to consider that the more experience a nurse has administering medication, the more proficient one should be.

The dependent variable (the score on the math calculation test) was measured in interval measurement. The independent variables of years of experience and frequency of calculation were recorded by participants at an interval level. In accordance with the conceptual framework and research question of this study, years of experience was

divided into categories of expert (greater than three years of experience) and novice (less than three years of experience). The variable was then analyzed as a dichotomous variable. A two-way ANOVA was used to answer the question of how frequency of calculation and years of experience influence score on a medication calculation test?

Characteristics of Subjects

Potential subjects were selected from specific nursing care units which dealt with medication administration on a routine basis. Four hundred and fifty-one questionnaires were administered via staff meetings and individual in-house mail boxes. Ninety-nine tests were returned (a 21.5% return rate) with five not meeting the inclusion criteria (four of these were unlicensed graduate nurses and one did not specify professional status). This resulted in a sample size of 92. All of the subjects were registered nurses.

The educational level of the sample resulted in 25% baccalaureate prepared, 36% associate degree prepared and the remaining 39% prepared at a diploma level. This is similar to reports of education level of registered nurses throughout the entire hospital (personal communication, Human Resources Department of Bronson Methodist Hospital, October 10, 1994).

Years of experience as a registered nurse varied from less than one year to 30 years (m = 10.9, SD = 6.8). Only 10% of the sample met the characteristics of a novice nurse

having three years of experience as a nurse or less. Fifty one percent of the sample has been a registered nurse for ten years or longer. There is no information available as to how the sample correlates to the general population of the hospital in this aspect.

Gender information regarding the sample could have been useful in data analysis. However, this was specifically not included in the demographics to protect anonymity as the potential sample has a very small percentage of males.

Years of experience in the current area being worked was slightly different. The years of experience in a current area ranged from less than one year to 22 years ($m = 7.0$, $SD = 4.7$). When grouping this value in a novice versus expert classification, 21% of the sample had been employed in their current area for three years or less. This indicated a small percentage of the sample fell into the novice classification with experience as a nurse overall, but more were novices in the area they currently work. Comparison data to the general population for length of time working in a current area is unavailable.

The subjects were asked to describe their overall skill and comfort level with medication administration prior to completing the test. These values were similar with 97% reporting average or above average skill levels and 95% reporting average or above average comfort levels. It is of interest that the 3 - 5% who rated their comfort and skill level as below average all scored 75% or less on the

calculation test.

Frequency of medication calculation ranged from less than once per day to fifteen times per day. This variable was dichotomized into less than or more than one time per day. Fifty six percent of the sample gave medication requiring calculation once per day or less. Of those nurses giving medication more than one time per day, the range was 1.5 to 15 times per day (m =4.8, SD 3.4).

The score on the mathematical calculation test ranged from 55 - 100% (m = 83.4%, SD = 11.2). Slightly over 42% scored 90% or higher on the calculation test. Bayne and Bindler (1991) identified the questions on the test relating to intravenous calculations (Appendix C, question 15 - 20) as the most difficult. When test scores are calculated with those questions removed, 57% of the subjects score 90% or higher.

<u>Analysis of the Research Hypothesis</u>

A two-way ANOVA was used to test the hypothesis that frequency of calculation and years of experience have a significant interactive effect on score on a medication calculation test. Results indicated no direct or interactive effects from either variable on the score ($F = 1.09$) thus the hypothesis was not supported. A multiple regression table indicated no significant correlation with either variable and test scores.

CHAPTER FIVE

Discussion and Implications

Discussion

This study replicated the work of Bayne and Bindler (1988, 1991) in examining the relationship between years of experience as a registered nurse and accuracy of medication dosage calculation. Bayne and Bindler (1988) initially utilized novice nurses with less than one year of experience to study calculation ability. In their second study (Bayne & Bindler, 1991) their sample consisted of registered nurses with varying experience levels. The researchers divided the nurses into categories based on experience but used greater than or less than one year of experience as their qualifying characteristic. This study utilized Bayne and Bindler's work (1988, 1991), along with Benner's (1986) conceptualization of novice to expert time frame to differentiate between novice and expert nurses. It was anticipated this study would show a relationship between years of experience and frequency of medication administration to score on a mathematical calculation test when expert and novice nurses were clearly defined with a

conceptual model. The data, however, did not support this premise. The findings of the study revealed no statistically significant relationship between the variables. This remains consistent with the original studies by Bayne and Bindler regardless of novice and expert definitions (1984, 1988, & 1991). There may be a number of factors influencing the findings.

Response to this survey was low (21%) and results could have been affected by this. While education level of the sample size closely paralleled the education level of the general hospital population, a larger sample size would have made it more credible to generalize to the larger hospital sample and further, to nurses in general. Ninety seven percent of the sample ranked themselves as average or above in math skills, while 96% rated their comfort level as average or above. It is conceivable that those nurses who felt skill and comfort level were below average did not return the test despite the guarantee of anonymity.

The original studies (Bayne & Bindler, 1988, 1991) utilized hospital orientation sessions for all new employees over a specific length of time. This assured a higher return rate of the calculation test as it was a requirement of the orientation session. A higher response rate may have affected results by yielding a more varied sample in terms of skill, comfort and years of experience. While guaranteeing a higher return rate, the potential sample is limited to only those entering the institution and does not

assess the calculation ability of present registered nurses within the organization. Additionally, by utilizing only new employee orientation session, the opportunity to have an increased number of novice nurses expands.

This study was done on a voluntary basis and completed in the setting of choice of the subject. The original studies (Bayne & Bindler, 1988, 1991) were completed in a controlled environment during orientation sessions. While intended to guarantee anonymity of the subject, this matter could have affected test results. Several subjects had written notes suggesting they "checked their answers" with other resources prior to returning the test. This could have resulted in changed answers but is difficult to predict the actual effect on the study itself.

Years of experience was examined as an independent variable affecting the score on the math test. Subjects were divided into novice and expert categories. Novice was considered less than three years and expert more than three years. With this sample, 10% of the respondents were considered novice nurses. This gave a disproportionate number of nurses in the expert category. It is difficult to analyze whether this is reflective of the entire hospital. However, for nursing in general, there are a large number of novice nurses graduating yearly from nursing schools and it is probably not a fair representation of nursing overall. In the original study report, Bayne and Bindler (1988) had 73% of their subject population with less than three years

of experience. However, that study utilized unlicensed graduate nurses as a portion of the subjects. In the later study, Bayne and Bindler (1991) reported only 23% of the nurses had three years of experience or less. The second study is more consistent with sample characteristics of this study. Within this study, a higher percent of nurses are novice to the current area of practice (21%) but the calculation test looked at general mathematical calculation ability, not knowledge specific to any particular area, so this should not affect results.

In examining scores on the test in comparison to the replicated study, 42% of the subjects scored 90% or higher. This is a great deal higher than Bayne and Bindler reported in their studies. They found 35% scored 90% or higher in 1988, and only 19% scored 90% or higher in their 1991 study (Bayne & Bindler, 1988, 1991).

Numerous subjects commented on the actual test questions. There existed some confusion about the purpose of the calculation test. Subjects were concerned over the intravenous additive calculations (Appendix C, questions 17 – 20) as this type of calculation is not currently done at this hospital. The emphasis on the test was on mathematical calculation ability, not specific to any hospital. This was explained in the cover sheet included with the test packet (Appendix A) and the prepared script used for introducing the test (Appendix B) but did not clearly state that some questions, while not in compliance with hospital procedure,

were being used only to examine calculation ability of the nurses. This issue likely affected this study in two ways. First, it would adversely affect calculation ability if nurses have little or no practice with these calculations. Additionally, if nurses viewed the test as specific to their hospital and therefore felt the intravenous additive questions were not appropriate, it is likely they were less concerned about the mathematical calculations. However, overall test score averages with all the intravenous questions omitted improved only minimally (from 83.4% with all questions, to 89.02% with intravenous questions deleted). Significance to the hypothesis remains unchanged though, as the limited number of novice nurses in the sample size is unchanged.

The test itself is an area of concern. Bayne and Bindler (1988) reported an odd-even split half test reliability of 0.82. The KR 20 for this group of subjects was 0.56, indicating poor reliability for the test with this subject group. The KR 20 for the test with the intravenous questions omitted is 0.41. There was no improvement in the reliability indicator for this subject group with the intravenous questions omitted.

Implications for Nursing Practice

While the hypothesis was not supported, there are important implications for nursing practice. The mean score on the test was 83%. As unit dose medication administration is increasingly common, it is tempting to suggest medication

calculation is less important. However, Long (1982) examined the number of medication errors in hospitals utilizing unit dose systems versus other medication administration systems and found no significant differences. So unit dose does not eliminate medication errors and may actually lead to more as the nurse becomes less practiced with actual calculations.

It is also useful to consider pencil and paper tests are not predictive of what actually occurs in a clinical setting. There are fewer demands on concentration levels when a nurse is completing a test than there potentially is during calculations on the unit. If only 42% of the nurses could score 90% or higher in a relatively low stress situation, it is questionable what percentage of accuracy is being achieved during actual medication administration. It could be a worthwhile project to offer math refresher courses specific to the institution periodically for all nurses who calculate medications to retain mastery of the topic and assist those who need extra clarification.

As this and other studies did not support frequency of calculation or years of experience as interacting to influence test scores, it may be that mathematical ability is an innate trait nurses posses before entering nursing. As such, nursing educators may need to identify those with low math calculation skills during new employee orientation or ongoing inservice and provide them with assistance. It would also be beneficial to clearly emphasize resources

available to the nurse on the unit calculating medication such as computer programs to assist in decreasing the number of medication errors related to dosage calculation.

<u>Recommendations for Future Research</u>

Although the hypothesis was not supported statistically, the fact is medication errors due to dosage miscalculation do occur. There are multiple areas for further research concerning this issue. First, additional replications of this study with a larger sample group utilizing current staff and new employees over a specified time period could give a more comprehensive sample of novice and experienced nurses. Secondly, restructuring the test to hospital specific procedures prior to replication would help eliminate some conflict subjects may experience. A better option would be research involving actual observation of nurses calculating medication on the unit. This would give more complete data on actual cause of medication errors. Unfortunately, this would be time-consuming and costly. However, determining the source of medication errors is necessary before the problem can be eliminated.

Bayne and Bindler (1988) indicate nurses with more limited years of study scored higher on the calculation test than those with longer experience as a nurse. It is possible novice nurses maintain a residual sensitivity to mathematical calculation related to training as a student nurse. Further research involving longitudinal studies examining the ability of the subject to calculate

mathematical problems as a student compared to their ability to calculate problems as a novice nurse would enhance this speculation.

Finally, it is difficult to determine whether mathematical calculation ability is a learned skill or an innate ability. Benner's novice to expert theory (1986) suggests that there is a definable learning curve with skill acquisition but does not take into account previous life experiences and abilities that transfer to the nursing setting. Further research on the applicability of Benner's ideas to various areas of nursing practice would be beneficial.

APPENDICES

Appendix A

Cover Sheet for Test Introduction

Dear Colleague:

Hospital nursing care has changed dramatically in the last few decades. Technology has expanded, acuity level has increased and the method of care delivery has changed. Nurses now are expected to be a jack-of-all trades in many instances. Nurses routinely administer multiple medications for numerous patients throughout the course of their regular work day, while at the same time managing the multifaceted activities of patient care. Most of the time, patient care is completed, interruptions are managed and the medication is given correctly. Occasionally, mishaps occur.

I am conducting a research project about the medication calculation skills of registered nurses. This is a skill that some areas of nursing use frequently on a daily basis and other areas may use less regularly. The test you are taking will help me determine the strengths and weaknesses of nurses regarding these skills. Please complete this test independently to help assure validity of the results. Use ONLY the conversion card attached to the test and a calculator to complete the test. The conversion card is yours to keep at completion of the test.

Each test has a card attached to it. The number on that card matches the number on your test. If you wish to know your test results, please remove the card and save it. If you do not wish your test results to be available, please indicate this in the appropriate area on the following page. When you have completed the test, return it by interdepartmental mail with the envelope provided. Following grading, your results will be available by your identification number in the floor conference room. This will assure that your test score is ONLY known by you. Neither I nor Bronson Methodist Hospital are interested in the score of individual nurses but only in group data. The identification number will be used only to return the test score to your unit. The demographic data asked for prior to the test will assist me in drawing conclusions about those characteristics of nurses which might predict strengths or needs in specific areas.

Thank you for participating in this study. Please call me with any concerns or difficulties with completing the test. I welcome your comments and hope this will be a useful experience for you. Information about the findings of this research will be available from me at your request.

Denise Deitzen, R.N., B.S.N.
Bronson School of Nursing
(616) 341 - 8910

Appendix B

Script for Test Introduction

Thank you for inviting me to your staff meeting. My name is Denise Deitzen, I am a master's student at Grand Valley State University completing my thesis. I am going to distribute a questionnaire and math test to you. This test will take approximately one half hour of your time to complete. Please feel free to use a calculator to complete the computations on the test. Please use ONLY a calculator and the yellow conversion card attached to the test to complete it. Pleas complete the test independently so test results will be valid. The conversion card is yours to keep as a small thank you for taking the time to complete this.

The white card attached to the test is an identification number so I may return your score to you. If you do not want your score available, please indicate this on the questionnaire, if you want to find out your score remove the card and save it. Scores will be returned to the unit with this number only. I will not have any way of knowing how an individual scores. I will be using this information to compare group results with demographics obtained from the questionnaire. Please return the test and questionnaire to me by (2 weeks from dispensing) in the attached envelope through interdepartmental mail. I will be sending a reminder to the floor in one week to help you remember to complete this.

Thank you in advance for completing the test and information. If you have any questions or concerns after you have turned in the test, please contact me at 341-8910.

Appendix C

Mathematical Calculation Test

Directions: Please calculate the following questions. Show your conversions and computation for each problem. Use only the conversion card attached and a calculator. All necessary conversions are listed. There are twenty problems.

1. Ordered stat: 250 mg Amoxicillin PO. The Amoxicillin on hand contains 1 gram in each tablet. How many tablets should the patient receive?

2. Ordered stat: Lanoxin elixir 0.2 mg PO. The drug on hand is Lanoxin elixir 0.5 mg/ml. How many ml should the patient receive?

3. Ordered stat: Acetaminophen gr X PO. The medication is available in a liquid of 500 mg/5 ml. How many ml should the patient receive?

4. Patient X weighs 176 lbs. A medication is prescribed for him. The dose is 50 mg/kg. How much medication should be ordered for this patient?

5. If a physician orders 10 cc of a certain medication to be given TID (three times per day) for 20 doses, you will need to dispense a total of how many fluid ounces?

6. Ordered stat: Atropine gr. 1/150. The label on the bottle reads 0.2 mg Atropine per tablet. How many tablets should be given to the patient?

7. Ordered stat: 1 gram Ganstrisin. The drug is available in 400 mg tablets. How many tablets would be given to the patient?

8. Medication X is available in an elixir form labeled 3 mg/5ml. How much medication is contained in each ml?

9. Ordered: Mineral oil two fluid drams TID (three times per day) for 7 days. How many fluid ounces will be taken by the patient by the end of 7 days?

10. A cortisone acetate solution contains 25.0 mg in 1.0 ml. If 80 mg of the medication is ordered, how many ml should be given?

11. Morphine grain 1/8 is ordered. The morphine vial reads "8 mg/ml". How many ml will you administer?

12. Penicillin G 400,000 U IM is ordered for your patient. A vial containing 5,000,000 U of Penicillin G powder is labeled: "Mix by adding 18 ml diluent. Resulting solution contains 250,000 U/ml". You mix the solution as ordered. How many ml should the patient receive?

13. The stock solution is labeled: "Meperidine 1.0 ml = 50.0 mg" If 80.0 mg of Meperidine is ordered IM, how many ml should be given?

14. Your patient has an order for Heparin 100 mg SQ every 8 hours. A 2 ml vial of heparin is available and is labeled "20,000 units per ml with 1 mg = 100 units". You should administer how many ml?

15. 0.25 of a liter IV solution has been given. How many ml remain in the bottle?

16. You must administer 2000 ml D5W IV over 12 hours. You use macrodrip and set the flow rate at how many drops per minute?

17. An order was written for 20 mEq KCl to be administered in 1 liter of IV fluid over 8 hours. It is several hours later and a new order has just been written for 40 mEq of KCl per 1 liter of IV fluid. When you check the patient you find that 500 ml of the original liter is still in the bottle. How much KCl will you add to the solution to fulfill the new order?

18. Aminophylline 250 mg has been ordered for administration in 1 liter IV fluid over 8 hours. The order has been rewritten for 500 mg per liter. You note that 750 ml remain in the IV bag. How much additional aminophylline will you add to the bottle?

19. A patient is begun on a dopamine drip solution (800 mcg/ml) IV. The order if for 400 mcg/min. Using microdrip tubing, how many drops per minute are infusing?

20. A patient has an order for 1500 ml of IV fluid over 8 hours. Using macrodrip tubing, the flow rate should be how many drops per minute?

Appendix D

Demographic Questionnaire

QUESTIONNAIRE

ID #____________

Directions:

Please answer every question. When answering a question, select or write in only one response.

1. What is your current professional status?

   1. Registered Nurse
   2. Unlicensed new graduate nurse
   3. Other (Please specify) __________________

2. What is your current educational level in nursing?

   1. Associate Degree
   2. Diploma
   3. Baccalaureate
   4. Other

3. How many years have you practiced as an RN? (Please write in the number of years).

   ____

4. How many years have you worked in the area/floor you are currently working on?

   ____

5. In what year did you receive your RN licensure?

   ____

Medication calculation is the determination of accurate drug dosage by arithmetical means.

6. Approximately how frequently do you perform some type of mathematical calculation before administering medication?

   a. 5 times per week or less
   b. More than 5 times per week

   If you chose b. (More than 5 times per week) please specify how many times per day a math calculation is performed?

   ____

7. How would you rate your overall <u>skill</u> in medication calculation?

   1. Above average
   2. Average
   3. Below average

8. How would you rate your overall <u>comfort</u> with medication calculation?

   1. Above average
   2. Average
   3. Below average

9. Would you like your score posted in your unit with the anonymous identification number?

   1. Yes
   2. No

10. Please indicate the number of minutes spent completing the test.

   ____

Appendix E

Registered Nurse Reminder Letter

To: Registered Nurses taking the Medication Calculation Test

From: Denise Deitzen

Just a reminder that the medication calculation test distributed in your mail box last week needs to be returned within one week to be included in the study. Please remember to complete the test independently using only a calculator and the attached conversion card. Save your white identification card if you want to find out your results and return the completed test to me through interoffice mail with the envelope provided. If you did not receive a math test and would like to participate in the study, please call me at 341-8910. If you have already returned your test, thank you for your assistance in completing my research project!

Appendix F

Permission to use Mathematical Test

Eastern Washington University
Whitworth College
Washington State University

INTERCOLLEGIATE CENTER
FOR NURSING EDUCATION

2917 W. Fort George Wright Drive
Spokane, Washington 99204-5291
Telephone Number (509) 326-7270
FAX: (509) 325-6173

July 27, 1992

Denise Deitzen
14133 S. 31st St.
Vicksburg, MI 49097

Dear Denise:

It was nice to talk with you last week about your interest in replicating the research done by Ruth Bindler and I. We have talked about your request and are willing to give you permission to use our Medication Calculation Test and questionnaire as a part of your thesis work.

We ask that you confirm your intent regarding replication of our research in writing as soon as possible. We also expect to receive a copy of your data as well as a copy of your thesis upon completion. Please note that the permission we give you is unusual. We expect that you will guard the integrity of our test - and use it for your research purposes only.

Ruth Bindler and I continue to do research related to medication calculation. You do not have permission to share the enclosed medication calculation test with others without our permission.

Good luck with your thesis work. We'll be anxious to see if your results are similar to those we have found.

Sincerely,

[redacted]

Tina Bayne, RN, MS
Assistant Professor

/lj

Appendix G

Conversion Card

1 kg = 2.2 lb.
1 ml = 15 - 16 minim
4 - 5 ml = 1 fluid dram = 1 tsp.
30 ml = 1 fluid ounce
500 ml = 1 pint
1000 ml = 1 liter
1 dram = 60 grain
1 ounce = 8 drams
1 fluid dram = 60 minim
1 grain = 60 milligrams

Intravenous tubing

Macrodrip factor = 15 gtt = 1 ml
Microdrip factor = 60 gtt = 1 ml

LIST OF REFERENCES

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Bayne, T., & Bindler, R. (1988). Medication calculation skills of registered nurses. The Journal of Continuing Education in Nursing, 19, 258-262.

Benner, P. (1983). Uncovering the knowledge embedded in clinical practice. Image: Journal of Nursing Scholarship, 15, 36-41.

Benner, P. (1984). From novice to expert: Excellence and power in clinical nursing practice. Menlo Park, CA: Addison-Wesley.

Benner, P., & Tanner, C. (1987). Clinical judgment: How expert nurses use intuition. American Journal on Nursing, 87, 23-31.

Benner, P., Tanner, C., & Chesla, C. (1992). From beginner to expert: Gaining a differentiated clinical world in critical care nursing. Advances in Nursing Science, 14(3), 13-28.

Betz, R. P., & Levy, H. B. (1985). An interdisciplinary method of classifying and monitoring medication errors. American Journal of Hospital Pharmacy, 42, 1724-1732.

Bindler, R., & Bayne, T. (1984). Do baccalaureate students possess basic mathematics proficiency? Journal of Nursing Education, 23, 192-197.

Bindler, R., & Bayne, T. (1991). Medication calculation ability of registered nurses. Image: Journal of Nursing Scholarship, 23, 221-224.

Bleyer, W. A., & Koup, J. R. (1979). Medication errors during intensive care. American Journal of Disabled Children, 133, 366-367.

Brandt, M., Deml, M., Gerke, M., & Lee, E. (1988). A severity index for medication errors. Critical Care Management Edition, 19, 80N-80O.

Brown, G. C. (1979, October 16). Medication errors: A case study. Hospitals, 61-63.

Byrd, L. (1984). A quality assurance study of medication errors in a psychiatric hospital. Topics in Health Record Management, 5(2), 61-67.

Cobb, M. D. (1986). Evaluating medication errors. Journal of Nurse Anesthetist, 16(4), 41-44.

Cohen, M. R. (1992). Medication errors: Help new nurses avoid making errors. Nursing92, 22(4), 21.

Conklin, D., MacFarland, V., Kinnie-Steeves, A., & Chenger, P. (1990). Medication errors by nurses: Contributing factors. AARN Newsletter, 46(1), 8-9.

Conti, A., & Beare, P. G. (1988). Performance on a mathematics/drug calculation test: Relationship to subsequent reported medication errors. Journal of Nursing Staff Development, 14, 54-58.

Corcoran, S. A. (1986). Planning by expert and novice nurses in cases of varying complexity. Research in Nursing & Health, 9, 155-162.

Cushing, M. (1986). Drug errors can be bitter pills. American Journal of Nursing, 86, 895-896.

Davis, N. M., & Cohen, M. R. (1987). Learning from mistakes: Medication errors to avoid. Nursing87, 17(5), 84-95.

Del Bueno, D. J. (1972). Verifying the nurse's knowledge of pharmacology. Nursing Outlook, 20, 462-463.

Dreyfus, S. E., & Dreyfus, H. L. (1980). A five-stage model of the mental activities involved in directed skill acquisition. Unpublished report supported by the Air Force Office of Scientific Research (AFSC), USAF (Contract F49620-79-C-0063), University of California at Berkley.

Francis, G. (1980). Nurses' medication "errors": A new perspective. Supervisor Nurse, 11(8), 11 -13.

Fuqua, R. A., & Stevens, K. R. (1988). What we know about medication errors: A literature review. Journal of Nursing Quality Assurance, 3(1), 1-17.

Graham, K. & McMahon, M. (1989). Medication incidents: A microgram of prevention. Dimensions in Health Care Services, 66(8), 21-24.

Harnden, L. (1988). Disciplinary responses to nurses' medication error. Dimensions in Health Care Services, 65(4), 26,32.

Hodgin, L. (1984). Sarnia general develops medication error report. Dimensions in Health Care Services, 61(3), 25.

Holden, G. W., & Klinger, A. M. (1988). Learning from experience: Differences in how novice vs. expert nurses diagnose why an infant is crying. Journal of Nursing Education, 27, 23-29.

Itano, J. K. (1989). A comparison of the clinical judgment process in experienced registered nurses and student nurses. Journal of Nursing Education, 28, 120-126.

Johnson, M. (1987). Drugs and discipline. Senior Nurse, 6(2), 14-16.

Killian, W. H. (1991). Medication errors expose RNs to liability. American Nurse, 23(2), 34.

Koska, M. T. (1989, June 5). Drug errors: Dangerous, costly and avoidable. Hospitals: The Magazine for Health Care Executives, 63, 24.

Long, G. (1982). The effect of medication distribution systems on medication errors. Nursing Research, 31, 182-184.

Long, T. (1992). Working with people: Pointing out medication errors. American Journal of Nursing, 92, 76-77.

Luquire, R. (1989). Nursing risk management. Nursing Management, 20(10), 56-58.

Markowitz, J. S., Pearson, G., Kay, B. G., & Loewenstein, R. (1981). Nurses, physicians, and pharmacists: Their knowledge of hazards of medications. Nursing Research, 30, 366-370.

McGovern, K. (1987). Take the first step toward reducing medication errors. Nursing87, 17(12), 49.

McNeilly, J. L. (1987). Medication errors: A quality assurance tool. Nursing Management, 18(12), 53-58.

Perlstein, P. H., Callison, C., White, M., Barnes, B., & Edwards, N. K. (1979). Errors in drug computations during newborn intensive care. American Journal of Disabled Children, 133, 376-379.

Pierce, M. E. (1984). Reporting and following up on medication errors. Nursing84, 14(1), 78-80.

Polit, D. F., & Hungler, B. P. (1987). Nursing research (3rd. ed.). New York: Lippincott.

Poster, E. C., & Pelletier, L. (1988). Primary versus functional medication administration: Monitoring and evaluating medication error rates. Journal of Nursing Quality Assurance, 2(2), 68-76.

Rheinstein, P. H., & McGinnis, T.J. (1992). Medication errors. American Family Physician, 45, 2720-2722.

Scholz, D. A. (1990). Innovations and excellence: Establishing and monitoring an endemic medication error rate. Journal of Nursing Quality Assurance, 4(2), 71-85.

Schwartz, L. A., & Lowe, D. (1989). Applying a theoretic framework for reducing medication errors in intensive care units. Focus on Critical Care, 16, 438-443.

Sherman, J. J., & Clinefelter, K. (1989). Medication variances: A multi-hospital comparison. Nursing Management, 20(5), 56-58.

Smith, L. S. (1990). Those medication errors dilemmas! Advancing Clinical Care, 5(5), 50-51.

Worrell, P. J., & Hodson, K. E. (1989). Posology: The battle against dosage calculation errors. Nurse Educator, 14(2), 27-31.