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A Comparison of Two Teaching Methods for Pediatric Medication Administration: Multimedia and Text-Based Modules

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A COMPARISON OF TWO TEACHING METHODS FOR PEDIATRIC MEDICATION ADMINISTRATION: MULTIMEDIA AND TEXT-BASED MODULES

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Dissertation Abstract

A Comparison of Two Teaching Methods for Pediatrics: Multimedia and Text-based Modules to Teach Pediatric Medication Administration

Nurse educators are in a position to design and develop effective methods that consider the cognitive structures and how the mind processes information to teach pediatric medication content to nursing students. The majority of methods teaching medication administration use only one mode: the visual mode. One mode to present leaning material does not take advantage of the additive effects of using two modes to present learning material.

The purpose of the study was to compare the effectiveness of two teaching methods to present learning material for teaching pediatric medication administration content: multimedia and text-based modules. The multimedia and text-based modules included worked examples with a step-by-step explanation and solution on how to calculate pound to kilogram, safe-dose ranges, intravenous flow rates, and fluid maintenance. The dependent variable was knowledge acquisition of mathematical calculation skills for medication administration. Calculation skills were defined operationally as a student's ability to calculate (a) weight-based safe-dose ranges, (b) intravenous flow rates for primary and secondary (intravenous piggy-back) medication infusion, (c) conversions from pounds to kilograms, and (d) fluid maintenance.

The results indicated that there were no statistically significant differences between the multimedia and the text-based module with regard to the pass rates and the four subtest items, pound-to-kilogram conversions, safe- dose calculations, intravenous flow rates, and fluid-maintenance calculations. The results also suggest that both modules

were not as effective for teaching pediatric medication administration content for the participants in the study, as one would expect.

As for additional findings, the majority of errors made by both groups were similar with the exception of three types of errors. The differences between the two groups were related to correctly setting-up the problem, mathematical functions, and calculation errors. The majority of the questions that were answered incorrectly were related to mathematical functions, for example, dividing, adding, or multiplying when not necessary. The text-based group made more mathematical functions errors and calculation errors compared with the multimedia group. All of other types of errors that were made between the two groups were similar.

This dissertation, written under the direction of the candidate's dissertation committee and approved by the members of the committee, has been presented to and accepted by the Faculty of the School of Education in partial fulfillment of the requirements for the degree of Doctor of Education. The content and research methodologies presented in this work represent the work of the candidate alone.

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CHAPTER I
RESEARCH PROBLEM

Medication administration is one of the most common and essential skills that is performed by nurses in clinical practice (Penti & Smith, 2006), and it is a crucial aspect in providing high quality and safe patient care (Harne-Britner et al., 2006). Medication errors continue to be a problem in health-care settings (American Academy of Pediatrics, 2003; Institute of Medicine, 2000). Specifically, calculation errors have been identified as one of the top 10 causes of pediatric errors (Cowley, Williams, & Cousins, 2001). With that said, it is imperative that student nurses are proficient with medication administration, particularly in pediatrics.

There are many factors that play a role in how prepared students are to administer medications to the pediatric population. All too often, when students are scheduled to take the pediatric clinical, they are not prepared to administer medications because throughout the nursing program, they have been taught medication administration primarily for the adult population. In the adult population, there is a standardized dose that is recommended for all adult patients. Therefore, because no calculations are required, errors are less likely to occur during medication administration.

In pediatrics, one of the most commonly reported medication error includes calculation of medication dosages (American Academy of Pediatrics, 2003; Hughs & Edgerton, 2005). In contrast to adult medication administration, there are few standardized dosing regimens for children. For instance, a standardized dose (one dosage) is not recommended for all children because of the wide range of body mass, differences in weight, metabolism, and excretion of various drugs compared with adults (Taketomo, Hodding, & Kraus, 2007-2008). These physiological differences warrant special considerations for medication administration in pediatrics. Consequently, medication dosages must be calculated based on a child's weight or body surface area and the child's clinical condition (Ghaleb et al., 2006; Taketomo et al., 2007-2008). Because all medication dosages for children are weight-based and require mathematical calculation, the possibility of dosing errors increases (Ghaleb et al., 2006). Incorrect medication dosages due to poor mathematical skills account for the majority of pediatric medication errors (Hughs & Edgerton, 2005). Therefore, accurate medication administration in pediatrics is critical to patient safety.

The literature indicates that the teaching practices of mathematical skills for medication administration, in schools of nursing, vary widely (Allen & Pappas, 1999; Polifroni, Mc Nulty & Allchin, 2003), such as, lecture, demonstration, workbook, and multimedia. Polifroni et al. (2003) conducted a nationwide survey to assess how nursing programs evaluated the mathematics skills for medication administration. Of the 594 schools of nursing selected randomly, 53% of the nursing programs responded to the survey. The majority of the mathematical tests for medication administration were developed by the faculty. These tests did not assess for a specific grade level of proficiency. There was a wide variation in the minimum possible score. For example, 10% of the baccalaureate programs, 5% of the diploma programs, and 17% of the associate degree programs required 100% correct as passing. Ninety percent correct was frequently most cited for the required passing; other programs required 80% correct to pass, and 15% of the nursing programs only required 70% correct to pass.

As for when medication administration content is integrated in the curriculum, 30% of the programs required a mathematics test when students were in the clinical setting where they were expected to administer medications, and 13% of the programs included mathematics content on every nursing test, even if no medications were administered. Eight percent of the programs tested mathematical skills on admission of the program, 11% tested before admission, and 3% of the programs tested in nonclinical courses. The results of Polifroni et al. (2003) study indicated that the initial testing of mathematical calculation skills varied widely for the nursing programs. Specifically, 56% of the programs required mathematical testing during the first clinical course, and 12% were tested prior to the first clinical course. This variation in testing can be problematic, because the first clinical course could be early in the program, midway, or closer to the end of the program.

In a study conducted by Allen and Pappas (1999), clinical faculty in the nursing program were becoming increasingly frustrated because many of the students were not able to solve clinical mathematical problems and many of the students were not taking seriously the importance of mathematical skills and the relationship to safe medication administration. All too often, many students failed the mathematical test multiple times. As a result, the clinical faculty were spending extra time to remediate the students who failed the mathematics examination. Because of the trend of nursing students' inability to solve clinical mathematical problems, Allen and Pappas (1999) sent a survey to associate and baccalaureate degree nursing programs to ascertain the teaching practices and common teaching methods used to teach medication calculation skills. The findings of the survey revealed that some programs required a mathematical-skills screening prior to admission to the program, some required a first-semester mathematical examination only, and others only required testing of mathematical skills each semester.

After careful evaluation of the current nursing programs mathematical competency policy and review of the results of the survey, Allen and Pappas (1999) instituted a new policy in their nursing program. Within the first 2 weeks of the semester, students were taught essential mathematical concepts and provided with sample problems including a mathematical reference book. Students were allowed two opportunities to take the mathematical examination with 90% correct to pass. If they did not pass after the second attempt, they were required to enroll in a one-hour mathematics course, which consisted of one-to-one tutoring. Students were required to complete the module midway through the semester before they could begin the first clinical course. If they were not able to pass two consecutive mathematical examinations with a 90% correct, they failed the clinical course. At the beginning of subsequent semesters, students were provided with sample problems and a study guide and were permitted two attempts to take the mathematics examination. If they did not pass after the second examination, they were required to complete the mathematics module.

For teaching mathematical competencies, Allen and Pappas (1999) study discovered that the majority of the nursing programs used person-person lessons accompanied by self-learning modules and that 64% of the nursing programs required the students to practice calculations of dosages in simulation laboratories. Ninety-five percent of the nursing programs provided the students with practice exercises to be used prior to taking the mathematical test. These results demonstrate that nursing programs use a wide range of teaching methods to instruct students in mathematical skills. Nurse educators are in a position to design and develop effective multimedia and use strategies that support understanding and learning.

There are many methods used by educators to teach medication calculations to student nurses. Many of the teaching methods do not consider the students' cognitive structures and processes, such as the constraints of the working memory. The literature consistently has shown that when multimedia instructional messages are designed specifically to address the limitation of the working memory by presenting learning material concurrently in the visual mode and the auditory mode, more information can be processed in both modes, rather than presenting learning material in one mode. When two modes are used to present learning material meaningful learning is more likely to occur. In numerous studies, students outperformed their counterparts when learning material was presented in two modes as opposed to learning material presented in one mode (Ginns, 2005; Moreno, 2006). The traditional instructional methods such as CD ROMs, lecture format, text-based practice problems, and online text were the most commonly used instructional methods to teach medication administration. These methods use one mode to present the learning material and do not maximize the cognitive structures and processes and do not facilitate schema construction and understanding.

This study used two instructional principles that support schema construction: multimedia (modality effect) that presents congruent learning material in the visual and auditory modes and worked examples. Research has shown that when presenting complex material in the visual (images, pictures, or animation) mode and in the auditory (spoken words) mode that are congruent as opposed to presenting the words in text (visual mode), more learning material can be processed (Mayer, 2009). The positive affect of using words and pictures to present instructional messages is known as the modality effect. The modality effect asserts that people learn better from pictures and spoken words as opposed to pictures and text (Moreno, 2006).

In the literature, worked examples have been used in a variety of methods to present learning material. Some of the common methods used to present worked examples are computer-based simulation, lecture, text-based and multimedia (Darabai, Nelson, & Palanki, 2007; Darabai & Nelson, 2004; Kalyuga, Chandler, Tuovinen, & Sweller, 2001; Wittwer & Renkl, 2012). Worked examples are an instructional strategy that is recommended for learning complex problems because they provide guidance that is similar to direct instruction (Darabi et.al., 2007) and they support the construction of problem-type schemas (Atkinson, Renkl, & Wortham, 2000; Darabi & Nelson, 2004). For example, worked examples typically are comprised of a problem statement and the solution to the problem and serve as an expert model for solving a particular problem (Atkinson et al., 2000; Atkinson & Renkl, 2007).

Purpose

The purpose of the study was to compare the effectiveness of two teaching methods to present learning material for teaching pediatric medication administration content: multimedia and text-based modules. The multimedia and text-based modules included worked examples with a step-by-step explanation and solution on how to calculate pound to kilogram, safe-dose ranges, intravenous flow rates, and fluid maintenance. The dependent variable was knowledge acquisition of mathematical calculation skills for medication administration.

For the purpose of this study, multimedia was defined as the presentation of instructional messages in two modes: visual and auditory (Mayer, 2009). The multimedia module that was used in this study presented images of worked examples with concurrent verbal explanation on how to calculate pound-to-kilogram conversions, pediatric medication safe-dose ranges, intravenous flow rates, and fluid maintenance. To develop the multimedia module, a document camera was used to capture the researcher writing on a white board using a sharpe to explain the steps on how to solve mathematical calculations related to medication administration. There was a microphone attached to the computer that recorded the verbal explanation given by the researcher. Two strategies, segmenting and worked examples, were used in the multimedia module. Segmenting is a design technique that can be used to manage essential processing (Mayer, 2009). When the learning material is presented in small segments, the learner can self-pace by skipping familiar content and review relevant content as needed (Mayer, 2009).

Theoretical Rationale

The theoretical rationale that guided this study was the cognitive theory of multimedia learning. The cognitive theory of multimedia learning is an instructional theory that takes into consideration cognitive structures and the processes that are necessary for meaningful learning to occur. When the cognitive processes and structures of the mind are considered meaningful learning is more likely to occur. It is crucial that multimedia instructional messages are designed to consider the cognitive structures and the limitations of the working memory. The cognitive theory of multimedia learning assumes that the mind is an information-processing system that includes: dual channels, limited capacity, and active processing. The dual channel assumption asserts that there are two separate and independent channels to process visual and auditory information: the limited capacity assumption emphasizes the human mind can only process small amounts of information for a short time and the active processing assumption asserts that learners actively must pay attention to relevant information, select and organize information into knowledge structures, and integrate the mental structures with schemata in long-term memory. An overview of cognitive theory of multimedia learning is presented in the following section.

The cognitive theory of multimedia learning has three components: the sensory memory, working memory, and long-term memory. Figure 1 is a representation of the conceptual model of how information is constructed and processed in the cognitive structures.

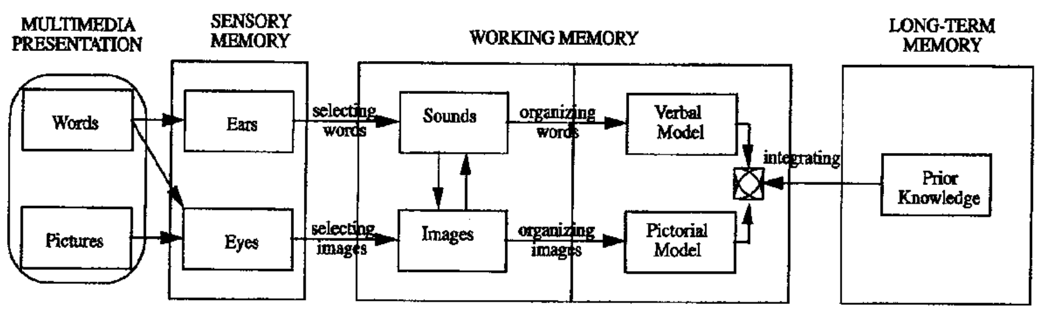

Figure 1. Conceptual Model of Cognitive Processing (Mayer, 2009).

The processing of information begins with the incoming words and pictures initially being processed in the sensory memory: ears and eyes. The next step includes the learner paying attention to the words and images and selecting relevant words and images. The words and images are then organized into coherent mental representations. The integration of the mental representations is where any schemata (prior knowledge) may be drawn from the long-term memory to help understand the information coming from the working memory.

Mayer (2001, 2005) described three cognitive processes that are necessary for active learning: (a) selection of relevant words and images, (b) organization of selected words and images, and (c) integration of selected words and images with prior knowledge (Mayer, 2005). When learning material is presented as spoken words (narration), it is processed and organized in the auditory modality; visual images and printed text are processed and organized in the visual modality. The first step of processing information begins when images (including printed text) and spoken words (narration) pass through the *sensory memory*: the eyes and ears. The sensory memory is where incoming images (pictures, illustrations, onscreen-text, animations, or video) temporarily are stored, in the *visual sensory memory*, as the actual visual image is seen. Similarly, spoken words, and other sounds pass through the sensory memory and temporarily are held in the *auditory sensory memory,* as the actual auditory sound.

Once the spoken words and images are processed through the *sensory memories*, selection and organization of the words and images are transformed to mental representations that temporarily are stored in the working memory. The process of selection and organization of words and images involves paying attention to some of the words and images. The selection of relevant words involves a change in knowledge representation from a sensory representation of verbal sounds to an internal representation of verbal sounds. Similarly, the incoming images are transformed from a sensory representation to an internal representation of the visual images (Mayer, 2009).

The organization of images and words is similar to the selection of words and images (Mayer, 2009). For instance, pieces of images and words are organized and connections are made between the selected words and images resulting in the formation of knowledge structures. Once the knowledge structures are formed, the words and other sounds are organized into a *verbal model* and the images and printed text are organized into a *pictorial model* (Mayer, 2009).

The last and most important cognitive process involves the integration of the *visual* or *pictorial model and auditory or verbal model.* This step occurs in the working memory and involves making connections between similar parts of the *pictorial model* and the *verbal model* plus making connections with relevant prior knowledge from long-term memory. This process is very demanding and requires the learner to makes sense of the visual and verbal representations. At this stage, the learner can retrieve and use prior knowledge in long-term memory to facilitate coordination of the integration process (Mayer, 2001, 2005).

Within the context of cognitive theory of multimedia learning, it is the educator's responsibility to present instructional messages in a manner that will facilitate knowledge construction (Mayer, 2005), and it is the student's responsibility to make sense actively of the information. Two crucial prerequisites essential for meaningful learning to occur are active learning and knowledge construction. Active processing involves paying attention, organizing incoming information, and integrating incoming information. Active processing occurs when the learner engages his or her cognitive processes to facilitate the construction of coherent mental representation from the learning material (Mayer, 2001, 2005).

When novel information is presented, the working memory will organize and share it with the long-term memory. If schemata are not available in long-term memory, however, learners will have to sort randomly, organize incoming information, and test for effectiveness. For example, when trying to solve a problem, searching for a random solution directs attention away from aspects of the problem important for learning, as a result, overburdens the working memory and interferes with schema construction (Mayer, 2005).

As an educator, it is imperative to have an understanding of the cognitive structures and the processes essential for processing information. Therefore, it is important that the pedagogies that are used maximize the cognitive processes. The working memory is a critical cognitive structure where incoming information is stored temporarily and at the same time processed (Baddeley, 1992). There are two severe limitations: (a) there is restricted capacity when dealing with novel information and (b) the working memory can only retain information for approximately 20 seconds at a time (Mayer, 2001, 2005; Sweller & Chandler, 1991). Essentially, the working memory has to work hard to organize and make sense of novel information, and, as a result, learners have to search randomly to make sense of the information. To further complicate matters, only 2 to 4 elements of information can be held in the working memory at one time, that is, only a few images and a few words can be processed in working memory at one time and learners are only able to remember portions of the images and narration (Mayer, 2005). Another limitation is the duration that information is able to be held in of the working memory. For example, learners can only hold information in the working memory for 20 seconds before it is lost (Mayer, 2005).

The Dual Coding Theory (Paivio, 1986) is the classical theory that provided a foundation for theories of cognitive structures and processes. This theory asserted there are two distinct and independent verbal and visual coding systems. Each of these coding systems uses a uniquely different manner for representing knowledge, and they are not equal. When information is presented by using words, it can be described in an interpretive or abstract manner, and learners may have to use some cognitive effort to translate the information. In contrast, image knowledge representations are more natural primarily because pictures are considered concrete and easily can be remembered as a visual image. As a result, when images or pictures are presented, they result in better memory than do words alone (Paivo, 1969; Reed, 2006).

This study focused on two instructional principles that have been shown to be effective strategies and are being used by educators to teach complex domain specific content such as mathematics. The instructional principles are worked examples and the modality principle. Each of these principles focuses on specific areas of cognitive processing. The principle for managing essential processing included in this study is the modality principle (Mayer, 2009; Mayer & Moreno, 2002). The modality principle is an instructional-design technique that can be used to manage essential processing of learning material. Essential processing is a cognitive process where the goal is to represent mentally the essential information in the working memory (Mayer, 2009). If the goal is for the student to understand a particular mathematical function, it is critical that the instructional message emphasizes the essential steps in solving the problem in order for the necessary information to be moved to the working memory and finally encoded in the long-term memory. The goal is to avoid essential processing overload. Essential processing overload occurs when the learning material is cognitively demanding, thus limiting cognitive capacity, thereby , limiting student the students capacity for deeper processing.

Multimedia that presents learning material in two modes supports the constraints of the cognitive structures and considers how information is processed. When learning material is presented in two modes, visual and auditory, learning outcomes have demonstrated positive effects when compared with other methods that use one mode to present learning material (Mayer, 2009; Moreno 2006). The modality principle is an instructional principle that considers the constraints of the working memory and how information is processed (Mayer, 2009). According to Mayer (2009), the premise behind the modality principle is that students learn better when learning material is presented using narration and images together as opposed to images and on-screen-text. Specifically, when learning material is presented as narration, the spoken words are processed in the auditory channel and images or pictures are processed through the visual channel (Mayer, 2009; Moreno, 2006). In this case, the load is distributed in each of the channels and neither is overloaded; consequently, the cognitive demand is decreased (Mayer & Moreno 2010). When learning material is presented as text-based and as images or pictures, the text material and the images are processed only in the visual channel. Because the learning material is processed only in the visual channel, the cognitive demand increases. Words and pictures are qualitatively different, however, when used together there is a complimentary effect, and understanding occurs when learners are able to integrate mentally and make meaningful connections of the image and verbal representations (Mayer, 2009). When an instructional message presents the step-by-step illustration with a verbal explanation on how to execute the safe-dose calculation or pound-to-kilogram conversion, learners are better able to build the connections between the words and images and, as a result, meaningful learning is more likely to occur than they could from images (text) or words only.

In addition to the modality principle, using worked examples is another strategy that has been shown to be effective for reducing extraneous cognitive processing (Mayer, 2005). The use of worked examples to teach mathematics consistently has been supported by the literature (van Gog, Paas, & van Merrienboer, 2004; van Merrienboer, Kirschner, & Kester, 2003). Several research studies on learning mathematics and learning in general found that, when students used worked examples as opposed to learning by the traditional lecture and then practice (Caroll, 1992; Kalyuga, Chandler, Touvinen, & Sweller, 2001) and conventional problem-solving (Darabi & Nelson (2004), they outperformed their counterparts.

The conventional problem-solving approach is not an effective means for learning because it can prevent novice learners from learning the most important aspects of a problems structure (Kalyuga et al., 2001). With the problem-solving approach, learners are forced to search for a solution when solving a problem, and this searching places strain on the working memory. By providing worked examples, there is a reduced need for searching for a solution and reduces extraneous cognitive processing (Mayer, 2009). The benefit of presenting worked examples and spoken words concurrently is that there is a verbal explanation describing the steps on how to solve the problem. The multimedia medication module in this research study used worked examples with the solution steps to present the pound-to-kilogram conversions, safe-dose calculations, intravenous flow rates, and fluid maintenance.

Background and Need

Throughout the United States, medication errors continue to be a problem in health-care organizations; as a result, these organizations are now taking a proactive approach through examination and root-cause analysis. Barriers to improvement and strategy design for prevention are part of the identification process (American Society of Health System Pharmacist, 1993; Institute of Medicine, 2006; Metules & Bauer, 2007). There is a growing trend in research that emphasizes continuous quality improvement, improvement in processes, and system analysis as methods of preventing medication errors (Serembus, Wolf, & Youngblood, 2001). In particular, system factors that contribute to medication errors and prevention strategies have been identified (Anderson & Webster, 2001; Etchells, Juurlink, & Levinson, 2008; Foote & Coleman, 2008; Fry & Dacey, 2007; Harding & Petrick, 2008). Strategies to reduce medication errors at a systems level are essential; however, they do not take into account human factors, namely, nurses' proficiency in calculating medication dosages, particularly in pediatrics. Although accurate and safe medication administration is a critical aspect of the nurse's role, many nurses have weak mathematical skills (Wolf, Hicks, & Serembus, 2006; Wright, 2008). Because of the high-risk nature of medication administration, medication errors are second to falls as a cause for lawsuits involving nurses (Anderson & Webster, 2001; Maricle, Whitebead, & Rhodes, 2007).

Cowley et al. (2001) collected data from two databases: the Medication Errors Reporting Program, a national database, and MedMARx, an Internet-accessible database, where data are collected locally and stored in a central storehouse that is maintained by the United States Phamacopeia. There were a total of 3,813 errors submitted to the

Medication Errors Reporting Program database, 9% (n=333) involved pediatric patients. The MedMARx database reported 43,287 errors, of those 5% (1,969) involved pediatric patients. The most frequently reported type of medication errors were wrong dose or quantity. In the Medication Errors Reporting Program, there were 337 types of errors identified; of those, 47% (n=157) were the wrong dose or quantity. Similarly, MedMARx reported 2,003 types of errors, of those, 25% (n=494) wrong dose or quantity errors were one of the most frequently reported medication errors. Of note, the cause of the wrong dose or quantity was not reviewed. Out of 1,969 pediatric records, however, 4% (n=121) of medication errors were attributed to calculation errors.

In pediatrics, the reported incidence of medication error rates that resulted in death or harm was 31% in comparison with 13% for adults (American Academy of Pediatrics, 2003). Likewise, in pediatrics one of the most commonly reported errors includes calculation of medication dosages (American Academy of Pediatrics, 2003; Hicks, Becker & Cousins, 2006). The root of the problem is that there are few standardized dosing regimens for children. A standardized dose (one dosage) is not recommended for all children because of the wide range of body mass, differences in weight, metabolism, and excretion of various drugs compared with adults (Taketomo et al., 2007-2008). These physiological differences warrant special considerations for medications administration. Consequently, medication dosages must be calculated based on a child's weight or body surface area and on the child's clinical condition (Ghaleb et al., 2006). Because all medication dosages for children are weight based and require mathematical calculation, the possibility of errors, in particular dosing errors (Ghaleb et al., 2006) is increased. Therefore, accurate medication administration in pediatrics is critical for patient safety.

In acute-care institutions, there is approximately one medication error per patient every day (Bayne & Bindler, 1997; Segatore, Miller, & Webber, 1994; Thomas, Holquist, & Phillips, 2001). Medication administration is one of the most common and essential skills that are performed by nurses in clinical practice on a day-to-day basis (Pentin & Smith, 2006). A high level of proficiency and accuracy with medication administration is critical in providing high quality and safe patient care (Harne-Britner et al., 2006; Wright, 2004), especially in pediatrics.

Hicks et al. (2006) conducted a retrospective review of medication errors related to pediatric patients that were reported over a 5-year period to the MEDMARX database by subscribing healthcare organizations. During the 5-year period, out of 580,761 records, there were 19,350 (3%) pediatric medication error reports submitted. Four percent of the records were identified as being harmful to the patient. Eleven percent (n=96) of the most commonly reported medications that were related to harmful pediatric medication errors were the opioid analgesics: morphine sulfate, and fentanyl. Morphine sulfate and fentanyl (64 of 108) were also the most commonly reported type of error, in which an “improper dose or quantity” was administered. Hicks et al. (2006) defined an improper dose as “any dose or strength that differed from the prescribed dose or strength; including incorrect quantity (e.g., tablets and vials) dispensed” (p. 295). If a patient receives an overdose, respiratory compromise can ensue and fatal consequences can occur. Although the type of error “improper dose or quantity” did not indicate if the dose was an overdose; however, it can be deduced that this is the case because these opioid analgesics were reported as causing harm.

When a medication error occurs, pediatric patients have a much higher risk of death than do adult patients (Hughs & Edgerton, 2005). In particular, they are at an increased risk for 10-fold medication errors (Doherty & McDonnell, 2012). Doherty and McDonnell (2012) defined a 10-fold dosing error as10 times or one-tenth the intended medication dose. Doherty and McDonnell (2012) conducted a retrospective study over a 5-year period with the purpose of examining 10-fold medication errors at a Toronto, Canada hospital. Medication-related incident reports were submitted voluntarily to the safety reporting database at a university associated with a pediatrics hospital. The outcome measures were severity of the error, drug and drug classes involved,10-fold medication error enablers, mechanisms, and contributing causes (Doherty & McDonnell, 2012). Out of 6,643 medication-related safety reports, 252 ten-fold medication errors were detected. The 10-fold medication errors were reported at a mean rate of .06 per 100 patient days. Ten-fold medications errors most frequently occurred in the prescription and administration phases of the medication process. There were 178 ten-fold overdoses and 74 ten-fold underdoses reported, and there were 129 ten-fold medication errors that reached the patient.

Doherty and Mc Donnell (2012) defined mechanism of errors as the “act or practice that led to the error source (e.g., misplacing the decimal point, adding or omitting a zero, or performing a mental dose calculation instead of using a calculator)” (p. 917).The mechanism of errors most frequently identified were addition of zeros and omission of zeros, programming multiple infusion rates simultaneously, and interswapping of infusion rates. There were 22 ten-fold medication error reports that described the patient as being harmed. Error sources that were frequently identified as causing patient harm were calculation errors, paper-based orders, and incorrect programming of a medication delivery device. Enabler errors are defined as factors that permitted an error to proceed through the medication process until it was intercepted and corrected or reached the patient. Ten-fold medication errors that were considered harmful enablers were urgent clinical scenarios, paper-based ordering, and overriding of alarm limits. Out of eight toxic potentially high-risk medications, five of these were morhine, heparine, hydromorphone, fentanyl, and insulin. These high-risk medications accounted for 28% (71) of the 252 ten-fold medication errors reported. High-risk medications can cause devastating effects such as permanent disability or even death.

During the administration phase (n=39), the 10-fold medication errors for the high-risk medications were reported more frequently than during the prescription phase (n=22). Twenty-two reports identified opioids as most frequently causing harm. Specifically, morphine was the most frequently identified medication. Seven 10-fold opioid medication errors warranted immediate airway intervention, and three required emergent actions to support life.

The results indicate there are many factors that contribute to 10-fold medication errors. Two causes of 10-fold medication errors identified resulting in harm to pediatric population were related to mathematical competency error sources such as calculation errors and mechanism of errors; these include misplacing the decimal point, adding or omitting zeros, or performing a mental dose calculation instead of using a calculator. Ten-fold medications errors most frequently occurred in the prescription and administration phases of the medication process. Nurses are responsible for preparing and administering medication on a daily basis. Nurses are accountable for the care that they provide, and this care includes accurately and safely administering medications. These results underscore the need for student nurses and nurses to have a solid mathematical foundation in calculation of pediatric medication dosages.

Nursing students learn how to calculate medication dosages and other mathematical functions related to medication administration in nursing school (Wright, 2005). Nurse educators are in a position to design and use effective pedagogies to teach medication calculations. Wright (2005) embarked on a study to investigate the most effective teaching method for teaching medication calculations and to improve her teaching skills for teaching medication calculations. To ascertain the students baseline mathematical competency, a pre-assessment diagnostic test with 30 questions that consisted of six categories and in each category contained five types of questions: percentages, ratios, fractions, place value, and interpreting information was conducted. Seventy-one nursing students participated in the pre-assessment diagnostic test.

Seventy out of 71 of the pre-assessment exams were returned. The results of the pre-assessment diagnostic test indicated that students had difficulty with test items that were related to medication calculations. Out of 30 questions, the mean was 16 (53%) and 36.7% of the students were unable to work out correctly half of the questions. The mean for interpreting information was 2.14 out of 5. Essentially students had difficulty extrapolating relevant information from a narrative and using the information to calculate the amount of drug to administer. Only 7% of the students answered the place-value questions correctly. The place-value questions involve dividing and multiplying numbers by 10, 100, or 1000. The mean for fractions was 3.9 out of 5; for multiplying fractions, the mean was 1.6 out of 5; the mean for ratios was 2.35 out of 5; and the mean for percentages was 3.96 out of 5. The results indicate that students do not have a high level of mathematical proficiency, which is problematic as medication administration calculations require 100% accuracy.

Based on the pre-assessment diagnostic test, Wright (2005) developed a 2-hour medication calculation session with strategies that focused on drug calculation formulas and in an effort to reduce mathematical deficiencies students were encouraged to use calculators. During the session Wright (2005) demonstrated how to use formulas and provided one-on-one feedback. Based on the observations during the teaching session, Wright and colleagues (2005) noted that students were committing the same types of mathematical problems identified in the diagnostic pre-assessment test. As a result of the observations made during the second session and reviewing the literature on strategies for teaching drug calculations, Wright (2005) adopted a virtual learning environment to teach medication calculations and added calculation questions in two clinical-skill sessions. The virtual learning environment was accessed on a website. There were self-assessment tests throughout the module. In addition, in-skills laboratory calculations related to clinical practice were instituted, that is, an intravenous-skills session involved students preparing an intravenous infusion where they had to calculate the infusion rate.

The result after the implementation of the new teaching strategies; virtual learning environments and relating calculations to practice was improved mathematical skills. Wright (2005) discerned that it is helpful to use the examples and equipment in the skills laboratory to explain the questions to the students. The new strategies implemented in the second half of the study support the use of virtual learning environment and simulation activities to help contextualize the mathematical calculations. The study results further strengthen the necessity that nursing students are highly proficient with regard to medication calculation skills.

The most common instructional methods used to teach medication calculation content are in the skills laboratory, lecture, text-based practice problems, independent text-based modules, online CD ROMs or Web-based learning, and, more recently, simulation. These methods are text-based learning materials, with the exception of lecture, skills laboratory, and simulation. Learning material presented in one mode does not consider the constraints of the working memory. Novice learners have a better understanding of learning material when it is presented in two modes. Effective instructional strategies that can be used to teach pediatric medication content are needed, especially for students with minimal domain specific knowledge.

According to Mayer (2005), multimedia has different meanings to different people, that is, some think of a multimedia presentation when instructional messages are presented on a computer screen with graphics and with spoken words from the computer speaker; watching a video on a television screen and listening to the words, music, or sounds; or watching a Powerpoint presentation with text and listening to the speaker explaining the content. Others may think of low-technology multimedia in the form of chalkboard and verbal explanation to present a lecture that contains printed text and illustrations. In the context of this dissertation research, Mayer's (2005) definition of multimedia was used. Multimedia is defined as the presentation of instructional messages using words and pictures. In addition, in keeping with this definition, the instructional principle known as the modality principle operates under the same premise as multimedia. The modality principle asserts that people learn better from pictures and spoken words as opposed to pictures and text (Moreno, 2006).The multimedia medication module in this research presented learning material in two modes: the visual mode (as images or pictures) and the auditory mode (as spoken words).

Although research has been conducted to compare multimedia with other teaching methods such as lecture, text-based self-paced modules, and online text-based modules, frequently the multimedia does not present learning material using instructional principles that support how the mind processes information. Many of the learning materials used to teach medication calculations include a CD-ROM that presents learning material in text-only with animation, this teaching method presents learning material by the visual mode. Similarly, an online module presents instructional messages with text and images. This type of online instructional message does not take advantage of using two modes to present learning material. The modality principle has been researched in many disciplines; however, there has not been a study that specifically examines the effectiveness of using spoken words concurrently with images of worked examples with the step-by-step instructions on how to solve common pediatric medication calculations and to describe the procedures for administering pediatric intravenous medications to novice nursing students.

In a meta-analysis conducted by Ginns (2005), the modality principle has been shown to be beneficial in a variety of content domains and with a variety of variables, outcome variables, and student characteristics. The meta-analysis synthesized 43 independent experimental-study results for the purposes of testing the modality effect. It was hypothesized that when presenting instructional learning material as pictures or images simultaneously with audio narration (modality principle), there would be a beneficial effect as opposed to presenting learning material using pictures or images and printed text. It also was hypothesized that the effects of two moderators, level of element interactivity (level of difficulty of learning material) and pacing of the presentation, would be more beneficial when presenting learning visual and auditory modes.

The results of the meta-analysis supported the hypothesis that students who learned from the materials using pictures or images with audio narration performed better than those who learned from pictures or images and printed text with an average effect of .72, which is a moderate to large effect size. Furthermore, the modality effect was moderated by element interactivity, which is the level of difficulty of the learning material (coincidentally, high-element interactivity is a function of high-intrinsic cognitive load), pacing of presentation, and between fields of study. For high-element interactivity, the average effect size was greater than for low-element interactivity, with the high-element interactivity effect size of .63. The moderate effect size for high-element interactivity indicates that when the learning material was more complex, there was a moderate effect on student performance. Studies that used system-paced learning material had comparatively larger effect sizes than with the self-paced. The average effect size was .93 for the system paced, which is a large effect size, and indicates that the when learning material is controlled by the delivery system, the students' performance was better than when they controlled the pace of the presentation. The moderate-to-large effect sizes support the use of system-paced delivery devices to present complex learning material using words combined with images. As for the field of study, there were statistically significant differences detected between mathematics and logic compared with science. The effect size for mathematics and logic was .58, this is moderate. It also was noted that the modality effect was moderated by element interactivity (level of difficulty of learning material).

In addition to the modality principle, worked examples are an effective strategy that can be used to teach medication calculations. Worked examples can function as an organizing framework and facilitate schemata construction because they illustrate how similar problems might be solved. The earlier research on example-based learning revealed the benefits of using worked examples when compared with conventional problem solving in a variety of learning domains (Carroll, 1992, 1994; Paas & van Merrienboer, 1994). Some of the more current research is examining the effectiveness of conventional problem solving and different types of worked examples. Darabi and Nelson (2004) examined the effects of problem solving and two different types of worked examples: process oriented and product oriented. It was asserted that process-oriented worked examples would render improved problem-solving performance and with transfer. With process-oriented worked examples an explanation on how to solve a problem including the rationale are provided (Darabi & Nelson, 2004). Product-oriented worked examples describe the procedures for solving a problem and are more effective for learners with high knowledge or experience in the learning domain (have constructed relevant schemata). The multimedia module used product-oriented worked examples because they provide a framework for solving similar type problems. The students who participated in the study had schemata for medication calculations related to the adult population. The multimedia presented the learning material with a verbal explanation while demonstrating how to solve the medication calculation. The visual presentation and the concurrent explanation should have assisted the learners in making the connections between the visual and auditory presentation.

Thirty-six chemical engineering college students were assigned randomly to three treatment groups: process-oriented worked example group, product-oriented worked example group, and the conventional problem-solving group. The participants received an instructional simulation about a water-alcohol distillation plant.

The results revealed there were no statistically significant differences between the treatment groups on the dependent measure of performance. As to why the process-oriented worked examples were not more beneficial than the other treatment groups, the researchers suggested that because all participants had some prior knowledge on distillation, perhaps they already had constructed relevant schemata related to the learning domain. The researchers suggested that the expertise reversal effect was supported. Likewise, the mental effort scores for all groups, on average, were considered low for solving relatively complex problems. The average mental effort for conventional problem solving was 40, product-oriented worked-out examples was 47, and process-oriented worked-out examples was 44 out of a score of 72. These results indicate that across the eight problems the tasks were not difficult. Similarly, the participants correctly solved the far transfer test questions with a lower than expected average number of trials with (M=15.86). These results further support the use of worked examples for low-prior-knowledge learners and the use of problem solving for learners with more experience and high-prior knowledge in a particular learning domain.

The multimedia and the text-based modules contain product-oriented worked examples to illustrate how to solve a medication calculation. Once students studied the worked examples for the medication calculations, they were provided with practice problems. The answers and the step-by-step solutions were provided for the students to check their work.

Educators are in a position to design and use effective pedagogies to teach medication calculations. The research conducted on the modality principle and worked examples can be used to inform nurse educators about instructional strategies that consider the cognitive structures and how information is processed in the most efficient manner. The modality principle, worked examples, and segmenting are design strategies that maximize cognitive processes and consequently are the most effective teaching methods to teach pediatric medication content. These design strategies should be used when developing multimedia because they promote meaningful learning.

In summary, there are many factors that must be considered when administering medication in the pediatric population. Because there are no standardized medication dosages for pediatric patients, medication dosages are based on a child's weight. Therefore, all pediatric medication dosages require the healthcare professionals to calculate the medication safe-dose range. The calculation of a medication dosage increases the chances of calculation medication errors. Another factor is that, too often, students are not prepared to administer medication in the pediatric population because throughout the nursing program they are taught medication administration content for the adult population. Also, there are differences in the procedures for administering medications in the pediatric population than the adult population. Specifically, in pediatrics, medication dosages are weight based and require mathematical calculations increasing the risk for miscalculations (Hughs & Edgerton, 2005) and consequently dosing errors (Ghaleb et al., 2006). Pediatric patients have a higher risk of dying compared with adult patients when a medication error occurs (Hughs & Edgerton, 2005).

Students must have a solid mathematical foundation when administering medications in the pediatric population. Nurse educators are in a position to develop and utilize multimedia to present instructional messages that maximize cognitive processes and foster meaningful learning. Instructional methods that have been shown to be effective for learners with low domain specific knowledge are worked examples (Atkinson et al., 2000) and the modality principle (Mayer, 2001, 2009). Worked examples also have been shown to aid in the development of mathematical schemata and provide an expert problem-solving paradigm for novice learners to model (Atkinson et al., 2000; Darabi & Nelson, 2004). The learning outcomes are improved when the modality principle is used to present instructional messages (Moreno, 2006).

Research Questions

This study examined the following research questions:

1. To what extent are there differences in knowledge acquisition of pediatric medication calculation skills between prelicensure nursing students using the multimedia-delivery module and those using text-based instructional module?
2. To what extent are there differences in the weight-based safe dose calculations between prelicensure nursing students using the multimedia-delivery module and those using text-based instructional module?

3. To what extent are there differences in the intravenous-flow-rate (iv) calculations between prelicensure nursing students using the multimedia-delivery module and those using text-based instructional module?
4. To what extent are there differences in the conversion calculations from pound-to-kilogram between prelicensure nursing students using the multimedia-delivery module and those using text-based instructional module?
5. To what extent are there differences in the fluid maintenance calculations between prelicensure nursing students using the multimedia-delivery module and those using the multimedia-delivery module and those using text-based instructional module?

Educational Significance

The literature indicated that medication errors continue to be a problem in healthcare organizations (American Academy of Pediatrics, 2003). In particular, pediatric patients are at higher risk for being harmed as a result of a medication error than adults, because of their wide- range body mass, differences in weight, metabolism, and excretion of the drug (Taketomo et al., 2007-2008). Consequently, all medication doses must be calculated based on the child's weight. Because all medication doses must be calculated, this increases the risk of harmful and devastating errors. Incorrect calculation of medication dosages, account for the majority of pediatric medication errors (Hughs & Edgerton, 2005). Medication calculation proficiency is an essential nursing skill that is required to administer medications safely. Therefore, it is critical that nursing students have a strong foundation.

Many educators are using multimedia to present learning material; however, more often than not, the design of the multimedia presentation does not consider the limitations of the cognitive structures and processes. The results of this study can be used to inform nurse educators on multimedia design techniques that consider the cognitive structures and processes to teach pediatric medication administration content. The results can serve as a motivation for educators to evaluate how they teach pediatric medication content and to consider developing instructional messages that support how the mind processes information. In addition to using design techniques that support cognitive process, educators need to consider new pedagogies that are effective. Pedagogies that encourage students to perform mathematical functions related to medication administration in simulation, skills laboratory, and in the clinical setting also are effective strategies that assist students in applying the theoretical mathematical calculations in real-life situations and simulated situations (nonthreatening environment). Furthermore, nursing schools vary widely as to medication administration teaching practice and medication administration assessment practices. Teaching methods that have been supported by research as well as integration of a variety of pedagogies that support a strong medication calculation foundation should be used throughout the nursing program.

Definitions of Terms

The purpose of this section is to provide the reader with the definition of the words and concepts used within the context of this study even though there may be other definitions used in the literature.

Baccalaureate Prepared Nurses have completed a 4-year (sometimes 5-years) college or university program. Students must fulfill both the degree requirements of the college or university as well as the nursing program. Baccalaureate degree includes curricula in the liberal arts, sciences, humanities, and nursing. The students begin the nursing program as sophomores and upon completion of the of the university and nursing program requirements, students are awarded a degree of bachelor of science in nursing (Berman, Snyder, Kozier, & Erb, 2008).

Calculation Skills are defined operationally as a students' ability to calculate weight-based safe- dose ranges, intravenous flow rates for primary and secondary (intravenous piggyback medications) infusions, pound-to-kilogram conversions, and fluid maintenance calculations (Giangrasso & Shrimpton, 2010).

Criterion-Referenced Test for this study is a 30-minute text-based mathematical test that contains test items for different types of mathematical calculations that are used commonly to administer mediations in the pediatric population. There are four different types of test items: pound-to-kilogram conversions, weight-based-safe dose-range calculations, primary and secondary intravenous flow rate calculations, and fluid maintenance calculations. Ninety percent of the test items must be answered correctly to pass the test.

End-to-Means-Analysis occurs when novice learners use problem-solving strategies because they are forced to search randomly for solutions and this searching randomly directs attention away from aspects of the problem important to learning, as a result the working memory is overburdened and schema construction is interfered (Atkinson & Renkl, 2007).

Essential Cognitive Processing occurs when the learner selects the essential material in the working memory. The selection of the essential material indicates that the learner is constructing mental representations of the learning material (Mayer, 2009).

Extraneous Cognitive Processing occurs when the learner is required to process unrelated and nonessential information that does not contribute the purpose of the instructional message. The learner is not able to engage in the selection, organization, and integration of learning material (Mayer, 2009).

Fluid maintenance is the amount of fluid a child requires over a 24-hour period. There are two fluid maintenance test items on the test. Fluid maintenance includes both oral and intravenous fluids. The formula to calculate 24-hour fluid requirements are the first 10 kg of a child's body weight is multiplied by 100ml, the second 10 kg of body weight is multiplied by 50ml, and for each kg above 20kg is multiplied by 20ml (Giangrasso & Shrimpton, 2010).

Generative Cognitive Processing occurs when the learner is making sense of the essential material that involves organizing and integrating the learning material that indicates deeper processing. Generative processing facilitates schema acquisition (Mayer, 2009).

High Element Interactivity indicates a test item is difficult (Moreno & Mayer, 1999) because the learning material is complex and has multiple steps.

Intravenous Flow Rates is what the infusion will be set in milliliters per hour to deliver the fluid over a specified amount of time (Giangrasso & Shrimpton, 2010). There are eight intravenous flow rate test items.

Interactive Multimedia is when the learner has the ability to control the pace and direction of the frames (segments), that is, the learner has the ability to pause-play, rewind, and fast forward and has direct access to a specific segment (Mayer, 2009).

Intrinsic Cognitive Load is the inherent complexity of the learning material, that is, learning material with high-element interactivity imposes a high cognitive load. In contrast, with low-element interactivity, there is a low cognitive load (Mayer, 2009).

Long-Term Memory is a memory store where large amounts of previous knowledge is held long term (Mayer, 2009).

Modality Principle is when people learn more deeply from pictures or images and spoken words rather than from pictures or images and printed text (Mayer, 2009).

Multimedia is technology that is used to present learning material in two modes: visual mode and the auditory mode (Mayer, 2001). In the context of this research stud, a document camera was used to capture the researcher writing on a white board using a sharpe to explain the steps on how to solve mathematical calculations related to medication administration. There was a microphone attached to the computer that recorded the verbal explanation given by the researcher.

Multimedia Instruction *(multimedia instructional message or multimedia instructional presentation)* includes presentations with words and pictures or images for the purpose of promoting learning. This definition also refers to the design of multimedia presentations that facilitate the building of mental representations and consider how the mind processes learning material (Mayer, 2009).

Multimedia Instructional Message is a presentation that involves pictures or images and spoken words (Mayer, 2009).

Multimedia Learning is when learners learn from words and pictures or images (Mayer, 2009).

Multimedia Medication Module is a pediatric medication administration module that is viewed as a multimedia presentation. The module consisted of a verbal explanation of how to solve common pediatric mathematical calculations. The worked examples in the module demonstrated step-by-step how to solve mathematical problems, and at the same time the researcher provided a verbal explanation on how to solve the mathematical problem (Mayer, 2009). Students were allowed one hour to study the module.

Prelicensure Nursing Students do not have any previous nursing background (Berman et al., 2008). In the context of this study, the prelicensure nursing students are in the second year of the nursing program and are juniors at the university.

Pretraining Principle involves presenting learners with key concepts and terms prior to viewing a complex instructional message (Mayer, 2009).

Pound-to-Kilogram Conversions are when a child's weight is converted from pounds to kg using the conversion factor one pound equals 2.2kg (Giangrasso & Shrimpton, 2010). There are four pound-to-kilogram test items.

Schema **Schemas** are organized knowledge structures about specific topics and prior experiences that assist learners in understanding learning material. Schemas are stored in long-term memory and function as the central executive for coordinating and processing information for working memory (Mayer, 2009).

Self-Paced module is defined as learning material presented in small segments where students are allowed to skip a segment, stop and pause, or go back to review content as needed.

Spatial Contiguity Principle is when words and pictures are presented adjacent to one another (Mayer, 2009).

Ten-fold Dosing Errors are defined as10 times or one-tenth the intended medication dose (Doherty & McDonnell, 2012).

System Paced module is defined as learning material presented in a continuous format. With this format students do not have the ability to pause, skip, or go back to review learning material.

Text-Based Medication Module in this study consists of a text-based explanation in conjunction with worked examples. The text-based module used worked examples to illustrate step-by-step how to solve mathematical problems. The worked examples are in close proximity to the text-based instruction on how to solve the mathematical problem. Students were allowed one hour to study the module.

Weight-Based Safe Dose is a medication dose that is based on the child's weight. A medication dose is based on a certain number of milligrams of drug per kg of body weight. The recommended number of milligrams is multiplied by a child's body weight in kilograms (Taketomoet al., 2007-2008). There are six weight-based safe dose calculation test items.

Worked Examples serve as a framework that illustrates a step-by-step solution to a mathematical problem (Atkinson et al., 2000; Kalyuga et al., 2001).

Working Memory The working memory is a temporary storage that provides manipulation of sound and images received through the eyes and ears, the sensory memories (Baddeley, 1992; Mayer, 2005). The working memory has a limited capacity, and it can only hold information for a short duration.

Summary

Medication administration is one of the most common and essential skills that is performed by nurses in clinical practice (Penti & Smith, 2006), and it is a crucial aspect in providing high quality and safe patient care (Harne-Britner et al., 2006). There are many factors that play a role in how prepared students are to administer medications to the pediatric population. All too often, when students are scheduled to take the pediatric clinical, they are not prepared to administer medications, because throughout the nursing program, they have been taught medication administration primarily for the adult population. For the adult population, there is a standardized dose that is recommended for all adult patients. Therefore, because no calculations are required, errors are less likely to occur during medication administration. Pediatric patients are at a higher risk for being harmed by a medication error because there are no standardized dosages for children and medication dosages must be calculated. This increases the risk of miscalculation errors **(**Hughs & Edgerton, 2005**).** In particular, pediatric patients are at an increased risk for 10-fold medication errors (Doherty & McDonnell, 2012), which can cause devastating effects.

Nurse educators are in a position to design and develop effective methods that consider the cognitive structures and how the mind processes information to teach pediatric medication content to nursing students. The majority of methods teaching medication administration uses only one mode: the visual mode. One mode to present leaning material does not take advantage of the additive effects of using two modes to present learning material. This study will focus on three instructional principles that have been shown by research to support the cognitive structures and how the mind processes information. The three instructional principles are (a) the modality principle, (b) segmenting, and (c) worked examples. The multimedia in this study presented learning material in two modes: the visual and auditory modes. By using two modes to present learning material, the working memory capacity is increased because the images and spoken words are processed in two separate modes; consequently there is an additive effect. The positive effect of using words and images to present learning material is known as the modality effect.

The multimedia also presented learning material in small segments. By allowing the learners to focus on the essential information in smaller manageable segments and permitting the student to progress at his or her pace. Worked examples are another strategy that has been shown to be effective for reducing extraneous cognitive processing (Mayer, 2005). In the past, a common strategy to teach mathematics was to use problem-solving approaches; however, this strategy is not an effective means for learning because it can prevent learners from learning the most important aspects of a problem structure (Kalyuga et al., 2001). With the problem-solving approach, learners are forced to search for a solution when solving a problem placing strain on the working memory. By providing worked examples, there is a reduced need for searching for a solution and extraneous cognitive processing is reduced (Mayer, 2009). The benefit of presenting worked examples and spoken words is that there is a verbal explanation describing the steps on how to solve the problem.

The next two chapters include the literature review and the method section. The literature review begins with an overview of the cognitive processes that are essential to learning: extraneous cognitive processing, essential, and generative cognitive processing.

Then a description of the modality principle is presented, which will be followed by a review of Ginns (2005) meta-analysis. After the meta-analysis, three current studies on the modality principle are reviewed, followed by a review of the example-based learning literature, which beginning with a few of the key research conducted in the previous two decades. The two studies examined the effectiveness of conventional problem solving and two types of worked examples. The literature review will conclude with a meta-analysis on worked examples with and without explanations (supported worked examples).

Chapter III begins with an overview of the problem and includes the purpose of the study, a description of the research design, and instruments to be used in the study, as well as, the protection of human subjects, characteristics of the study sample, a description of the of the content of the instructional modules, the study procedures, and data analysis. Chapter IV presents the results of knowledge acquisition of pediatric medication calculation skills between the multimedia-delivery instructional module and the text-based instructional module. The next section of chapter IV includes the results of the pass rates between the comparison and the multimedia groups. Last, the results of the comparison between the text-based instructional module and the multimedia instructional modules four subtest items; weight-based safe dose calculations, intravenous-flow-rate (iv) calculations, fluid maintenance calculations, and pound-to-kilogram conversions followed by additional analysis. Chapter V contains the discussion of the results and includes the implications for practice and recommendations for future research.

CHAPTER II
LITERATURE REVIEW

The purpose of this study was to compare two methods for teaching pediatric medication administration content, a multimedia instructional message with a text-based instructional message. This literature review provided the basis of the research study conducted on the beneficial effects of using instructional messages that consider how the mind processes information. This literature review is divided into three sections. The first section provides an overview of the cognitive processes that are essential to learning. The next two sections are focused on instructional methods that facilitate meaningful learning and include a select number of research studies conducted on the modality effect and worked examples.

Cognitive Processes

The Cognitive Theory of Multimedia Learning has recognized three types of cognitive processes (Mayer, 2009) that take place during learning. These cognitive processes were derived from cognitive load theory, and they are synonymous with Sweller's original terms. Specifically they are referred as extraneous cognitive processing (extraneous cognitive load for Sweller), essential cognitive processing (intrinsic cognitive load for Sweller), and generative cognitive processing (germane cognitive load; Chandler & Sweller, 1991; Sweller & Chandler, 1991). The following sections detail each of the three types of cognitive processes.

Extraneous Cognitive Processing

Many educators use multimedia to present instructional messages. All too often, the design of many multimedia presentations do not maximize cognitive structures and processes, and, as a result, the instructional message does not contribute to learning

(Ginns, 2005; Moreno, 2006). When educators design effective multimedia, the goal is to limit extraneous cognitive processing as much as possible. Extraneous cognitive processing occurs when the design of a multimedia does not consider the limited capacity of working memory. In fact, poorly designed multimedia can contribute to extraneous cognitive processing. Extraneous learning material is defined as nonessential information, or unnecessary background music, animation, or static pictures that do not contribute directly to the message (Mayer, 2009). In addition, when disparate sources of information, such as text and diagrams, are not presented in close proximity of one another, the learner has to integrate mentally the disparate sources of information, which results in extraneous cognitive processing. Moreover, when the learner is forced to process extraneous information that is cognitively demanding, the available cognitive capacity is not able to engage in cognitive process for learning, such as the selection, organization, and integration of learning material (Mayer, 2009).

Another condition that contributes to extraneous cognitive processing occurs when learners are confronted with a novel problem where they have to search for solutions because they do not have previously constructed schemas that solve the problem (Mayer, 2005; Sweller, van Merrienboer, & Paas,1998). This searching is known as a means-ends analysis. When a means-ends analysis is used, learners have to “consider the current problem state (e.g., a/b=c), consider the goal state (e.g., a=?), isolate the differences between the two states, and find a problem-solving operator (what are the rules of algebra) that can be used to get rid of the differences between the problem state and goal state” (Sweller et al., 1998, p. 263). The means-ends problem-solving approach does not contribute to schema construction or learning. Worked examples are a method that can be used to eliminate extraneous cognitive processing because they eliminate the need for random searching for the solutions to the mathematical problem (Renkle, 2005). This research dissertation presented pediatric mathematical calculations using worked examples.

Essential Cognitive Processing

The purpose of essential cognitive processing is for the learner to represent mentally the essential learning material in the working memory. Essential cognitive processing occurs when the learner selects and builds mental representations of the essential learning material. The complexity of the learning material will determine how the essential information is represented.

If the design of multimedia eliminates any extraneous learning material, the learner will not have to process the extraneous information and instead he or she can use the cognitive capacity to process essential information, that is, the learner will be able to represent mentally the essential information (Mayer & Moreno, 2010). Mayer (2009) asserted that multimedia design techniques that can be used to manage essential cognitive processing are segmenting and modality. Multimedia that presented learning material in small segments rather than as a one continuous presentation is known as the segmenting principle (Mayer, 2009). Modality refers to presenting learning material using spoken words concurrently with pictures or animation rather than pictures and text (Mayer, 2009). These principles will be discussed in more depth later in the chapter.

Generative Processing

Generative processing occurs when the learner is making sense of the essential material; this process involves organizing incoming words and images into coherent structures and integrating the word structures and image structures with each other and with any prior knowledge (Mayer, 2009) Generative process signifies a deeper processing. Generative processing facilitates schema acquisition (schemas are knowledge structures). Schema construction and automation are the primary tasks for learning (Kalyuga, Chandler, Tuovinen, & Sweller, 2001). Cognitive processes are hindered when the learner is required to use cognitive processes that are not immediately related to schema construction and automation.

It is essential that nurse educators continue to design and develop multimedia that supports pedagogies that assist learners' in building mental representations of presented material. Multimedia is defined as the presentation of instructional messages using words and pictures. Properly designed multimedia learning material can provide a substitute for not having prior knowledge and allows learners to construct more efficiently their own schemata. Multimedia presentations that use words and pictures as opposed to words alone foster generative processing.

This next section focuses on an instructional design strategy that is intended to manage essential cognitive processing. The strategy was used in the development of the multimedia medication module for this research study. The multimedia design strategy is the modality principle. The modality principle states that when pictures or images and spoken words rather than pictures or images and printed text are used in multimedia presentations meaningful learning is more likely to occur. The modality principle was the focus of this dissertation and will be discussed in depth later.

Modality Principle

Multimedia presentations that concurrently use spoken words and pictures or images consistently have demonstrated beneficial effects. The positive effect of using words and pictures to present instructional messages is known as the modality effect. The modality effect asserts that people learn better from pictures and spoken words as opposed to pictures and text (Moreno, 2006). Since the 1980s, cognitive research has supported the beneficial effects of multimedia presentations that maximize cognitive processes.

A wide variety of teaching methods have been used to teach nursing students mathematical skills. Some of the common medication calculation teaching methods that have been researched range from self-paced CD ROMs, text-based study guides with practice problems, and independent self-paced online programs (Jeffries, 2001; Sung, Kwon, & Eunjung, 2008;Wright, 2005). Similarly, other commonly used methods to teach medication administration include lecture format, one-to-one tutoring, drug calculation workbook in conjunction with practice problems (Sung et al., 2008; Wright, 2004, 2005). The problem with these types of learning materials is that they are text based with images or pictures with text instructions. The learning material is presented in one mode. These methods do not consider the limitations of the cognitive structures or maximize cognitive processing (Mayer, 2009). The modality principle has been researched in many domains of learning, and the modality effect has been supported consistently when learning material was presented using spoken words and images and animation (Ginns, 2005; Moreno, 2006); however, there has not been a study that specifically examines the effectiveness of using spoken words concurrently with images of worked examples with the step-by-step instructions on how to solve common pediatric medication calculations for novice nursing students. In addition, the methods to teach medication administration to nursing students have focused on medication calculations for the adult population. No studies on teaching methods for medication administration have focused on pediatric medication calculations. The purpose of this study was to compare a multimedia module that specifically used design techniques that support cognitive structures and process with the traditional method a text-based module to teach mathematical computations.

Multimedia that presents instructional messages in two modes visual and auditory maximizes cognitive processes and promotes meaningful learning. The modality effect states that learning will be improved when words are presented as narration rather than printed text in conjunction with pictures or images. In a meta-analysis conducted by Ginns (2005), there were 43 studies examined. Of those, 39 between-group experiments were analyzed.

Across studies, the results indicated the average effect size for the modality effect was moderate at .72, which is close to large. For studies that used system-paced learning material, there were comparatively larger effect sizes than for self-paced: the system-paced average effect size was .93 and the self-paced effect size was .14. In the dissertation research self-paced module is defined as learning material presented in small segments where students are allowed to skip a segment, stop and pause, or go back to review content as needed. System Paced module is defined as learning material presented in a continuous format. With this format students do not have the ability to pause, skip, or go back to review learning material. Conventional problem-solving is defined as using an ends-to-means approached to solve a problem.

As for the field of study, the effect size for mathematics and logic was .58, which is a medium effect, and for science, the effect size was 1.20, indicating a very large effect. In addition, the comparison between the presentation modalities revealed that the effect size was larger for studies that used Virtual Reality head mounted displays compared with computer screens and audio-tapes, with Virtual Reality effect size at 1.34, computer screen effect size .55, and the audio-tape effect size was .64.

The meta-analysis results support the beneficial effects of the modality effect with moderate to large effects over a wide range of learning content that used graphics with narration compared with those who using graphics with printed text. In particular, the modality effect was an important moderator for element interactivity and for system pacing of the learning material. The results support the use of pictures or images concurrently with words as narration, rather than text to present instructional messages across a wide range of learning content, age groups, and learning outcomes (Ginns, 2005). Some of the common domains of learning included in the review were science, mathematics, engineering, social sciences, and English comprehension. Nevertheless, there were no studies that examined the use of multimedia to present learning material using picture or images with concurrent spoken words to teach pediatric medication calculations. The results serve to further support teaching methods such as multimedia that use spoken words concurrently with pictures or animation to teach novel learning material to novice student nurses.

The research conducted between 1990 and 2010 formed the foundation for research on the modality principle. The meta-analysis conducted by Ginns (2005) examined the modality effects in a variety of domains of learning. This section presents relevant research conducted after the Ginns' (2005) meta-analysis. The following three studies are the most current research conducted on the modality principle.

In a study conducted by Moreno (2006), the modality effect was examined across three different computer media and found that students who learned with a narrated explanation outperformed students who learned with onscreen text. Three different computer media were examined for the modality effect. Three experiments were conducted: (a) experiment one, examined whether a desktop multimedia instructional message was more effective in promoting meaningful learning when presented in the auditory and visual modalities (modality principle), (b) experiment two, examined whether a multimedia messages that include animated pedagogical agents (APSs) was more effective when spoken words were presented concurrently, and (c) experiment three explored whether using virtual reality environments that are considered to be immersive media have better learning outcomes than less immersive media.

In experiment one, there were 78 college students who viewed computer animation explanation on the formation of lightning. Of the 78 participants, 40 viewed the instructional message with an on-screen-text explanation, and 38 participants listened to a narrated explanation that contained the same content as the onscreen-text message. After viewing the instructional messages, both groups were given retention and transfer tests. On the retention and transfer tests, there was a statistically significant modality effect on both learning measures for the students who learned with the narrated explanation compared with those who learned with on-screen-text explanation for both learning measures.

In the second study**,** the researchers examined whether the modality effect would pertain to the Design-a-Plant Game and whether presenting the instructional message by way of an animated pedagogical agent (APA) would promote meaningful learning. There were 64 college students who were taught how to design the roots, stem, and leaves of plants that could survive in numerous different environments by navigating through the agent-based botany game. The agent's words were presented as spoken words or on-screen text, and the agent's image was either on the screen or not. Of the 64 participants, 15 participated in the image and text group, 17 participated in the image and narration group, 16 participated in the no-image and text group, and 16 participated in the no-image and narration group. The results indicated that students performed statistically significantly better on the retention and problem-solving transfer test when the words were presented as spoken words as opposed learning as is to on-screen text, which supports a modality effect for retention and transfer. The use of animated pedagogical agent's had no effect on student performance, and there were no modality by media interactions.

In experiment three**,** 89 college students participated in the Design-a-Plant game to learn botany. Three delivery media conditions were used: desktop, head-mounted display, and head- mounted display plus walking. There were three measures of retention, problem-solving transfer tests, and a presence questionnaire. The presence questionnaire was designed to elicit the participants' perceived sense of presence in each of the learning delivery conditions. The degree of immersion media was varied. In addition, the three delivery media conditions were separated into two groups. One group learned with a narrated explanation, and the other group learned with on-screen-text explanation. Seventeen participants were in the narration and desktop group, 17 were in the text and desktop group, and 13 were in the narration and head-mounted display group, 13 were in the text and head-mount display plus walking group, 13 were in the narration and head-mounted display plus walking group, and 14 were in the text and head-mounted display plus walking group. After the participants completed the delivery media condition, they were asked to indicate on a questionnaire their perceived sense of presence for each of the learning conditions; they also answered test items on retention and problem-solving transfer.

The students who learned with narrated explanations performed statistically significantly better than those who learned with an on-screen-text explanation on retention and transfer. There was a statistically significant modality effect for the learning measures: retention and transfer. In contrast, the students who learned with the two-headed-mounted display media conditions reported a higher sense of presence than those who learned using the desktop display condition, there was no immersion effect on learning, and there was no modality by media interaction. The results indicated that when the modality principle was used within the context of virtual reality learning environments it was an effective instructional strategy.

In experiment two, the treatment sample size was not sufficient to make generalization related to the sample population. The reliability and validity was not discussed for the multimedia content, virtual learning environment, and multimedia animated pedagogical agent. Also, the virtual reality or multimedia animated pedagogical agents were not tested for navigation and ease of use. The results of the Moreno (2006) study support the modality effect when three different computer media, desktop, virtual reality environments, and agent-based multimedia games were used to present learning material. This research study used a computer to present learning material in two modes, the visual and auditory modes, however, the learning content focused on medication calculations.

Dunsworth and Atkinson (2007) conducted a study in which they evaluated three effects: (a) the modality effect, narration compared with on-screen text, (b) embodied agent effect, narration plus agent compared with on-screen text, and (c) the image effect, narration plus agent compared with narration to present the human cardiovascular system. This study included retention, near transfer, and far transfer questions to evaluate learning outcomes. The participants also were required to draw a human heart and complete an attitudinal survey. Fifty-one undergraduate students who were enrolled in one of several educational technology courses volunteered to participate in the study. The participants were assigned randomly to one of the three computer-based learning conditions, that is, 17 in each of the three learning conditions.

On the overall posttest for the presentation mode, there was a statistically significant effect on student performance. The students who reviewed the narration and pedagogical agent performed better than the students who used the on-screen text, the resulting effect size was .80, which is a large effect size. Similarly, the students who used the narration and pedagogical agent outperformed the narration group; the effect size was .66, a medium effect size.

As for the retention questions for the presentation mode, there was a statistically significant effect on student performance. The students who received the narration and the pedagogical agent outperformed the students who received the on-screen text, with an effect size of .91, which is a large effect size. Narration and the pedagogical agent statistically significantly outperformed the narration group, with an effect size of .81, a large effect size. In contrast, for the presentation mode, there were no statistically significant differences for the group conditions, narration plus pedagogical agent, narration, on-screen text, even though narration plus pedagogical agent had the highest mean on the near-transfer questions and far-transfer problems. This result indicates there was no modality effect, which is in direct contrast to previous studies that have supported the modality effect (Ginns, 2005; Mayer & Moreno, 1998; Moreno & Mayer, 1999; Mousavi, Low, & Sweller, 1995). Dunsworth and Atkinson (2007) suggested that the participants had to learn the structure and function of the human heart and that more complex material required a great deal of mental efforts and visual searching during the learning process. The researchers also suggested that in the previous studies the learning material was linear and less complex and that difference could explain why there was not a modality effect for narration compared with on-screen text.

On the retention test, even though the narration plus pedagogical agent had higher means than the on-screen text condition for the near-transfer and far-transfer tests, the effect size for near transfer was .57 and the far-transfer effect size was .40; these are medium effect sizes.

As for the image effect for the retention test, the narration plus the pedagogical condition, performed better, on average, than the narration condition. In this study, the pedagogical agents function was to point out relevant information, which may reduce the need to search visually and assist participants in connecting information between the visual and auditory channels.

The narration plus pedagogical agent condition had higher means on the posttest drawing than the narration condition; however, there were no statistically significant differences between the three conditions. There were no statistically significant differences with regard to perceived instructional value or satisfaction with the learning environment among the three presentation conditions. As for the time spent on the computer-based learning material, there were no statistically significant differences in learning time between the presentation conditions.

In the previous studies with the exception of the Dunsworth and Atkinson (2007), there was support for the beneficial effects of using narration rather than text when combined with pictures or images or animation. The researchers suggested that the learning material on the structure and function of the heart was complex. The lower effect sizes may be attributed to the more complex learning material as well as the small sample size.

As with the Dunsworth and Atkinson (2007) study, similar results were found in a study conducted by Tabbers, Martens, and van Merrienboer (2004). The purpose of this study was to evaluate the effectiveness of the modality effect and the cueing effect. There were four variables that were measured: (a) training time, (b) mental effort, (c) retention scores, and (d) transfer scores. One-hundred-and-eleven second-year college students from a Belgium University participated in the study. The experiment was conducted in three sessions with between 35 to 40 students in each session. The sessions took approximately 2 1/2 hours each. There were 40 multimedia computers with 10 computers for each experimental condition. The students were assigned randomly to the condition. The participants studied a web-based multimedia instructional message for one hour, which was followed by a retention and transfer test. Also, during the instructional lesson, the tests and self-report mental effort measures were obtained. There were four conditions. There were two audio conditions in which the participants listened to the audio explanation through headphones as they viewed the diagrams. In the two other conditions, the text explanation was above the diagrams. The text and audio explanation for all conditions was the same.

The researchers developed the multimedia instructions from the four-component instructional design (4C/ID) model developed by van Merrienboer. The instructional design model was used for training difficult cognitive skills. The website was the format for the instructional material and the structure of the format was linear where worked examples were shown and were followed by an explanation of the design strategy. The instructions emphasized how to develop a training program blueprint that included the required steps for complex skills. The instructions included a short written introduction to the 4C/ID model, which was followed by six sequential diagrams that contained the skill steps and sequences of the learning tasks. There were two worked examples. The first worked example was comprised of the first six sequential diagrams. The complex steps of the worked examples showed how to do experimental research. The second worked example included three diagrams that showed the complex steps for developing a blueprint to teach the skills required to design a house. Last, there were two diagrams that included a summary of the plan for the 4C/ID model. With all of diagrams, there was a text explanation on how the model was used in specific situations.

During the instructional phase, participants were given a maximum of 70 minutes to study the learning material. After the instructional phase, three paper-and-pencil tests were administered. For the retention test, participants were allowed 10 minutes, and for the transfer test, they were allowed a maximum of 30 minutes to design a training program. After each test, the participants were asked to self-rate their mental effort on a 9-point scale, which was similar to the ones used in the instructions. The last part of the data collection included a questionnaire to evaluate the experience during the experiment, and the participants were asked if they had any problems with the learning material or the computer.

The results revealed that the text condition required considerable less time to study than the audio condition. The results of the evaluation questionnaire, however, revealed that slower downloading of the audio files form the Internet were part of the reason for the differences in the training time. During instruction, the mean mental effort was four, which is considered a low score. There was higher mental effort score for the text condition (M=4.2, SD=1) than the audio condition (M=3.8, SD=1), and there was no statistical significance. For the mental effort on the retention test, the participants in the text condition reported higher mental effort scores (M=6.8, SD=1), on average, than the participants from the audio condition (M=6.1, SD=1), and there was no statistically significant effect for modality. As for the transfer test, there was no statistical significance between the text condition and the audio condition. In contrast, for the modality, there was a statistically significant effect for the text condition on the retention test compared with the audio condition. The text condition scored statistically significantly higher (M=32.8, SD=5.2) on the retention test than the audio condition (M=29.4, DS=5.0). There effect size was .66, which is a moderate effect. On the retention test, there was a statistically significant effect for the cueing condition compared with noncueing condition. For instance, the diagrams with cues received higher scores (M=32.0, SD=5.3), on average, than the noncueing condition (M=30.3, SD=5.4). The effect size was .33, which is a small effect size. On the transfer test, there was a statistically significant effect on modality for the text condition and for the retention test, the participants text condition had higher scores (M=21.9, SD=6.4), on average, than in the audio condition (M=19.0, SD=5.9), with an effect size of .33, which is a small effect size. There was no effect of cueing.

The results of the Tabbers et al. (2004) study were contrary to previous studies that support the modality and cueing effect. In this study, the cueing effect was evident on the retention test but not on the transfer tests or was it reflected in the mental effort scores. On the retention and transfer test, the participants in the text condition performed better, on average, than in the audio condition. As for mental effort between the text condition and the audio condition, there was practically no difference. As for the retention test, the text condition had higher mental effort scores, on average. The researchers attributed the higher average retention scores to the participants devoting more mental effort. They also pointed out that the participants in the text condition spent statistically significantly less time on instruction than those in the audio condition. For the audio condition, however, the participants did experience slow downloading times, and this slow time could be the reason for the differences in study time between the text and audio conditions. Even though there were slow downloading times and consequent difference in study times, the researchers asserted that the participants in the text condition performed better than those in the audio condition. As for the results not supporting the modality effect, the researchers noted that their study was designed to test the generalizability of the modality effect in a more natural setting such as the classroom. Many of the previous studies were conducted in more controlled environments. In contrast, in the classroom setting, there may be confounding factors that are not controlled as in a laboratory setting. Also, the study time was a maximum of 70 minutes compared with the shorter study times in the previous research studies conducted on the modality effect.

To account for the contrary results of this study compared with previous studies conducted on the modality effect, Tabbers et al. (2004) offered two other explanations as to why the modality effect was not supported. The content taught and the pacing presentation used for this study differed from previous research. They suggested that that text may be more appropriate for presenting procedural information than using audio. For instance, there may be more time to reflect on the learning material as opposed to listening to the audio. The participants in the audio condition, however, did have the opportunity to listen to the audio as often as they liked. Another rationale as to why the modality effect was not found to be more effective than the text condition is that this study used a learner-paced instructional format. In previous research conducted, participants who used system-paced instructions performed better than those who used self-paced instructions (Mayer & Moreno, 1998; Moreno & Mayer, 1999**).**

Participants were assigned randomly to one of the four treatment groups with 30 or less in each of the four groups. There were small sample sizes and limits the generalizability of the findings to the larger population. The computer-based instructional content used in Tabbers et al. (2004) study have been previously used in another study. Also, the posttest was adapted from the posttest that was previously used in another study. There was no mention of construct validity for the attitude survey. Because of the complexity of the learning material, the researcher could have included pretraining (providing definitions of the scientific terms before the instruction message) before the instructional messages (Mayer, 2009). This way the leaner does not have to learn scientific terms during the instructional message.

In summary, even though the modality effect was not replicated in the Tabbers et al. (2004) study and in the study conducted by Dunsworth and Atkinson (2007), numerous studies have supported the modality effect across different fields of study and variety of content domains (Ginns, 2005; Mayer & Anderson, 1991; Moreno & Mayer, 1999; Mousavi et al., 1995). Because the majority of the research conducted on the modality effect has been shown to be effective when compared with text-based only learning content, this research dissertation study used multimedia to present learning material in two modes. By using the modality principle, the learner was able to see and hear how to solve pediatric medication calculations. The audio-visual presentation in the dissertation research showed the researcher writing on the whiteboard the steps on how to solve a medication calculation, and, at the same time, the learner heard a verbal explanation. The audio-visual presentation allowed the learner to make the visual and auditory connections between the learning content.

Worked Examples

All too often, multimedia instructional messages do not use design techniques that consider the limitations of the cognitive structures and how the mind processes information. Worked examples are a design technique that has been shown to be effective for teaching domain specific mathematical content to novice learners. Specifically, worked examples are comprised of a problem statement, solution steps, and the solution to the problem and serve as an expert model for solving a particular problem (Atkinson, Derry, Renkl, & Worthham, 2000; Atkinson & Renkl, 2007).

Much of the research evidence since 1970 overwhelmingly has supported the superiority of worked examples over conventional problem solving. Current research conducted has focused on four areas (Atkinson & Renkl, 2007; Carroll, 1992; Darabai & Nelson, 2004; Gerjets, Scheiter, & Catrambone, 2006; Kalyuga et al., 2001; Renkl, 2002): (a) the effects of using worked examples and problem-solving has been examined, (b) worked examples and the effects of self-explanation, (c) worked examples in comparison to practice, and (d) worked examples with instructional explanations or prompting self-explanation. This section begins with some of the key research conducted in the1990s and 2000s on example-based learning and ends with a meta-analysis on worked examples with and without instructional explanations (supported worked examples).

Using worked examples facilitates schema construction of problem-type schemas as opposed to solving problems by a means-end analysis (randomly search for solutions), thereby reducing extraneous load (Sweller et al., 1998). Numerous studies revealed that when learners were presented with traditional practice problems, they randomly search for solutions (means-end analysis), which is similar to novice learner strategies (Darabi & Nelson, 2004), and research has been demonstrated that this approach in not effective because learners have to search for random solutions and this directs attention away from aspects of the problem important to learning (Sweller et al., 1998), as a result, the random searching overburdens the working memory and interferes with schema construction. Research has proven that worked examples support the construction of problem-type schemas (Atkinson et al., 2000; Darabi & Nelson, 2004). For example, worked examples typically are comprised of a problem statement, solution steps, and the solution to the problem and serve as an expert model for solving a particular problem (Atkinson et al., 2000; Atkinson & Renkl, 2007).

The next two studies examine the effectiveness of conventional problem solving and two types of worked examples. Darabi and Nelson (2004) examined the effects of problem solving and different types of worked examples: process oriented and product oriented. Thirty-six senior engineering students who were enrolled in a Chemical Engineering Design course participated in the study. The participants were assigned randomly to three treatment groups that were (a) process-oriented worked-out examples, (b) product-oriented worked-out examples, and (c) conventional problem solving. The researchers asserted that process-oriented worked examples would render improved problem-solving performance for transfer (Darabi & Nelson, 2004). With process-oriented worked examples, an explanation on how to solve a problem was provided including the rationale.

Product-oriented worked examples describe the procedures for solving a problem and are more effective for learners with high knowledge or experience in the learning domain, that is, they have constructed relevant schemata (Darabi & Nelson, 2004). The performance measures were as follows: (a) number of correct diagnosis, (b) student-reported number of incorrect diagnosis, and (c) the time to diagnose a malfunction correctly. Self-perceived mental effort to perform the task also was measured. A scale of 1 to 9 (Pass & van Merrieboer, 1994) was used. A rating of one represented *very, very low mental effort,* and nine represented a *very, very high mental effort.* The self-reported mental effort ratings were used to measure cognitive load.

The participants received an instructional simulation about a water-alcohol distillation plant. Because the participants had varying levels of prior knowledge of distillation, they were separated into high-and-low-distillation knowledge. Then they were assigned randomly and equally to the three treatment groups: process-oriented worked examples, product-oriented worked examples, and conventional problem solving. Process-oriented worked examples provide an explanation on how to solve a problem including the rationale. Product-oriented worked-examples describe the procedures for solving the problem and with the conventional problem-solving students use an ends-to-means approach. With the end-to-means analysis students randomly search for solutions and this directs attention away from aspects of the problem important to learning.

In the initial phase, all three treatment conditions presented the instruction on how to operate the simulation. After the instruction, the participants were tested on a near-transfer task in which the participants were requested to diagnose novel eight malfunctions (time limit of 12 minutes). The participants completed the far-transfer test using a computer simulation program known as CHEMCAD that is commonly used by chemical engineers.

The researchers hypothesized that the process-oriented worked examples would be more effective than the other treatment groups. The results, however, revealed there were no statistically significant differences between the treatment groups on the dependent measure of performance. The researchers suggested as to why the process-oriented worked examples were not more beneficial than the other treatment groups maybe because all participants had prior distillation knowledge; therefore, they already had constructed relevant schemata related to the learning domain. The researcher suggested that the expertise reversal effect was supported (Kalyuga et al., 2001). The mental effort scores for all groups, on average, were considered low for solving relatively complex problems. For instance, the average mental effort for conventional problem solving was 40, product-oriented worked examples was 47, and process-oriented worked-out examples was 44 out of a score of 72. The low mental effort scores indicates that across the eight problems the task were not difficult. Similarly, the participants correctly solved the far-transfer test questions with a lower than expected average number of trials with M=15.86.

In short, because the learners had some prior knowledge (schema) on distillation, they did not need process-oriented worked examples (worked examples with an explanation on how to solve the problems). Instead, the problem-solving approach to solve problems is more effective for learners with prior knowledge. The results do not support the use of worked examples, particularly, process-oriented worked examples for high-prior knowledge learners. The problem-solving approach is more beneficial for learners with more experience and high-prior knowledge in a particular learning domain. The multimedia medication module in the dissertation research study used product-oriented worked examples to present medication calculations for low-prior-knowledge nursing students. The multimedia instructional message presented medication calculations in an audio-visual format. The multimedia provided a verbal explanation on how to solve the medication calculation concurrently with a visual step-by-step instruction on how to solve the medication calculation.

Darabi, Nelson, and Palanki (2007) conducted a study to examine the effects of three instructional strategies, two types of worked examples (process-and product-oriented) and conventional problem solving to teach how to troubleshoot chemical-plant malfunctions in a computer-based simulation. The conventional problem-solving approach consists of practicing trouble-shooting malfunctions without any of the supportive information that was provided to the process and product oriented worked-example groups. There were three phases of the experiment: the instruction, treatment, and transfer performance. The pre-instructional and the treatment phases were completed in succession, and the performance phase was completed 7 to 12 days later. There were 67 students who were enrolled in an engineering course. There were two classes: one was an introductory course in engineering and the other was an advanced design course in chemical engineering. In each class, the participants were assigned randomly to one of the three instructional strategies.

All participants were provided with pregeneral instructions on how to operate the simulation. These instructions were followed by the treatment phase and the learning sessions. The process-oriented worked-examples group studied text and graphics that described how to troubleshoot a malfunction using principled-based reasoning, which is an explanation that includes how to solve the problem as well the rationale as to why the decision was made. The product-oriented worked-examples group studied the text and the graphics that described the worked examples step-by-step on how to solve the problem only. The problem-solving group was not provided with instruction on how to troubleshoot malfunctions. Instead, the problem-solving group practiced troubleshooting the problems immediately after the pre-instruction. In the transfer phase, all of the participants diagnosed the same set of eight malfunctions in the simulation. Participants were asked to rate their mental effort on a scale of 1 to 9 (9 was considered *very, very high*, and a rating of 1 was considered *low*) while they were troubleshooting the malfunctions.

The results indicate on the transfer performance (measured by the total number of correct diagnosis) there were statistically significant differences in the three instructional strategies. There was a statistically significant difference (t = 2.70, df= 64, η^2 =.10) between the conventional problem solving and worked examples, with an average measure of practice importance and with problem-solving strategy having the greater mean. As for the differences between the worked examples, process-oriented and the product-oriented, there was no statistical significance.

Darabi et al. (2007) examined whether prior knowledge makes a difference in terms of performance transfer tasks. Based on prior knowledge, the participants were categorized into two groups of experienced and less experienced. For the experienced participants' transfer task performance, there were no statistically significant differences between the instructional strategies. Nevertheless, for the conventional problem-solving condition, the performance scores were higher (M = 7.17, SD=0.84), on average, than the process-oriented (M = 6.75, SD=0.97) and product-oriented (M = 6.92, SD=1.00) worked-example conditions. For the three instructional strategies, the performance on the transfer task for the less experienced participants, there was a statistically significant difference. For the problem-solving ($t = 2.98$, $df = 28$, $\eta^2 = .24$) condition there was a statistically significant difference between the worked-examples conditions, with a large measure of practical importance. Similarly, for the less experienced participants, for the two worked-example conditions there were statistically significant differences between them ($t = 2.28$, $df = 28$, $\eta^2 = .16$), with a large measure of practical importance.

In summary, the conventional problem-solving group who used an interactive simulation outperformed the computer-based worked-examples group. Darabi et al. (2007) accounted for prior domain knowledge and found that the instructional strategies were not statistically significantly different between the more experienced learners. In contrast, for the instructional strategies, there were statistically significant differences between the inexperienced learners. The inexperienced learner who used the problem-solving strategies outperformed the inexperienced participants who used process-oriented or product-oriented worked examples. Regarding transfer performance, when worked examples are used, they need to be followed by practice problems. Worked examples are not sufficient to ensure transfer performance.

There are numerous factors that can influence the effectiveness of worked examples. For example, instructional explanations can assist learners in processing worked examples more effectively. Wittwer and Renkl (2010) conducted a meta-analysis that examined the effectiveness of studying from worked examples combined with instructional explanations and worked examples without instructional explanations. In addition, the researchers examined the role of the diverse factors that are related to example-based learning plus instructional explanations. The meta-analysis included 21 experimental studies that examined example-based learning. Other inclusion criteria were as follows: (a) there were at least two experimental conditions, worked examples plus an instructional explanation, (b) worked examples only, (c) studies that included general instructions on the principles to be learned prior to studying the worked-out examples, and (d) studies that examined the benefits of using instructional explanations with worked-out examples.

The meta-analysis conducted by Wittwer and Renkl (2010) included moderator variables that had the potential to influence the magnitude of the effect of the instructional explanations on example-based learning. The moderator variables were coded and are as follows: (a) the learning domain in some of the studies included mathematics, sciences such as biology or physics, or instructional design, (b) the presentation of worked example included worked examples only or with or without problems to be solved, (c) the number of learning opportunities included how often learners were given to study worked examples and to solve problems in the skill acquisition phase, (d) the type of instructional explanation combined with the worked examples included the presentation of information about operators, principles, or operators and principles, (e) the provision of instructional explanations refers to whether instructional explanations were available by default or on learner demand, (f) the prompted self-explanation in the comparison group included all learners in the comparison group learned by studying worked-out examples without instructional explanations, in some of the studies, the participants in the comparison group were required to generate self-explanations when prompted by a question, and (g) the type of learning measure in the posttest included near transfer (solving worked-example problems structurally similar to those studied), far transfer (solving worked-example problems structurally different to those studied), farther transfer (solving problems in a different domain), near and far transfer (conceptual knowledge and declarative knowledge about principles and concepts), situational knowledge (declarative knowledge relevant to problem solving), and strategic knowledge (declarative knowledge related to strategies and heuristics relevant for problem solving).

There were seven research questions and hypothesis that were examined by Wittwer and Renkl (2010). The results revealed there was a statistically significant weighted mean effect size of the 28 pairwise comparison: however, the effect size was d=.16, which is small, indicating that when instructional explanations were combined with worked examples the effects were marginal. Similarly, the studies that used worked examples combined with instructional explanations that tested near transfer, far transfer, farther transfer, near and far transfer, situational knowledge, and strategic knowledge had average effect sizes that were not statistically significant. When worked examples combined with instructional explanations were used, there was a statistically significant and positive effect for the moderator variable of conceptual knowledge. The effect size for the acquisition of conceptual knowledge was d=.36, which is small. To examine whether specific types of instructional explanations would improve learning outcomes, learners were presented with different types of instructional explanations. These instructional explanations included principles only, operators only, or principles and operators combined. There was a statistically significant effect size for one study where the instructional explanation provided learners with information regarding the operators only. The operators instructional explanation effect size was a large effect (d=.92), which is a large effect size.

Another area examined whether the effect of worked examples would be affected if learners in the comparison group were prompted to self-explain or were not prompted to self-explain the worked examples. The averaged effect size for the studies where the learners were in the comparison group and were presented with worked examples without prompting to self-explain was statistically significant. The effect size was small with d=.22. The next area examined studies that used worked examples combined with instructional explanations in which learners were provided opportunities for solve problems. The average effect size for the studies that used worked examples only as well for studies that used worked examples plus problem-solving was not statistically significant. Another area examined whether example-based learning would be affected differentially if the instructional explanations were provided by default or by learner request. The average effect size for studies with default instructional explanations was statistically significant. The effect size was small with d=.17, and in studies where the instructional explanations on learner demand, the effect size was not statistically significant.

The last area examined studies with different domains of learning such as mathematics, science, and instruction design. The average effect size for studies where mathematics was taught was statistically significant, with an effect size d=.22, which is small and for the other learning domains there was not a statistically significant average effect size. In addition, the average effect size for studies that taught mathematics there was a statistically significant difference from the average effect size for studies with the learning domain as instructional design, that is, there was a beneficial effect when mathematics was the learning domain compared with when instructional design was the learning domain. These results support the use of worked examples to teach mathematics. In the research dissertation, the multimedia medication module included worked examples that illustrated the steps on how to solve common pediatric medication calculations.

As for the use of instructional explanations in conjunction with worked examples, the benefits were minimal. For instance, the use of instructional explanations combined with worked examples for learning conceptual knowledge as well as for the presentation of information about operators positively supported learning outcomes. There was support, although minimal, for learners in the control conditions who were presented with worked examples and were not prompted to self-explain. Hence, instructional explanations have beneficial effects on learning outcomes when compared with learning without self-explanation support. Also, learners who received the default instructional explanations benefited more than when learners were able to choose to use the instructional explanations on demand. Last, when worked examples were used to teach mathematics, there was a beneficial effect when compared with the other learning domains.

Summary

There are three cognitive processes that learners engage in during learning. According to Mayer (2009) the cognitive processes are extraneous, essential, and generative cognitive processing. Extraneous cognitive processing does not allow the learner to engage in cognitive processes critical for learning, such as, essentials cognitive processing and generative cognitive processing (Mayer, 2009). Essential cognitive processing is the selection of the essential material and is represented in the working memory. Generative cognitive processing occurs when the learner is making sense of the essential material; this process involves organizing incoming words and images into coherent structures and integrating the word structures and image structures with each other and with any prior knowledge (Mayer, 2009). Generative process signifies a deeper processing. It is essential that nurse educators design and develop multimedia that supports pedagogies that assist learners' in building mental representations of presented material.

In the literature, there was a wide variety of teaching methods that have been used to teach nursing students medication administration skills. Some of the common medication calculation teaching methods that have been researched range from self-paced CD ROMs, text-based study guides with practice problems, and independent self-paced online programs (Jeffries, 2001; Sung et al., 2008;Wright, 2005, 2008). Similarly, other commonly used methods to teach medication administration include lecture format, one-to-one tutoring, drug calculation workbook in conjunction with practice problems, virtual learning environments, simulation, and skills laboratory (Sung et al., 2008; Wright, 2004, 2005). The problem with these types of learning materials is that they are text based with images or pictures with text instructions. The learning material is presented in only one mode: through the visual mode. These methods do not consider the limitations of the cognitive structures or maximize cognitive processing.

The literature supports two instructional methods that foster meaningful learning. The modality principle has been researched in many domains of learning, and the modality effect has been supported consistently when learning material was presented using spoken words and images and animation (Ginns, 2005; Moreno, 2006), however, there has not been a study that specifically examined the effectiveness of using spoken words concurrently with images of worked examples with the step-by-step instructions on how to solve common pediatric medication calculations for novice nursing students. The use of worked examples has been shown to be an effective strategy to reduce extraneous cognitive load (Renkl & Atkinson, 2010). In addition, the methods to teach medication administration to nursing students have focused on medication calculations for the adult population. No studies on teaching methods for medication administration have focused on pediatric medication calculations. The purpose of this study was to compare a multimedia module that specifically used design techniques that support cognitive structures and process with the traditional method a text-based module to teach mathematical computations.

The next chapter is the method section. The method begins with the purpose of the study and is followed by a description of the research design, instruments used in the study, a review of the institutional review board approval, description of the sample and the medication modules, and ends with the procedures used in the dissertation research and the data analysis.

CHAPTER III
METHOD

Medication errors continue to be a problem in health-care settings (American Academy of Pediatrics, 2003; Institute of Medicine, 2000). In particular, calculation errors have been identified as one of the top 10 causes of pediatric errors (Cowley, Williams, & Cousins, 2001). Dosing regimens in adults typically are based on a standard dose for all adults. In contrast for pediatrics, one dose for all children is not correct, primarily because of the large differences in height, weight, and body surface area. These differences effect how a medication is metabolized and excreted by the body. Due to these differences, dosages are determined by calculating the medication safe dose based on a child's weight and body surface area (Taketomo, Hodding, & Kraus; p.113 2007-2008). The weight-based calculation of dosages for medication administration is foreign to nursing students because they typically are taught only to administer medications for the adult population. An incorrect calculation that leads to the wrong dose is responsible for the majority of pediatric medication errors (Hughs & Edgerton, 2005).

Purpose of the Study

The purpose of this study was to compare the effectiveness of two medication administration instructional methods: multimedia delivery module and text-based module. The multimedia delivery was an instructional message that presented learning material in spoken words as audio narration combined with images or pictures. The text-based medication administration module presented the learning material as text only. This chapter includes a description of the research design, instruments used in the study, and protection of human subjects, characteristics of the sample, and a description of the content in the instructional modules, procedures, and data analysis.

Research Design

A quasi-experimental research design was used in this study. The treatment had two levels: multimedia and text-based medication modules. There was one dependent variable: knowledge acquisition of calculation skills. Prelicensure, junior nursing students in the first 5 weeks of the 10-week quarter were assigned to the text-based treatment, and the second 5-week group was assigned to the multimedia-delivery-module treatment. Calculation skills were defined operationally as a student's ability to calculate (a) weight-based safe-dose ranges, (b) intravenous flow rates for primary and secondary (intravenous piggy-back) medication infusion, (c) conversions from pounds to kilograms, and (d) fluid maintenance.

Participants

A convenience sample (*n*=37) of second-year prelicensure baccalaureate nursing students enrolled a pediatric theory course in a California State University located in the greater San Francisco area was recruited from two campus locations. The nursing program is diverse in that there is a multiethnic and multicultural student body. The nursing students from two campuses who were enrolled in a regularly scheduled pediatric theory course were recruited to participate in the study. Of 127 nursing student enrolled in the nursing program, 37 students were available to participate in the study; of those, 34 were used in the study. One student declined, and two were not included in the study. The two students took the test; however, because they require special testing services where they must have a quiet room and extra time for testing, their data were not included. These two students scored the lowest in their respective groups. Of the 34 students, 70%

(*n*=24) were females and 29% (*n*=10) were males who participated in the study. The number of participants were equal in both groups, that is, 17 students in each.

Protection of Human Subjects

The researcher and the research assistant completed the online Human Subjects Research Training course at the institute where the research was conducted. In order to protect participants' rights, approval from the institutional review board from the study site and the University of San Francisco was obtained prior to the study**.** The research study adhered to the ethical principles and standards of practice, specifically Standard 8: Research and Publication, as outlined by the American Psychological Association (2010). The researcher did not anticipate any risks to those who participated in the study. The purpose and overview of the study procedure for data collection is described in the following section. Students were informed that participation in the study was voluntary and would not affect their grade or class standing. An informed written consent (Appendix A) was obtained prior to data collection, and students were invited to participate in the study. No names were collected, and all documents have been kept confidential and in a locked file cabinet.

Instrumentation

The criterion-referenced test is based on the multiple steps and numerous types of calculations that are required in order to administer pediatric medications. The following section describes the different types of medication calculations student nurses must be proficient with in order to administer medications and includes a description of the criterion-referenced test. The medication process begins with the physician ordering an intravenous antibiotic. The following examples are the typical mathematical functions that student nurses were required to compute for the criterion-referenced test. For the pound-to-kilogram conversion, the child's weight needs to be converted from pounds to kilograms. *1Kgx 9lb=9lb ÷2.2lb=4.09.* Next, for the safe-dose range calculations: The recommended safe dose ranges are *25mg-40mg/kg/day every 6 to 8 hours*. The calculated recommended low and high safe-dose ranges are compared with the ordered dose. There are other factors the student must consider when administering intravenous medications, that is, the intravenous flow rate, recommended intermittent infusion time to administer an intravenous medication, the total volume to be infused, the flush, and the minibag volume. To calculate the intravenous flow-rate, the student nurse must know what the recommended intermittent infusion time is and the volume of the medication minibag.

Next, in order for the medication to be correctly and accurately administered, other factors that students must consider is the total volume to be infused and the flush. For example, the total volume to be infused includes the medication minibag volume plus the flush. In pediatrics, because the intravenous minibag volumes are smaller relative to adult intravenous minibag volumes, a 20ml flush must be included in the equation when calculating the total volume to be infused. The rationale for the flush is that if a medication is dispensed in a 25ml minibag, 20ml of the 25ml of the medication will remain in the intravenous tubing. Therefore, the 20ml flush ensures that the medication is administered.

Last, accurate calculation of fluid maintenance is critical because infants and children who are severely ill are not able to tolerate fluid overload or deficits (Giangrasso & Shrimpton, 2010; Taketomo et al., 2007-2008). There here is a standard formula that is used when calculating fluid maintenance for 24 hours and for 8 hours, that is, the first

10kg or less of a child's weight is multiplied by 100ml, the second 10kg of a child's weight is multiplied by 50ml, and any additional weight is multiplied by 20ml. The sum of these three computations equals a child's 24-hour minimum fluid requirements.

Because of the specialized knowledge and procedures that are required to administer medications in the pediatric population, a 30-minute criterion-referenced test was developed by the researcher. The content for the criterion-referenced test was taken from a medication administration examination that was being used in the second-year pediatric clinical rotation at the time of the study. Two pediatric clinical faculty reviewed the test for content validity (Appendix B). All students were given 30 minutes to complete the text-based test. There was a total of 118 points; depending on the difficulty of the questions, the least difficult questions were worth 2 points and the most difficult were worth 4 points. The examination was scored objectively. If a question was answered incorrectly, no points were given, and if a question was answered correctly points were given based on the assigned value for the level of difficulty of the question.

The criterion-referenced test was comprised of three questions on the pound-to-kilogram conversions; four safe-dose calculations, four questions "is this a safe dose," five minibag volume questions, five total volume to be infused questions, five flush questions, four questions on intermittent infusion times, five intravenous medication-flow rates, two primary intravenous-flow rates, two fluid-maintenance questions, and two clinical-related problems. In addition, there were other test items that are required to administer intravenous medications and were included on the test. These include a 20 ml flush, volume-to-be-infused, intermittent infusion time, minibag volume, and "is this a safe dose"?

The criterion referenced test began with a paragraph on the instructions for completion of the test. There were a total of seven questions with multiple subtest items. Of the seven test questions and subtest items, the first five test questions contained all of the relevant information needed to solve the pediatric medication calculations (Table1) and the last two test questions and subtest items were related to a clinical-related scenario. Table 2 is a representation of a clinical-related word-problem test question and subtest items and the respective assigned point value on the criterion-referenced test.

Table 1
Test Instructions and Example of Test Question with Subtest Items

You will have 30 minutes to complete the test. Show all of your calculations on the examination, circle your answers, and you may use a calculator. Read the questions carefully (118 pts).	
Dr. orders metronidazole 158 mg IV q 6 hr. Child's weight 46.2 lb. Recommended safe dose is 30mg/kg/day in equally divided doses q 6 hrs Minibag.volume = 100mls +10mls medication additive (fractional dose). Recommended intermittent infusion time: 60 minutes.	
A. What is weight in Kg?	2pts
B. What is recommended safe dose?	2pts
C. Is dose safe?	2pts
D. What is the minibag volume?	2pts
E. What is the total volume to be infused?	2pts
F. What is the recommended infusion time to administer the medication?	2pts
G. What is the amount of the flush required?	2pts
H. What will you set your IV flow rate (ml/hr) to administer the medication	4pts

The two medication administration clinical–related word problems required students to analyze, synthesize, and contextualize clinically relevant patient data that they would typically encounter in the clinical setting. The clinical-related word problem included a culmination of the safe-dose calculations, intravenous flow rates, fluid maintenance, and pound-to-kilogram conversions, and other related medication calculations. Each test item required the student to perform mathematical computations and conceptualization of mathematical problems in the context of the clinical situation.

Table 2
Clinical-Related Word Problem

Your patient, Natalie, weighs 18 Kg. At 154 Natalie's oral intake was 50 ml and at 1600 she drinks an additional 50ml. Cefazoline 500mg Q 8hrs is due at 1800. The drug reference book recommends a safe dose range for Cefazoline 100mg/Kg/day divided doses Q 8hr and the intermittent infusion time is 30-60 minutes. Cefazoline was dispensed in a 50ml minibag of 0.9%. The IV Cefazoline was administered over 30 minutes and the medication finished at 1830.	
A. What are Natalie's fluid maintenance requirements for 24hr and 8hrs?	2pts
B. What is the minibag volume?	2pts
C. What was her oral intake?	2pts
D. What is the total volume to be infused?	2pts
E. What is the amount of the flush?	2pts
F. What is the recommended infusion time to administer the antibiotic?	2pts
G. What will you set the intravenous flow-rate (ml/hr) at to administer the medication?	4pts
H. Once the antibiotic is finished, what will you set the IV flow rate (ml/hr) to meet the 8hr fluid maintenance for the remainder of the shift?	4pts

Pilot Study Results

The purpose of pilot testing the criterion-referenced test was threefold: to learn if a pretest was needed for the research study, to ascertain whether 30 minutes was sufficient time to complete the test, and to learn if one hour and 15 minutes was sufficient time to complete the module. The criterion-referenced test and the text-based medication module were pilot tested on a convenience sample (*n*=16) of junior-level nursing students. The nursing students were sent an electronic mail (email) message informing them that they were invited to pilot test the criterion-referenced test. On the first day of the pediatric theory course in the Spring quarter, nursing students who were enrolled in the course were invited to pilot test the criterion-referenced test. The students were informed of the purpose of the pilot test and that participation was voluntary. The students were allotted 30 minutes to complete the criterion-referenced test.

The majority of the students completed the test in approximately 20 minutes, with a few requiring at most 30 minutes. With regard to safe-dose calculation test items, 62.5% to 81.3% were answered correctly, 18.87 % to 37.5% were answered incorrectly, and 0.0 to 6.2% were left blank (see Table 3). As for minibag volume test items, a range of 62.5% to 93.8% were answered correctly, the range for incorrectly answered was from 0.0% to 6.2%, and a range of 6.2% to 37.5.0% were left blank. Also, for the total volume to be infused test items, 6.2% to 18.8% were answered correctly, 50% to 75% were answered incorrectly, and 6.2% to 43.8% were left blank (see Table 4).

Table 3
Pilot Test Results for Safe-Dose Items

	Attempted		Correct		Incorrect		Blank	
Item	f	%	f	%	f	%	f	%
1	16	100.0	10	62.5	6	37.5	0	0.0
2	16	100.0	12	75.0	4	25.0	0	0.0
3	16	100.0	10	62.5	6	37.5	0	0.0
4	16	100.0	13	81.3	3	18.8	0	0.0
5	15	93.8	11	68.8	4	25.0	1	6.2
6	15	93.8	12	75.0	3	18.8	1	6.2

There were six test items that made up the flush, and of those 12.5% were answered correctly, 43.8% to 62.5% answered them incorrectly, and 25% to 43.8% were left blank (Table 5). As for the time for medication administration test items 43.8% to 87.5 % were correctly answered, 6.2% to 12.5% were answered incorrectly, and 0.0% to 43.8% were left blank (Table 6). For the fluid-maintenance test items, 6.2% were answered correctly, 12.5% to 37.5% were answered incorrectly, and 56.3% to 81.3% were left blank (Table 7).

Table 4
Pilot Test Results for Minibag Volume and Total Volume Items

	Attempted		Correct		Incorrect		Blank	
Item	f	%	f	%	f	%	f	%
1 Mini	15	93.8	14	87.5	1	6.2	1	6.2
1 Total	15	93.8	3	18.8	12	75.0	1	6.2
4 Mini	15	93.8	15	93.8	0	0.0	1	6.2
4 Total	12	75.0	2	12.5	10	62.5	4	25.0
5 Mini	15	93.8	15	93.8	0	0.0	1	6.2
5 Total	10	62.5	2	12.5	8	50.0	6	37.5
6 Mini	15	93.8	14	87.5	1	6.2	1	6.2
6 Total	14	87.5	2	12.5	12	75.0	2	12.5
7 Mini	12	75.0	11	68.8	1	6.2	4	25.0
7 Total	13	81.3	2	12.5	11	68.8	3	18.8
8 Mini	10	62.5	10	62.5	0	0.0	6	37.5
8 Total	9	56.3	1	6.2	8	50.0	7	43.8

Table 5
Pilot Test Results for Flush Items

	Attempted		Correct		Incorrect		Blank	
Item	f	%	f	%	f	%	f	%
1	12	75.0	2	12.5	10	62.5	4	25.0
4	10	62.5	2	12.5	8	50.0	6	37.5
5	11	68.8	2	12.5	9	56.3	5	31.3
6	10	62.5	2	12.5	8	50.0	6	37.5
7	10	62.5	2	12.5	8	50.0	6	37.5
8	9	56.3	2	12.5	7	43.8	7	43.8

Table 6
Pilot Test Results for Time Items

	Attempted		Correct		Incorrect		Blank	
Item	f	%	f	%	f	%	f	%
1	16	100.0	14	87.5	2	12.5	0	0.0
5	14	87.5	13	81.3	1	6.3	2	12.5
6	14	87.5	13	81.3	1	6.3	2	12.5
7	12	75.0	11	68.8	1	6.3	4	25.0
8	9	56.3	7	43.8	2	12.5	7	43.8

Table 7
Pilot Test Results for Fluid-Maintenance Items

	Attempted		Correct		Incorrect		Blank	
Item	f	%	f	%	f	%	f	%
1	7	43.8	1	6.2	6	37.5	9	56.3
2	4	18.8	1	6.2	3	12.5	13	81.3

As for the test items for intravenous-flow rates, 0.0% to 68.8% were answered correctly, the range for incorrect answers was 6.2% to 37.5%, and 12.5% to 81.3% were left blank (Table 8). The blank test items suggest that the students had not been taught the content and did not know how to solve the problem. All of the students left many test items blank or they incorrectly answered test items, which resulted in not passing with 90% correct.

Table 8
Pilot Test Results for Intravenous-Flow Items

	Attempted		Correct		Incorrect		Blank	
Item	f	%	f	%	f	%	f	%
1	14	87.5	10	62.5	4	25.0	2	12.5
4	12	75.0	11	68.8	1	6.2	4	25.0
5	12	75.0	8	50.0	4	25.0	4	25.5
6	13	81.3	7	43.8	6	37.5	3	18.8
7	11	68.8	9	56.3	2	12.5	5	31.3
7	5	31.0	0	0.0	5	31.3	11	68.8
8	8	50.0	5	31.3	3	18.8	8	50.0
8	3	18.8	0	0.0	3	18.8	3	81.3

As for the pound-to-kilogram conversions, 100% of these test items were answered correctly. This type of calculation was not difficult to perform because the students previously had learned and performed pound-to-kilogram conversions throughout the year. Based on these results, there was no need to administer a pretest, and 30 minutes was sufficient time to complete the test. Given the results, only a posttest to measure knowledge gains was used in the study**.** The medication module also was piloted to learn if one hour and 15 minutes was sufficient time to study. Most students required 45 minutes, and one student used the one hour and 15 minutes to study the module. Based on the results, one hour and 15 minutes was sufficient time to study the module.

Reliability

Because of the small sample size and the high percentage of blank answers, Cronbach's coefficient alpha was not computed on the pilot test data to assess the internal consistency of the instruments. The reliability was assessed on the data for the study. The reliability for the total test was excellent (see Table 9).

Table 9
Reliability Estimates for the Four Subtests and the Total Test

Test	Cronbach's Coefficient alpha	Sample size
Weight Conversion	---	34
Safe Dose 24hr Calculation	.63	33
IV Flow Rate	.78	22
Fluid Maintenance	.80	19
Total	.92	17

The total reliability was based on the variable test items, pound-to-kilogram conversion, safe-dose calculation, intravenous flow rates, and fluid- maintenance calculations, as well as, the test items that are needed to in order to administer intravenous medications, for example, the total volume to be infused, flush, intermittent infusion time, and the minibag volume. A breakdown of the specific variable test items revealed that the reliability was not able to be computed for the weight-to-kilogram conversions, there was poor reliability for the safe-dose calculation test items, and the reliability for the intravenous flow rate was acceptable. For the fluid-maintenance test items, the reliability was acceptable. Reliability could not be computed for weight-to-kilogram conversions because the students performed the calculations correctly or almost correctly for all items.

Validity

The criterion-referenced text-based test and the text-based medication administration module were reviewed by two pediatric experts for content validity evidence. The experts were sent a content validity form (see Appendix B) and instructional sheet that asked them to decide if each individual test item met any one of the medication administration module objectives. They also were asked to rate the level of difficulty for each of the test items. On the test sent to the content experts, there were three numerical rating values: a numerical value of two was the least difficult, a numerical value of four was moderately difficult, and a numerical value of eight was the most difficult. Based on the feedback from the content experts, most of the test items were rated as two or four. As a result, the numerical ratings values were changed from three numerical rating values to two rating values: a rating of two indicates that the test item is least difficult and a rating of four indicates the test item is moderately difficult. The experts agreed that there were no test items that warranted a rating of eight that indicated most difficult.

Next, the content experts were sent a content validity form (see Appendix C) and were asked to ascertain whether the subtest items in the module met one of the medication administration module objectives. The content experts were instructed to assign one of the medication administration module objectives to each test item. The objectives for the medication administration module were the students' ability to calculate (a) safe-dose ranges for mg/kg/24 hours in equally divided doses, (b) safe-dosage calculations for mg/kg/dose, (c) parenteral (intravenous) flow rates for primary and secondary (piggyback) medication administration, (d) conversion of pounds to kilograms, and (e) fluid maintenance. All of the test items met one of the medication administration modules objectives.

Treatment

Because of the specialized knowledge and procedures that are required to administer medications in the pediatric population, a multimedia and text-based medication module was developed by the researcher. Two one-hour-and-15-minute pediatric medication administration modules that contained worked examples were developed by the researcher: a text-based and a multimedia-delivery module.

The content for the text-based module was derived from the medication calculation content taken from a medication text-based self-study module that was being used in the second-year pediatric clinical rotation at the researcher's university. The text-based module included worked examples with a step-by-step explanation and solutions on how to calculate pound-to-kilogram conversions, safe-dose ranges, intravenous flow rates, and fluid maintenance as the multimedia module (Appendix D). Other necessary content-related medication administration that was included in the text-based module was the flush, intermittent infusion time, total-volume-to-be-infused, and, "is the ordered does safe?" The module was comprised of three segments. The first segment began with purpose and objectives, which was followed by brief description of the rationale for weight-based calculations in the pediatric population. The first segment contained worked examples illustrating the steps on how to convert pounds-to- kilograms and calculate safe-dose calculations plus the text for further explanation. At the end of the segment, there were two practice problems that the students could complete, which was followed by a review with the step-by-step instruction on how to solve the problem. Segment two began with some definition of terms that were needed to administer pediatric intravenous medications, which was followed by worked examples illustrating the steps on how to calculate the intravenous flow-rate including the intermittent infusion time, flush and the total volume to be infused plus the text for further explanation. At the end of the segment, there was one practice problem that included a culmination of prior learning content in the module that the students could complete, which was followed by a review with the step-by-step instruction on how to solve the problem. The third segment began with an explanation on how to calculate fluid maintenance for 24 hours and 8 hours, which included worked examples illustrating the steps on how to calculate fluid maintenance plus the text for further explanation. At the end of the segment there was one practice word problem that the students could complete, which was followed by a review with the step-by-step instruction on how to solve the problem.

The advantage of using a multimedia with images and concurrent spoken words permits the learners to view the steps and hear an explanation as the problem is solved. Research has shown that when learning material is presented in one mode such as text only, less information is processed in the working memory (Mayer, 2005, 2009). In contrast, when presenting complex images (visual presentation) such as worked examples with spoken words as an audio narration as opposed to presenting the words in text (visual presentation). More learning material can be processed when two modes are used to present learning material (Mayer, 2005).

To develop the multimedia-delivery module, a document camera was used to capture the researcher writing on a white board with a sharpe to show step-by-step how to solve mathematical calculations related to medication administration. A video camera with audio recording was used to record the researcher solving the medication calculation. Research has shown that worked examples provide an expert's problem-solving paradigm for the novice learner to follow (Atkinson, Derry, Renkl, & Wortham, 2000). The multimedia module consisted of worked examples with concurrent audio narration with a step-by-step instruction on how to calculate pound-to-kilogram conversions, pediatric medication safe-dose ranges, intravenous flow rates, and fluid maintenance. The module also included other relevant information related to medication administration such as the flush, intermittent infusion time, the total-volume to-be-infused and, "the ordered dose safe?" After each segment, there were one-to-two practice problems that the student could complete. To ensure equivalency between the multimedia and the text-based module, the researcher used the text-based module as the script for the multimedia module. After the development of the multimedia module and to further support equivalency between the two modules, a registered nurse was instructed to read the text-based module while listening to the multimedia module. No discrepancies were reported.

The multimedia-medication-module content originated from a self-study module that was being used in the second-year pediatric clinical rotation. The content was identical to the content used in the text-based medication module. The multimedia module content was presented in three 15- to 30-minute segments. The rationale for presenting the learning material in three segments was to allow the students to skip sections if they were familiar with the content or if they needed to review specific content they could go directly to the segment with the specific content and review. Students had the ability to pause and restart the multimedia, at any time (Appendix E). The first segment included the purpose of the medication module, which was followed by a brief rationale why drug dosages are weight-based in the pediatric population, which was followed by the worked examples that illustrated how to convert pound-to-kilogram and safe-dose calculations (single dose and 24-hour calculations). The second segment included definition of terms for parenteral piggyback medication administration, which included recommended infusion time, total volume to be infused, intravenous flow rates, and flush. There was one practice problems where students were verbally provided with the relevant information that was required to complete the problem. After completion of the practice problems, the students listened to the verbal explanation while viewing the steps on how to solve the problem. The third segment included worked example with step-by-step instruction on how to calculate fluid maintenance for 24hours and 8 hours with concurrent verbal explanation. Afterward, students were presented with a clinically related word problem that was a culmination of the previously presented medication content. The students were verbally provided with the relevant information that was required to answer the clinical-related word problem. Afterward, they were provided with a verbal explanation on how to solve the problem concurrently while they were able to see the problem solved using worked examples.

The multimedia group listened to the instructional message with earphones ensuring no noise distractions. The recorded audio visual instructional message was burned onto a CD-ROM and was on a laptop for the students to click on the multimedia module icon to view the instructional message. Once the students clicked on the multimedia icon, there was a display of three segment titles. When a segment title was clicked on, the student was able to view the audio-visual instructional messages. At the end of the segment, the subsequent segments were available to view.

Two pediatric drug reference books that contained adult and pediatric medication content were used as references for the development of the text-based module and the multimedia module (Giangrasso & Shrimpton, 2010; Taketomo et al., 2007-2008). In addition, for the multimedia-delivery medication modules, the medication calculation content was taken from a medication text-based self-study module that was being used in the second-year pediatric clinical rotation at the researcher's university**.** Both of the modules followed the same format and contained identical content and included worked examples with a step-by-step explanation and solutions on how to calculate pound-to-kilogram conversions, safe-dose ranges, intravenous flow rates, and fluid maintenance. Under normal circumstances, when administering medications, student nurses would consult a pediatric drug reference book for the essential information that is required in order to administer safely medications: however, all of the essential information was included in both modules. For example, the essential information that was included in the modules were the recommended safe-dosage ranges, recommended intermittent infusion times to administer safely intravenous medications, dilutions, and other relevant information related to medication administration.

Procedures

In the 10-week quarter, there are two 5-week sections of the pediatric theory course, and each class section is held on a Monday morning from 9:00 a.m. to 10:50 a.m.

On February 11, 2013, the first day of class, data were collected from the text-based group (*n*=18). On April 8, 2013, the first day of class, data were collected from the multimedia group (*n*=19). The students who were enrolled in the regularly scheduled pediatric theory course were invited to participate in the study. Of the 19 students in the multimedia group, one declined because she previously had failed the pediatric theory course but had passed the concurrent clinical and the medication test. Therefore, the student was not required to take the pediatric medication test again. In addition, there were two other students, one in the comparison group and one in the multimedia group, who required special testing services. Students who use special testing services require a quiet place and extra time to take the test. Therefore, the two students took the test; however, the test results were not included in the data analysis.

There were three research assistants who were trained on the data-collection process, including how to navigate through the multimedia-delivery medication module and the text-based module, as well as familiarity with the medication module and the criterion-referenced test content. For consistency, the main research assistant was present for both data collections and was the designated script reader for both groups. The other two assistants were available to set-up the room and provide support for the main research assistant. All of the research assistants were available to answer any questions related to the content, during the study.

For the multimedia group, the researcher made arrangements, in advance, to have 18 laptops in the computer lab. The Friday prior to the conduction of the multimedia research study, the researcher went to the research site and consulted with the information technologist who would be assisting with the research study. The researcher and the information technologist tested all of the laptops, CD-ROMs, and earphones to ensure that there were no defects or problems with the equipment. After the testing of the equipment, the room was locked and was not used until the following Monday for the research study.

One hour before the multimedia data collection, the researcher, information technologist, and research assistants set up the laptops, CD-ROMS, and the earphones and prepared the room. Once the room was prepared, the researcher left the room but was on site and available by phone if the research assistant had questions. After the study, the researcher needed to speak with the students regarding the course. At the start of the class, there were two research assistants for the administration of the multimedia study, and there was an information technologist (IT) who provided instruction to the participants on how to navigate through the multimedia instructional message and was on standby for any technological problems.

For both groups, when students walked into the class, they were instructed to write their name next to numerical code on the sign-in sheet. The research assistant handed each student an envelope with the code that corresponded with the code on the sign-in sheet. There was a numerical code on the criterion-referenced test that corresponded with the one on the envelope and sign-in sheet. The text-based module group was given an envelope with two copies of the consent forms, text-based module, text-based test, and readings on pediatric medication. The multimedia group was given an envelope with two copies of the consent forms, text-based test, and readings on pediatric medication. For both groups, text-based module and the multimedia module, a 15-minute introduction was provided by the research assistant. The research assistant read a script

(Appendix F) on the study purpose and the data-collection process. Students were invited to participate in the research study. Students who did not want to participate in the research study were instructed to read the articles on pediatric medications. Students who decided to participate in the research study were instructed to read the consent and sign both copies of the consent forms and to keep one and insert the other form in the envelope.

The multimedia group was instructed on the multimedia module and on how to navigate through the module by the information technologist. The text-based module group was instructed to take the text-based module out of the envelope and how to proceed through the text-based module. The text-based module group took one hour and 22 minutes instead of the planned one hour and 15 minutes. The additional time was due to the fact that some of the questions did not match-up with the answers. As a result, one of the research assistants had to contact the researcher to identify the correct answers for each question. This added an extra 7 minutes to the data-collection time. At the end of one hour and 22 minutes, the text-based group was instructed to insert the text-based module in the envelope and instructed to take out the test. After the study was completed, the researcher reviewed the miss matching of the questions and answers and reviewed the multimedia module to correct the issue. For the multimedia module, when it was recorded, the miss matching was not an obvious problem; however, the research assistants were aware of the potential problem and were instructed on a work around.

At the end of one hour and 15 minutes, the multimedia group was instructed to close the multimedia module and to take the test out of the envelope and complete the test. The multimedia and the text-based groups were allotted 30 minutes to complete the text-based test. Upon completion of the text-based test, the research assistant instructed the students to keep the articles about pediatric medications and to insert the text-based test in the envelope, seal it, and place it in the box on the research assistant's desk. For the multimedia module, the total time to complete the basic instruction, the multimedia module, and test was 2 hours. For the text-based module the total time to complete the basic instruction, the medication-module, and test was 2 hours and 7 minutes (additional 7 minutes due to the correction of the miss matching of questions and answers).

After data collection, the research assistants separated the consent forms from the test and placed them in a separate envelope and returned them to the researcher. Immediately after the study, the research assistants and the researcher graded the mathematical tests. The names of the students were matched with the codes for the purpose of identifying the students who passed and did not pass, so they could be notified of their testing status. After the tests were scored and those passing identified, the list of codes and names were destroyed by the research assistant. Students were notified by email if they passed the test and were informed that they were able to administer medications. Students who did not pass the test were sent an email to inform them that they did not pass. They were instructed to download the medication administration module from the course management system, Blackboard, and to study the medication administration module in preparation to take the medication test. The researcher also sent an email to the clinical instructor to inform her of the students who passed and did not pass the medication administration test, so she would know who needed to take the medication test and who would be able to administer medications. The students who did not pass were notified by their clinical instructor of the date of the medication test.

Data Analysis

The research questions are as follows:

1. To what extent were there differences in knowledge acquisition of pediatric – medication-calculation skills between prelicensure nursing students using the multimedia-delivery module and those using text-based instructional module?
2. To what extent were there differences in the pound-to-kilogram conversions between prelicensure nursing students using the multimedia-delivery module and those using text-based instructional module?
3. To what extent were there differences in the weight-based safe-dose calculations between prelicensure nursing students using the multimedia-delivery module and those using text-based instructional module?
4. To what extent were there differences in the intravenous-flow-rate calculations between prelicensure nursing students using the multimedia-delivery module and those using text-based instructional module? (e)
5. To what extent were there differences in the fluid maintenance calculations between prelicensure nursing students using the multimedia-delivery module and those using the multimedia-delivery module and those using text-based instructional module?

For research question one, an independent-samples *t* test was conducted to investigate if there were statistically significant differences between the groups on the total test. If there was a statistically significant difference, then an effect size was computed to assess the magnitude of the difference. As for research question two because the data were categorical, and not continuous, a chi-square test was conducted. If statistical significance was found, then a measure of explained variation was computed.

Because the data for research question three was categorical, a chi-square test was conducted. If statistical significance was found, then a measure of variation was computed. As for research question four, an independent-samples *t* test was conducted to investigate if there were statistically significant differences between the two groups. If there was a statistically significant difference, then an effect size was computed to assess the magnitude of the difference. As for research question five because the data were categorical and not continuous, a chi-square test was conducted. If statistical significance was found, then a measure of explained variation was computed.

Researcher Qualifications

The researcher has 25 years of pediatric acute-care experience. She has worked in a wide variety of subspecialty areas in a pediatric trauma center that serves the Northern California region. She also has 11 years of teaching experience at a public university in the Greater San Francisco Bay Area. She is the lead pediatric faculty in which she teaches the pediatric theory course for all of the students at both campuses. She is also the lead pediatric clinical faculty.

CHAPTER IV
RESULTS

The purpose of the study was to compare the effectiveness of two teaching methods to present learning material for teaching pediatric medication administration content: multimedia and text-based modules. The multimedia and text-based modules included worked examples with a step-by-step explanation and solution on how to calculate pound to kilogram, safe-dose ranges, intravenous flow rates, and fluid maintenance. The multimedia module that was used in this study presented images of worked examples with concurrent verbal explanation on how to calculate pound-to-kilogram conversions, safe-dose range calculations, intravenous flow rates, and fluid maintenance, and the text-based module presented worked examples with the text explanation how to calculate pound-to-kilogram conversions, safe-dose range calculations, intravenous flow rates, and fluid maintenance. There was one dependent variable, knowledge acquisition of calculation skills. Calculation skills were defined operationally as a student's ability to calculate (a) weight-based safe-dose ranges, (b) intravenous flow rates for primary and secondary (intravenous piggy-back) medication infusion, (c) conversions from pounds to kilograms, and (d) fluid maintenance.

The results of this study are presented in three sections. In the first section, the research questions are presented. The next section includes a brief description of the test, the results of knowledge acquisition of pediatric medication calculation skills between the multimedia-delivery instructional module and the text-based instructional module, followed by the results of the pass rates between the comparison and the multimedia groups. Next, the results of the comparison between the text-based instructional module and the multimedia instructional modules four subtest items: weight-based safe-dose calculations, intravenous-flow-rate (iv) calculations, fluid-maintenance calculations, and pound-to-kilogram conversions are presented.

The research questions that were examined in this study were

1. To what extent were there differences in knowledge acquisition of pediatric medication calculation skills between prelicensure nursing students using the multimedia-delivery module and those using text-based instructional module?
2. To what extent were there differences in the pound-to-kilogram conversions between prelicensure nursing students using the multimedia-delivery module and those using text-based instructional module?
3. To what extent were there differences in the weight-based safe-dose calculations between prelicensure nursing students using the multimedia-delivery module and those using text-based instructional module?
4. To what extent were there differences in the intravenous-flow-rate (iv) calculations between prelicensure nursing students using the multimedia-delivery module and those using text-based instructional module?
5. To what extent were there differences in the fluid-maintenance calculations between prelicensure nursing students using the multimedia-delivery module and those using the multimedia-delivery module and those using text-based instructional module?

A 30-minute criterion-referenced test developed by the researcher was comprised of worked examples and clinical-related problems. Some of the typical computations students were required to perform included pound-to-kilogram conversions, weight-based safe-dose range calculations, primary and secondary intravenous-flow-rate calculations, and fluid-maintenance calculations, and clinically-based medication administration problems.

Research question one was examined, followed by the pass rates. An overview of the means, standard deviations, and independent-samples *t* test for the total test for the multimedia and comparison groups are presented in Table 10. The total test means for both groups were similar. Because the sample sizes were the same the assumption for equal population variances was robust. An independent-samples *t* test was conducted to examine whether there were statistically significant differences for the total test means between the two groups. The results revealed there were no statistically significant differences between the two groups; therefore, no effect size was computed for the total test means.

Table10

Means, Standard Deviations, and *t*-test Results for the Total Test

	Comparison (*n*=17)		Multimedia (*n*=17)		
Test	Mean	SD	Mean	SD	*t df=32*
Total	105.2	9.34	104.23	9.53	.40

With regard to the pass rates, a few more students in the comparison group scored higher on the test compared with the multimedia group (Table 11). Similarly, a few more students in the multimedia group did not pass the test than number of students in the comparison group. Because the data were dichotomous, a chi-square test was conducted to examine whether there were statistically significant differences between the comparison and the multimedia group. The results revealed there was no statistically significant difference for the pass rates between the two groups.

Table11

Frequencies and Percentages for the Pass Rate for
Total Test Broken Down by Group

	Pass Rate					
	Pass		No Pass		Total	
Group	*f*	%	*f*	%	*f*	%
Comparison	9	52.9	8	47.1	17	100.0
Multimedia	7	41.2	10	58.8	17	100.0

For research question two, pound-to-kilogram conversion both groups did not have a problem converting pound to kilograms. Ninety-four percent of the students in the text-based group and 88.9% of the students in the multimedia group answered this type of question correctly. An overview of the frequencies, percentages, and chi-square test for the multimedia and comparison groups are presented in Table 12. Because the data were categorical, a chi-square test was conducted to examine whether there were statistically significant differences between the two groups; there was not a statistically significant difference (χ^2 (df=1= .36.)

Table12

Frequency of Correct Answers for the Pound Kilogram Conversions,
Safe-Dose Calculations, and Fluid Maintenance by Group

	Comparison		Multimedia	
Calculations	*f*	%	*f*	%
Pound to Kilogram	16	94.1	15	88.9
Safe Dose	12	70.6	10	58.8
Fluid Maintenance	12	70.6	11	64.7

As for the safe-dose calculations in research question 3. 70% of the text-based group and 58.8% of the multimedia group (Table 12) answered this type of question correctly. A chi-square test was conducted to examine whether there was statistically significant differences between the two groups; there was no statistically significant differences between the groups (χ^2 (df=3)= 2.01).

The fourth research question examined the difference between multimedia-delivery module and the text-based instructional module on intravenous flow-rate calculations. The intravenous-flow-rate means between the comparison and the multimedia groups were similar (Table 13). An independent-samples *t* test was conducted to examine whether there were statistically significant difference; in the subtest item intravenous-flow-rate means between the two groups, there was no statistically significant difference.

Table13

Means, Standard Deviations, and *t*-test Results for IV Flow Rate

	Comparison (*n* = 17)		Multimedia (*n* = 17)		
Test	Mean	SD	Mean	SD	*t df=32*
IV Flow	24.24	6.88	24.47	5.02	.19

With regard to fluid maintenance for research question 5, a similar number of students were able to answer all of the fluid maintenance questions correctly between the two groups (Table 12). Seventy-percent of the text-based group and 64.7% of the multimedia group were able to answer this type of question correctly. A chi-square test was conducted to examine whether there was statistically significant difference with the fluid-maintenance calculations between the two groups; there was no statistically significant differences between the two groups (χ^2 (df=2)=3.04).

Additional Findings

The next section focuses on the type of mathematical errors that were made by the text-based and the multimedia groups. The multimedia group made more errors with setting-up problems than the comparison group (see Table 14). Both groups were similar with regard to using the wrong formula to solve problem.

The next most frequent error made was an incorrect use of mathematical functions. The most common incorrectly used mathematical functions that were made were division problems (dividing when not needed), using addition when not needed, using multiplication when not needed, did not multiply when was should, and multiplied using the wrong number. With regard to the mathematical function questions, the comparison group made the majority of this type of error compared to the multimedia group. As for calculation errors, the comparison group made more of these types of errors than the multimedia group.

Table 14
Frequencies and Types of Errors Made

	Comparison (*n=17*)	Multimedia (*n=17*)
Types of Errors	*f*	*f*
Set-up	1	5
Wrong form	3	2
Mathematical	0	0
Function	14	9
CalcuError	7	3
Rules	1	1
Definterm	1	1
Misunderstood	0	0
Question	1	1
Anxiety	1	1
Lack of work	1	4
Lack of time	1	1

Both groups were similar with regard to the other types of errors made. There were several students who calculated the correct answer; however, they had the question "is the dose safe?" wrong. It is unclear why they answered the question incorrectly. There is a possibility that they may have misunderstood the question, or they were not aware of the rules for rounding-up, and there may have been some test anxiety present. In the comparison group, fewer students left test questions, at the end of the test, blank compared with the multimedia group. One student left 5 questions blank, one student left 3 questions blank, and one left 9 questions blank. More students (n=6) in the multimedia group left more questions, at the end of the test, blank. One student left 3 questions blank, three students left 8 questions blank, one student left 5 questions blank, and one student left 9 questions blank.

Summary

In summary, there were no statistically significant differences for the pass rates and the four subtest items, pound-to-kilogram conversions, safe-dose calculations, intravenous flow rates, and fluid-maintenance calculations. Both the text-based module and the multimedia module were similar with regard to the pass rates, however, both modules were not as effective for teaching pediatric medication administration content for the participants in the study.

As for the additional findings, the majority of errors made by both groups were similar with the exception of three types of errors. The differences between the two groups were related to correctly setting-up the problem, mathematical functions, and calculation errors. The majority of the questions that were answered incorrectly were related to mathematical functions, for example, dividing, adding, or multiplying when not necessary. The text-based group made more mathematical functions errors and calculation errors compared with the multimedia group. All of other types of errors that were made between the two groups were similar.

CHAPTER V
SUMMARY, LIMITATIONS, DISCUSSION, RECOMMENDATIONS, AND CONCLUSIONS

The purpose of the study was to compare the effectiveness of two teaching methods to present learning material for teaching pediatric medication administration content: multimedia and text-based modules. There was one dependent variable: knowledge acquisition of calculation skills. Calculation skills were defined operationally as a student's ability to calculate (a) weight-based safe-dose ranges, (b) intravenous flow rates for primary and secondary (intravenous piggy-back) medication infusion, (c) conversions from pounds to kilograms, and (d) fluid maintenance. The chapter begins with a summary of the results, followed by the limitations of the study and a discussion of the study results. Also included are sections on recommendations for practice and future research, and the chapter ends with the conclusions of the study.

Summary of Results

With regard to mathematical knowledge acquisition, the results indicated that the total test means for the comparison (M= 105.2) and the multimedia (M=104.2) groups were similar and there was no statistically significant difference. In addition, the pass rates for both groups were low with 53% for the comparison group and 41% for the multimedia group; there was no statistically significant difference. The subtest items, pound-to-kilogram conversions, safe-dose calculations, intravenous flow-rates and fluid-maintenance calculations were analyzed as well. For the pound-to-kilogram conversions, 94% of the students in the comparison group and 88.9% of the students in the multimedia group answered all of the questions correctly. For the subtest item safe-dose calculations, 70.6% of the students in the comparison group and 58.8% of the students in the multimedia group answered all of the questions correctly. As for the subtest item, intravenous-flow-rate calculations, there were minimal differences between the means of the comparison (M=24.24) group and multimedia (M=24.47) group, and there was no statistically significant difference. For the subtest item, fluid-maintenance calculations, 70% of the students in the comparison group and 65% of the students in the multimedia group answered all the questions correctly.

Last, the majority of the errors made by both groups were similar; however, there were differences between the groups related to setting up the problem, mathematical functions, and calculation errors. For instance, the multimedia group made more errors with setting up the problem. The majority of the questions that were answered incorrectly were related to mathematical functions. The text-based group made more errors related to the mathematical function, for example, dividing, adding, or multiplying when not necessary, compared with the multimedia group. As for calculation errors, the text-based group made more of these types of errors compared with the multimedia group. The other types of errors that were made between the two groups were not knowing the rules, unfamiliar with the definition of terms, using the wrong formula, misunderstanding the question, test anxiety, not showing the work, and insufficient time. Both groups made few of these types of errors.

In summary, the results indicated there were no statistically significant differences for the knowledge acquisition as well as for the subtest items: conversions, intravenous flow rates, safe-dose calculations, and fluid-maintenance calculations between the text-based and the multimedia instructional modules. It can be surmised that both of the groups yielded similar results with regard to knowledge acquisition. With regard to the types of errors made, the majority of errors made by both groups were similar. For example, the multimedia group made more errors with setting up the problem and the majority of the questions that were answered incorrectly were related to mathematical functions. The text-based group made more errors related to mathematical function, for example, division, addition, and multiplication errors, compared with the multimedia group. As for calculation errors, the text-based group made more of these types of errors compared with the multimedia group. All of the other types of errors that were made by the two groups were similar.

Limitations

There are several limitations for this study: small sample size, a convenience sample was used, and student anxiety. The first limitation of this study was that a convenience sample of prelicensure nursing students who were enrolled in the pediatric theory course participated in the study. Furthermore, the students were not assigned randomly to the treatment groups, and there was a small sample size in each group. Therefore, the results cannot be generalized to represent nursing students in the larger population.

Several students expressed concern to the research assistants of the uncertainty of what to expect, and there was some anxiety because they knew that they were required to pass the medication examination in order to pass the pediatric rotation. Student anxiety and the pressure to study the module and then take the medication test in a specified amount of time may have affected some of the students' ability to perform well on the test. Under normal circumstances, students study the module at their own pace over an extended period of time. They are also allowed time to ask questions and receive clarification on content before expected to take the mathematical examination. The mathematical examination is usually administered on the second clinical and not on the first day of lecture, as well.

Another limitation of the study was the study time of the module and the time to take the test. Even though the study time for the module and test time were determined by the pilot study conducted with nursing students who were enrolled in the previous pediatric theory course, several students complained there was not sufficient time to complete the test. Normally, students study the medication module at their own pace, without any time constraints and over an extended period of time. In the current study, several students conveyed to the researcher that the test time was insufficient. Consequently, there were several students who did not complete the mathematical test and left multiple questions blank on the last page and a half.

Last, the results may not be generalized to other schools of nursing, particularly associate degree nursing (ADN) programs. Many ADN programs in the Greater San Francisco Bay Area are not competitive, that is, students are admitted into the ADN program by the lottery system. Although the lottery system is currently in the process of changing to a more competitive process, similar to the study-site nursing program. Some of the students who are admitted may not have high grade point averages (GPA) as those students in the baccalaureate nursing program. Baccalaureate (BSN) nursing program are competitive as all students compete to be admitted into the program. As a result, students admitted to the program have higher GPAs.

In addition, the educational preparation between the ADN and BSN nursing programs are different. For example, the focus of ADN nursing programs is on clinical and theory with some lower division general education courses compared with a BSN nursing program. Nursing students who are enrolled in a BSN program also take fundamental nursing coursework with the clinical component, similar to the ADN program. They also take additional coursework in statistics, biochemistry and communication and they have broader general education background.

Discussion

Medication administration is one of the most common and essential skills that are performed by nurses in clinical practice on a day-to-day basis (Pentin & Smith, 2006). A high level of proficiency and accuracy with medication administration is critical in providing high quality and safe patient care (Harne-Britner et al., 2006; Wright, 2004, 2008), especially in pediatrics. The pediatric literature illustrates that there continues to be medication errors related to miscalculations and that the effects of a miscalculation can have a devastating effect (Cowley, William & Cousins, 2001). Because there are no standardized medication dosages for pediatric patients, medication dosages are weight-based and require the healthcare professionals to calculate the medication safe-dose range. The calculation of a medication dosage increases the chances of calculation medication errors (Hughs & Edgerton, 2005). When a medication error occurs, pediatric patients have a higher risk of dying compared with adult patients (Hughs & Edgerton, 2005). Therefore, it is critical that student nurses have a strong medication calculation foundation.

Nurse educators are in a position to design, develop, and use effective pedagogies that assist student nurses to acquire medication-administration calculation skills. Research has supported two instructional design techniques: worked examples and the modality principle. Because the working memory has a limited capacity as to the amount of information it can hold at a time and process (Baddeley, 1992), design techniques that consider the limitations of the working memory are essential. Many multimedia instructional designs do not consider the limitations of the working memory and, as a result, place increased cognitive demand, which does not contribute to learning. Multimedia that presents learning material in two modes, visual and auditory modes, considers the limitations of the cognitive processes and how the mind processes information (Mayer, 2009) and, consequently, maximizes cognitive processes and promotes learning.

The modality principle asserts that learners learn better when words and images as opposed to images and text (Mayer, 2009) are used to present instructional messages. Inappropriately designed multimedia that does not consider the cognitive structures and how the mind processes information forces the learner to unnecessarily use cognitive capacity on extraneous processing (Mayer, 2009). Therefore, the design of multimedia should assist the learner to use cognitive capacity to manage essential processing. According to Mayer (2009), essential processing occurs when the learner is able to represent mentally the essential information and, as a result, generative processing occurs. Generative processing is when the learner is makes sense of the material and includes organizing the mentally organizing the essential information into coherent structures and integrating the structures with each other and with schemata (prior knowledge).

Furthermore, the modality principle has been shown to be an effective instructional method because words and images are qualitatively different and complement one another. Consequently, understanding occurs when leaners are able to mentally integrate the image and verbal representations and build the meaningful connections between the image and verbal representations (Ginns, 2005; Mayer, 2009).

The multimedia used in the research study presented learning material in two modes: visual and auditory modes. The multimedia module presented pediatric mathematical calculation content in three segments, and the students were able go back and review specific segments if needed. The multimedia module was uploaded to the computer, and the students listened with earphones and viewed each segment of the module on the computer screen. In the Ginns's (2005) meta-analysis, the effect size for mathematics and logic was .58, which is a medium effect. The multimedia medication module in this study presented mathematical content in relatively short segments so students would be allowed to progress through each segment at their own pace. A meta-analysis conducted by Ginn (2005) examined self-paced and system-paced multimedia. The system-paced average effect size was .93, and the self-paced effect size was .14. Even though the Ginn's (2005) meta-analysis found system-paced learning material to be more effective, it is important to allow the students to have the flexibility to control the pace of the module. The rationale for using self-paced module is to allow students to pause and go back and review content at any point of the segment or to skip over content they already know and focus on less familiar content.

For research question one, to what extent were there differences in knowledge acquisition of pediatric medication calculation skills between prelicensure nursing students using the multimedia-delivery module and those using text-based instructional module, the results indicated the comparison and the multimedia module were similar with regard to mathematical knowledge acquisition. For instance, the means for the total test were similar, and there was no statistically significant difference between the two groups. Ninety percent is a passing score. The scores ranged from 75% to 100% correct in the comparison group and the multimedia group, and in both groups, at least one student had 100% correct on the test. There were minimal differences in the number of students who passed the test between the two groups. Fifty-three percent of the students in the comparison group passed with a 90% or better, and 41% of the students in the multimedia group passed with a 90% or better. Perhaps the low pass rates may be attributed to high student anxiety levels and insufficient time to study the module and test.

Even though the passing rates were low in this study, the majority of the research conducted on the modality effect has been shown to be effective when compared with text-based only learning content. In a study conducted by Moreno (2006), the modality effect examined whether a desktop multimedia instructional message was more effective in promoting meaningful learning when presented in the auditory and visual modalities (modality principle). The results revealed on the retention and transfer tests that there was a statistically significant modality effect on both learning measures for the students who learned with the narrated explanation compared with those who learned with on screen-text for both learning measures. In contrast, Dunsworth and Atkinson (2007) examined three presentation modes to present the human cardiovascular system. The three presentation modes were (a) embodied agent (narration plus pedagogical agent compared with on-screen text), (b) modality effect (narration compared with on-screen text), and (c) image effect (narration plus agent compared with narration). The overall posttest means for the narration (M=15.12) compared with on-screen text (M=14.71) were not significantly higher than the on-screen text. In short, the study did not support the modality effect. Dunswoth and Atkinson (2007) suggested that learning about the human cardiovascular system was complex learning material and that may have been why the modality effect was not supported. Perhaps because the learning material was complex the embodied agent condition (narration plus pedagogical agent compared with on-screen text), and the image condition (narration plus agent compared with narration) provided the extra support for learning complex learning material. In the dissertation research, worked examples were used to present mathematical computations.

With regard to insufficient time to complete the test, there were several students who conveyed to the researcher that the test time was insufficient, even though the test time was determined by the pilot study conducted with nursing students who were enrolled in the previous pediatric theory course. The students who studied the multimedia module and did not pass the test left more questions blank on the test compared with the text-based group. For example, in the multimedia group, there were at least four students who did not answer all of the questions on the last page of the test, and a few students who did not answer the last few questions on the last page. In the text-based group, there were fewer students who did not complete multiple test questions. For example, there was one student who did not complete the last page, one who did not answer half of the questions on the last page, and one student did not complete the last few questions on the last page.

There are many factors that may have contributed to both groups not performing as one would expect. These factors include insufficient time to study the module and test time, student anxiety, and not knowing what to expect. Under normal circumstances students study the module independently on their own time without any time constraints. In this research study, both groups were permitted one hour and 15 minutes to study the module. It is plausible that insufficient time to study the module may account for low pass rates for both groups. Another factor that may have attributed to the low pass rates, particularly in the multimedia group, includes the pace of the multimedia module. The pace of the module may have been slower than the students reading pace. When the multimedia module was recorded, it was recorded over one-hour and 15 minutes. As a result, the students may not have had sufficient time to perform all of the calculations. It also may have been problematic to control the pace of the multimedia module compared with the text-based module. For example, it may have been easier or quicker to skip sections of the text-based module as opposed to the multimedia module and there may not have been sufficient time to go back and review sections more than once in the multimedia module.

In this dissertation research, the students who used the text-based module (53% of students passed) performed somewhat better than those who used the multimedia module (41% of students passed). Between 50% and 60% of the students in both groups did not pass the examination. Based on multimedia research regarding the positive learning outcomes, one would expect multimedia that presents learning material in the visual and auditory modes would render better learning outcomes than when text and images are used (Ginns, 2005; Mayer, 2000; Moreno, 2006), however, the results of this dissertation research did not support the modality effect. Tabbers, Martens, and van Merrienboer (2004) also did not obtain the modality effect in their study that examined the modality effect and the cueing effect. The participants in the Tabbers et al. (2004) study reviewed a web-based multimedia instructional message that presented learning material on how to develop a training program blueprint, which included the necessary steps to develop complex skills. The instructional format was comprised of worked examples which were followed by an explanation. The results revealed that the text-based condition required considerable less time to study than the narration condition. As for the transfer test, there were no statistically significant differences between the text-base and the narration condition, as well.

As for the retention test, the mean for the text-based condition (M=32.8) was statistically significantly higher than the narration condition mean (M=29.4), the effect size was .66, which is a moderate effect. Hence, there was no modality effect. Tabbers et al. (2004) suggested that perhaps the modality effect was not supported because it may have been attributed to the type of content and the pacing of the presentation used in their study was different with previous studies that examined the modality effect. For example, the instructional message in Tabbers et al. (2004) was complex, and text-based learning material may be more appropriate for presenting procedural information (less complex) and may allow learners more time to reflect on the learning material. Tabbers et al. (2004) also suggested that the learners in their study used a self-paced format and in previous research conducted participants who used system-paced instructions performed better than those who used self-paced instructions (Mayer & Moreno, 1998; Moreno & Mayer, 1999). Similarly, in this dissertation research, the multimedia module presented learning material in three segments and students had the ability to control the pace of the module, that is self-pced. Also, in this dissertation research the learning material presented worked examples of the step-by-step explanation on how to solve medication administration calculations and perhaps the mathematical computations were too complex. Therefore, a self-pacing module and complex learning material could explain why the modality effect was not supported in this dissertation research.

For the research question two, pound-to-kilogram conversion calculations, the majority of the students in both groups were able to answer this type of question correctly all of the time. This type of calculation was not difficult to perform because throughout the nursing program students are taught medication administration content for the adult population. There are a few types of calculations that are used in the adult population that also are used in the pediatric population. Some of these calculations are intravenous flow-rates and pound-to-kilogram conversions. Because students in the research study have had a consistent exposure to these two type calculations (they have prior knowledge), it can be assumed that the students were not novice learners with regard to these types of calculation.

It is asserted that high-prior knowledge learners require less detail in learning content, and if learning content has too much detail, it can interfere with learning. When knowledgeable learners are required to use and retrieve schemas from long-term memory as well as construct schemas that they already have acquired, undue overload is placed on the working memory capacity and can interfere with learning (Mayer, 2005); which is known as the expertise reversal effect. The expertise reversal effect could explain why both groups in the dissertation research study had low pass rates.

Darabi and Nelson (2004) examined the effects of conventional problem-solving and different worked-examples: product and process oriented. The researchers asserted that process-oriented worked examples would render improved problem-solving performance for far transfer. Process-oriented worked-examples provide an explanation on how to solve a problem including the rational. Product-oriented worked examples describe the procedures for solving the problem. The results for Darabi and Nelson (2004) revealed there were no statistically significant differences between the treatment groups: process-oriented worked-examples (M=14), product-oriented-worked examples (M=15.9), and conventional problem-solving (M=17.5) on far transfer performance. As to why process-oriented worked-examples were not more effective than product-oriented and problem solving on far transfer performance, Darabi and Nelson (2004) suggested that the participants of their study had pre-existing schemata on the learning domain and they did not need an explanation on how to solve the problem as well as the rationale. Even though the dissertation research used product-oriented worked examples, there may have been too much detail in the solutions for the kilograms-to-pound conversions and intravenous flow-rates. The students in the dissertation research had prior knowledge on how to convert pounds to kilograms and intravenous flow-rates and may have experienced the expertise-reversal effect.

Calculation errors have been identified as one of the top 10 causes of pediatric errors (Cowley et al., 2001). Because medication administration in the pediatric population is critical to patient safety, it is imperative that students have a strong foundation with regard to medication calculation competency. With regard to research question three, safe-dose calculations, overall, both groups were similar in their ability to calculate safe dosages, and there was no statistically significant difference between the two groups. This result suggests that the multimedia and the text-based modules were not as effective for teaching safe-dose calculations, as one would expect.

Nurse educators are in a position to use pedagogies that are effective for teaching pediatric medication calculation. Worked examples are design techniques that have been shown to be effective for teaching mathematics (Darabi & Nelson, 2004; van Gog, Paas, & van Merrienboer, 2004). Because the working memory has a limited capacity as to the amount of information it can hold at a time and process (Baddeley, 1992), it is essential that the design techniques consider the limitations of the working memory. Worked examples consider the limitations of the working memory because they facilitate schema construction of problem-type schemas as opposed to solving problems by a means-end analysis, thereby reducing extraneous load (Sweller, van Merrienboer, & Paas, 1998). When novice learners are presented with new mathematical problems to solve they typically use a means-ends analysis to solve the problem (randomly search for solutions), this method for solving problems is very demanding on cognitive processes, and there are no reserves left for processes relevant to schema construction (Van Gog et al., 2004).

In the Wittwer and Renkl's (2010) meta-analysis, one study found beneficial effects when instructional explanations were used in conjunction with worked-examples for teaching conceptual knowledge. In this dissertation research, the multimedia medication module included worked examples (without an instructional explanation) that illustrated the steps on how to solve common pediatric medication calculations. Worked examples typically are comprised of a problem statement and the solution to the problem and serve as an expert model for solving a particular problem (Atkinson, Derry, Renkl, & Wortham, 2000; Atkinson & Renkl, 2007). Because worked examples reduce extraneous load, learners are able to use all available working memory capacity to study the worked example solution steps as well as construct schema for solving similar problems in long-term memory (Sweller & Chandler, 1991).

In a meta-analysis conducted by Wittwer and Renkl (2010), the average effect size for studies where mathematics was taught was .22, which is small. Even though the effect size was small, the worked example effect was present. Studying mathematics requires students to use conceptual knowledge and is defined as when “participants are required to present their declarative knowledge about the principles and concepts that were learned” (p. 401)**.** In the dissertation research, there were two clinical-related word problems where students were provided with a clinical situation and the relevant patient information. The clinical-related word problem was a culmination of all of the medication calculations that were included in the medication module. The students were required to interpret the information and then use the information to perform the required mathematical calculations. Wright (2005) defined conceptual knowledge as interpreting information in order to work-out a mathematical problem. The study conducted by Wright (2005) found that students had difficulty interpreting and using the information (M=2.14) they were presented with in order to calculate the correct dosage (using the correct formula). With fluid-maintenance calculations students are presented with information that is necessary to calculate the 24hours and 8 hours fluid-maintenance requirements. Calculation of fluid maintenance requires the student to conceptualize (interpret the information and use it correctly). For the fluid-maintenance calculations, a similar number of students were able to answer all of the fluid-maintenance questions correctly between the two groups. Seventy-percent of the text-based group and 64.7% of the multimedia group were able to answer this type of question correctly. There were no statistically significant differences between the two groups in their knowledge acquisition. Similar to the dissertation results, Wright (2005) found that student nurses had difficulty with conceptual knowledge**.**

As for the intravenous-flow-rate calculations, the means for the groups on this type of calculation were the same. The independent-samples *t* test was conducted, and there was no statistically significant difference for the intravenous-flow-rate calculations between the two groups, which is not surprising. Because intravenous-flow-rate calculations are taught at the start of the nursing program and throughout the program and is a commonly used calculation, they had pre-existing knowledge on this type of medication calculation and may have experienced the expertise reversal effect. This may explain why product-oriented worked examples were not as effective for presenting learning material to students with pre-existing knowledge.

Darabi, Nelson, and Panki (2007) examined the effects of problem-solving and different types of worked examples: process-oriented and product-oriented. The problem-solving group practiced problem-solving in an interactive computer simulation format, and the worked-examples, product-oriented and process-oriented, used a computer to study them. When novice learners are presented with new mathematical problems to solve, they typically use a means-ends analysis to solve the problem (randomly search for solutions), this method for solving problems is very demanding on cognitive processes, and as a result, there are no reserves left for processes relevant to schema construction (Van Gog et al., 2004). Darabi et al. study (2007) revealed, there were significant differences between the worked examples and the conventional problem-solving. The participants who used the interactive simulation significantly outperformed the worked-example groups; they also scored lower on the mental effort scores during the transfer task. After accounting for domain knowledge differences, there were no significant differences between the experienced participants in the three groups. In contrast, for the less experienced participants who studied using the interactive simulation problem-solving outperformed the worked-example groups and their mental effort scores while performing the transfer tasks were statistically significantly lower than all participants. As with the Darabi et al. (2007), the dissertation results did not support the use of worked examples for teaching mathematics (conceptual knowledge) particularly for novice learners. In contrast, Wittwer and Renkl's (2010) study results supported the use instructional explanations in conjunction with worked examples for teaching mathematics (conceptual knowledge).

With regard to the types of errors made, the majority of errors made by both groups were similar. The multimedia group made more errors with setting up the problem and the majority of the questions that were answered incorrectly were related to mathematical functions. The text-based group made more errors related to the mathematical function, for example, division, addition, and multiplication errors were most often made compared with the multimedia group. As for calculation errors, the text-based group made more of these types of errors compared with the multimedia group. These results are consistent with the results found in a study conducted by Wright (2005). Wright's study results revealed that students had difficulty with multiplying fractions, ratios, and conceptualization of knowledge. All of the other types of errors that were made between the two groups were similar. With regard to the types of medication errors that were made, the differences between the groups were small. If there are were no time constraints to study the module, the benefits of studying from multimedia that uses the modality principle should be beneficial for all students and, possibly, more for students who require special testing services.

In summary, the results indicate that the text-based module and the multimedia module were not as effective as one would expect. The multimedia module and the text-based module did not yield high pass rates. With a 53% pass rate for the comparison group and 41% pass rate for the multimedia group. In addition, there were no statistically significant differences between the groups on the four subtest items: pound-to-kilogram conversions, weight-based safe dose calculations, intravenous flow rate, and fluid maintenance calculations. The results also suggest that for several students there was insufficient time to study the module and to complete the test. Perhaps one hour and 15 minutes was not sufficient time to study the module and 30 minutes also was insufficient time to take the test. Perhaps the low pass rates may be attributed to insufficient time to study the module and to take the test and not related to the teaching method used.

Even though the modality effect has been supported by numerous research studies (Ginns, 2005; Moreno, 2006), some studies have not supported the modality effect (Dunsworth & Atkinson, 2007; Tabbers et al., 2004). Although there have been numerous studies that have supported the use of worked examples: product-oriented and process-oriented (Wittwer and Renkl , 2010) for novice learner, the results of the dissertation research did not support the use of product-oriented worked examples for presenting pediatric medication administration calculations. Some of the worked-example research conducted has not supported the use of worked examples (Darabi & Nelson, 2004; Darabi et al., 2007). Even though the dissertation research results did not support the modality effect or the use of product-oriented worked examples, this should not deter the use of instructional design techniques that have been shown to be an effective strategy for teaching complex learning material to novice learners. To support this assertion, there are more studies that support the beneficial effects of using the instructional design techniques worked examples and the modality principle to teach mathematical content novice learners.

Recommendations for Practice

In pediatrics, one of the most commonly reported medication error includes calculation of medication dosages (American Academy of Pediatrics, 2003; Hughs & Edgerton, 2005). Because medication administration in the pediatric population is critical to patient safety, it is imperative that students are able to administer medication with 100% accuracy. Many educators are using multimedia to present learning material; however, the design of the multimedia presentation often does not consider the limitations of the cognitive structures and processes. In a meta-analysis conducted by Ginns (2005), 43 studies were examined. Across the studies, the results indicated the average effect size for the modality effect was .72, which is close to large. Multimedia that presents learning material in two modes, visual and auditory, considers the limitations of the cognitive processes and how the mind processes information (Mayer, 2009) and, consequently, maximizes cognitive processes and promotes learning. Because medication calculations are an essential skill for nurses, it is imperative that they are able to perform calculations with 100% accuracy. Educators are in a position to use pedagogies that are effective for teaching medication calculations (Wright, 2004);

therefore, it is recommended that educators design and develop multimedia that has been supported by research as being effective for teaching pediatric-medication calculations skills.

Multimedia instructional messages that use design techniques that maximize cognitive processes may be beneficial for students who require special testing services as well as for presenting the mathematical problems. According to Mayer (2009), words and pictures are qualitatively different and complement one another and understanding occurs when leaners are able to mentally integrate the image and verbal representations. Consequently, understanding occurs when learners are able to build the meaningful connections between the image and verbal representations (Mayer, 2009).The majority of mathematical errors that were missed by both groups were mathematical functions, setting up the problem, and calculation errors. Because the modality principle and worked examples have been supported by research (Darabi et al., 2007; Ginns, 2005; Mayer, 2009), particularly for novice learners with low-domain- specific knowledge, perhaps students who require special testing services may benefit from using multimedia that present learning material in two modes: visual and auditory.

The results of this study can be used to inform nurse educators on effective pedagogies that consider the cognitive structures and processes. The results also can serve as a motivation for educators to evaluate how they teach pediatric medication content and to consider developing instructional messages that support how the mind processes information. In addition to using design techniques that support cognitive process, educators need to consider new pedagogies that are effective. Based on the results of the study, it is highly recommended that other pedagogies are used to in conjunction with the theoretical knowledge. For example pedagogies that encourage students to perform mathematical functions related to medication administration should be taught in skills laboratory, in the clinical setting, and in simulation.

Teaching medication calculations have traditionally focused on the theoretical knowledge and test taking. A logical next step for teaching medication administration calculations is to use simulation in conjunction with the medication administration theoretical knowledge. Simulation is an effective strategy that can assist students in applying the theoretical mathematical calculations in a simulated situation (nonthreatening environment). Simulation allows students to master the cognitive and psychomotor skills of preparing a medication in a non-threatening environment. Simulation also allows students to have a better to understanding of mathematical concepts because they are able to apply the concepts as they would in a real clinical situation.

Consistent utilization of teaching methods that have been supported by research as well as integration of a variety of pedagogies that support a strong pediatric medication calculation foundation should be used throughout the nursing program. In particular, strategies that assist students in apply the theoretical knowledge is paramount. Based on the results, student nurses need to be exposed to medication administration content on an ongoing basis and not sporadically. Whenever students are in a clinical setting they should be required to take a mathematical examination and have the opportunity to apply the mathematical knowledge in a simulation environment.

Recommendations for Future Research

In nursing programs, a wide variety of instructional methods have been used to teach nursing students mathematical skills. Some of the common medication calculation teaching methods that have are used range from self-paced CD ROMs, text-based study guides with practice problems, and independent self-paced online programs (Jeffries, 2001; Sung, Kwon, & Eunjung, 2008; Wright, 2005, 2008). Similarly, other commonly used methods to teach medication administration include lecture format, one-to-one tutoring, virtual learning environments, simulation, and skills laboratory (Sung et al., 2008; Wright, 2004, 2005). The problem with these types of learning materials is that they are text based with images or pictures and text instructions. The learning material is presented in one mode through the visual mode. With the exception of simulation, virtual learning, and skills laboratory, these methods do not consider the limitations of the cognitive structures or maximize cognitive processing (Mayer, 2009). It is recommended that more research that examines the effectiveness of using spoken words concurrently with images of worked examples with the step-by-step instructions on how to solve common pediatric medication calculations for novice nursing students is conducted.

Pediatric patients are at higher risk for being harmed as a result of a medication error than adults, because of their wide-range body mass, differences in weight, metabolism, and excretion of the drug (Taketomo, Hodding, & Kraus, 2007-2008). Because all medication doses must be calculated, this increases the risk of harmful and devastating errors. Incorrect calculation of medication dosages, account for the majority of pediatric medication errors (Hughs & Edgerton, 2005).

Throughout the nursing program, students are taught medication administration content for the adult population. There are a few types of calculations that are used in the adult population that also are used in the pediatric population. Some of these calculations are intravenous flow-rates and pound-to-kilogram conversions. Because students have had a consistent exposure to these two type calculations, they have prior knowledge (schema). The expertise reversal effect (students with prior knowledge require less detailed instruction) could explain why both groups in the research study had low pass rates. Darabi and Nelson (2004) examined the effectiveness of conventional problem solving with two types of worked examples: product (description of procedures for solving a problem) oriented and process (explanation how to solve the problem with a rationale) oriented. The Darabi and Nelson (2004) study did not find statistically significant differences between the work-examples: process and product-oriented approach and the problem-solving approach. Because the students in the dissertation research had some prior knowledge on intravenous-flow-rates and pound-to-kilogram conversions, the problem-solving approach may be more effective for students with high prior knowledge. It is recommended that there should be more research conducted on the expertise reversal effect, modality principle, and worked examples for teaching pediatric-medication-administration calculations.

When there are no time constraints to study the medication module, the benefits of studying from multimedia that uses the modality principle and worked examples should be beneficial for all students, particularly for students who require special testing services. Therefore, other recommendations for future research would be increased time to study the module and to take the examination. Students would be allowed to study the module on their own time over a 2-day time period and then take the mediation examination on the third day and take the examination over 45 minutes. In addition, if there are students who require special testing, they would have the same 2-day period to study; however, they would have extra time to take the mathematical test in special testing services. Other recommendations for futures research would be would to assess cognitive gains, monitor study time, assess students' satisfaction with the module, and ascertain student preference for studying the medication module, as well as the examination of the types of errors made.

Conclusions

When a medication error occurs, pediatric patients have a much higher risk of death than do adult patients (Hughs & Edgerton, 2005). Therefore, patient safety is dependent on 100% accuracy when it involves medication administration, particularly in the pediatric patient population. Because, there is no standardized dose for pediatric medication, weight-based calculations are required, and this increases the risk of a miscalculation (Hughs & Edgerton, 2012). Because medication administration is critical to patient safety, it is imperative that student nurses have a solid medication administration foundation.

Medication administration content often is taught without regard to cognitive structures and how the mind processes information. Nurse educators are in a position to design, develop, and use pedagogies that support cognitive structures and processes. The modality principle and worked examples are instructional design techniques that have been shown to be effective for teaching domain specific mathematical content to novice learners (Atkinson & Renkl, 2007; Ginns, 2005).

The purpose of the research study was to compare two teaching methods, text-based module and multimedia module, to teach pediatric medication calculations. This study examined the effectiveness of using the modality principle and worked examples to teach pediatric medication calculations to novice student nurses. The results have indicated that text-based and multimedia instructional methods for teaching pediatric medication administration content were adequate. Considering the high-stakes nature of medication administration, the learning outcomes for the majority of the students were inadequate. Two factors that most likely contributed to the less than ideal learning outcomes were limited time to study the module and limited to time to test. Even though the research study did not find multimedia that used worked examples to be more effective than text-based multimedia to present pediatric medication calculation content, the value of using audio-visual modes to present learning material cannot be underscored, especially because there is ample literature that supports multimedia and worked examples as effective instructional design techniques to teach students with low domain specific mathematical content. The results highlight the need to continue to examine the use of pedagogies that considers the limitations of the cognitive processes and how the mind processes information (Mayer, 2009) and, consequently, maximizes cognitive processes. Similarly, more research needs to be conducted on the modality effect, expertise reversal effect and worked example effect for presenting pediatric medication calculation content to student nurses.

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Appendixes

Appendix A

Informed Consent to Participate in Research Study

STUDENT CONSENT FOR RESEARCH PARTICIPATION

Purpose and Background

Educators who teach pediatrics are challenged to teach students the necessary mathematical concepts and skills that are critical for safe medication administration. They are in a position to develop effective pedagogies to teach medication administration content. This study is designed to investigate methods to each pediatric medication computation.

The researcher, Renee Granados, is a doctoral student at University of San Francisco. She is conducting a research study for her dissertation.

You are being asked to participate in this study because you are a nursing student who is currently enrolled in the Baccalaureate nursing program and you are taking the pediatric theory course. You will be asked to complete a pediatric medication administration module and a pediatric medication test. You will be given one hour to study the medication module, afterward you will be given 30 minutes to complete the test.

Procedures

- If you agree to participate in this research study, the following will occur:
- the purpose of the study will be explained
- written consent will be obtained
- you will review the medication administration module
- you will take the pediatric medication test
- total time commitment will be 2 hours
- the study will take place at the Oakland Professional Center in Oakland in room 6
- the study will be on the first day of class

Risks and/or Discomforts

There are no foreseeable psychological risks for the participants as they are familiar with taking criterion-referenced test and computing medications for adult patients.

Benefits

The benefit to the participant is an exposure to pediatric medication calculations and medication administration content prior to the regularly scheduled time to study the medication module and test. As a result, the medication content will prepare the participant to administer medications in the pediatric setting. If you pass the test, then you will not have to take the regularly scheduled test.

Costs

There are no costs to you.

Payment/Reimbursement

There will be no compensation for participating in this research.

Confidentiality

Participation in this research will not result in a loss of confidentiality as no names will be gathered and your individual responses will be kept confidential. There is a numerical code on the criterion-referenced test that corresponds with the envelope and sign-in sheet. The RA will keep the list of names and codes. After the tests have been scored and those passing identified, the list will be destroyed by the RA. No one will have access to or see your test or your scores except for the researcher. Original copies of all written data will be kept anonymous, and the participants' names will not be used in any publication resulting from the study. Copies of the data will be kept locked at the researchers' home. Only the researcher will have access.

Questions

If you have any further questions about the study, you may contact the researcher by email or phone. If for some reason you do not wish to do this, you may reach the IRBPHS office by calling (415) 422-6091 or by writing to the IRBPHS, School of Education Building, University of San Francisco, 2130 Fulton Street, San Francisco, CA 94117-1080.

Consent

You have been given a copy of this consent form to keep.

PARTICIPATION IN THIS RESEARCH IS VOLUNTARY. You are free to decline to participate in this research study, or to withdraw your participation at any point, without penalty. Your decision whether or not to participate in this research study will have no influence on your present or future status.

Signature ______________________________ Date: _________
Research Participant

Signature ______________________________ Date: _________
Researcher

Thank you,
Renee Granados, RN
Doctoral Student, University of San Francisco

STUDIENT CONSENT FOR RESEARCH PARTICIPATION
CONSENT FORM

_________ I agree to participate in this study.
_________ I do not agree to participate in this study

Appendix B

Form for Validity Evidence for Pediatric Criterion Referenced Test

Criterion-referenced Test Content Validity

The purpose of the Content Validity form is to assist the researcher in ascertaining whether the test accurately and authentically measures the pediatric intravenous medication administration content that is essential in order to administer intravenous medication in the pediatric clinical setting.

Below are the test objectives:

1. The student will demonstrate safe dosage/s calculations for mg/kg/24 hours in equally divided doses for medications in the pediatric population.
2. The student will be able to demonstrate safe dosage/s calculations for mg/kg/dose.
3. The student will be able to calculate parental (intravenous) flow rates for primary and secondary (piggyback) medication administration.
4. The student will be able to demonstrate conversion of pounds to kilograms.
5. The student will be able to demonstrate fluid maintenance calculations for 24 hours and 8 hours.

In the right hand column, assign the number of the objective or objectives next to each test item of the question. After you do this, rate the level of difficulty of each test item. For example, rate test items A to H. A rating of 2= least difficult, 4= moderately difficult, and 8=most difficult.

Appendix C

Form for Validity Evidence for Pediatric Medication Module

Medication Module Content Validity

The purpose of the Content Validity form is to assist the researcher in ascertaining whether the Medication Module accurately and authentically measures the pediatric medication administration content that is essential in order to administer intravenous medications in the pediatric clinical setting.

Below are the test objectives:

1. The student will demonstrate safe dosage/s calculations for mg/kg/24 hours in equally divided doses for medications in the pediatric population.
2. The student will be able to demonstrate safe dosage/s calculations for mg/kg/dose.
3. The student will be able to calculate parental (intravenous) flow rates for primary and secondary (piggyback) medication administration.
4. The student will be able to demonstrate conversion of pounds to kilograms.
5. The student will be able to demonstrate fluid maintenance calculations for 24 hours and 8 hours.

Circle the objective that the test question meets, for example, in the column to the right, Circle 1, 2, 3, 4, or 5 to indicate the specific objective. You can provide comments on the last page.

Appendix D

Text-Based Medication Module

PEDIATRIC MULTIMEDIA MEDICATION MODULE

The purpose of this module is to prepare the student to:

1. Demonstrate safe dose range/s calculations for mg/kg/24 hours in equally divided doses for medications in the pediatric population.
2. Demonstrate safe dose range/s calculations for mg/kg/**dose** for medications in the pediatric population.
3. Calculate parenteral (intravenous, IV) flow rates for primary and secondary (piggyback) medication administration.
4. Demonstrate conversion of pounds to kilograms.
5. Describe the primary and secondary (piggy-back) parenteral medication administration procedure.

Pediatric Dosages

For pediatric dosages, it is not enough to use an adult dose to calculate a pediatric safe dose because of differences in weight, metabolism and excretion of various drugs (Taketomo, Hodding, & Kraus, 2007-2008). It is essential to use a pediatric drug reference book because pediatric recommended dosages are listed by giving a certain number of milligrams (mg) of drug per kilogram (kg) of body weight. Weight is almost always measured in kilograms. If weight is in pounds (lb), it needs to be converted to kilograms (kg) in order for safe dose range calculations to be computed.

Note: When you compute calculations, you need to compute your calculations to the hundredth place and round off to the tenth place. If hundredth place computation is 0.05 or greater, you need to round up; if the computation is less than 0.05, you need to round down.

The first step you want to do is to convert your pounds (lb) to kilograms (kg) using the conversion factor of 1 kg = 2.2 lb. You have a child who weighs 9lb. How many Kg do they weigh?

$$\frac{1\text{kg}}{2.2\text{lb}} = \frac{X}{9\text{lb}} \qquad 1\text{Kg} \times 9\text{lb} = 9 \div 2.2\text{lb} = 4.09$$

Remember your computing to the hundredth place. When you compute to the hundredth place and if, the hundredth place computation is 0.05 or greater, you need to round up to the tenth place. The hundredth place is greater than .05, then, you round up to the tenth place. The weight in kg will be 4.1 Kg.

X = 4.1 Kg

Step 2. Now that you know the weight in Kg, the next step is to look up the recommended safe dose range in a pediatric drug reference.

Step 3. Once you do that, you are going to calculate the safe dose based on the child's weight in Kg. For example, you are going to multiply the recommended safe dose x weight in kg ÷ how many times the medication will be given in 24 hr = Single dose

Next are to **practice examples**: What is a safe dose for oral codeine for a 35 kg child? **The physician orders 20mg of oral Codeine:** The first thing that you want to do is look up in the pediatric drug reference book the recommended safe low and high dose ranges for orap codeine.

The pediatric drug reference book recommends a safe low dose range of 0.5mg and a high safe dose of 1 mg/ kg / **DOSE** Q 4-6 hr. Whenever you look up a safe dose range in a pediatric drug reference book and you see **Kg/dose,** you will multiply the recommended low safe and high dose ranges by the weight in Kg and this will give you the single dose.

Next, you multiply the recommended safe low and high dose ranges for codeine. The child weighs 35 Kg.

Recommended safe low dose:

0.5mg x 35 Kg = 17.5 mg **per dose**
This is the recommended safe low dose based on the child's weight

Recommended safe high dose:

1mg x 35 Kg = 35 mg **per dose**
This is the recommended safe high dose based on the child's weight

The calculated recommended low and high safe dose ranges are 17.5 mg/dose to 35mg/dose

The physician ordered oral codeine 20mg. Next, you want to **compare the ordered dose** with the calculated low and high safe dose ranges. It was calculated that 17.5 mg-35 mg are the safe low and high dose ranges and the **order was for 20 mg** of oral codeine. Codeine 20 mg is within the calculated low and high safe ranges, the dose is safe. You can safely give the child this medication.

Example 2: The physician orders Pen G IV 250,000 units and the child weighs10kg. Next, you need to look up in the pediatric drug reference book the recommended safe dose ranges. The pediatric drug reference book recommends Penicillin G IV: 25,000 to 100, 000 U/ kg /day in equally divided doses q 4 hrs. Whenever the drug reference book recommends **kg/24hrs,** there is an extra step that needs to be done in the calculation. The extra step is that you need to divide by how often the medication is to be given in a 24hr period. The physician orders the medication to be given every 4 hrs and the medication will be given 6 times in a 24 hr period. The last step of the calculation you will divide by 6. You will see this when the calculation of done.

The recommended safe dose ranges:

Calculate recommended safe low dose:

25,000 x 10Kg ÷ 6**= 41,666.6 u/dose**

Next, calculate the recommended safe high dose:

100,000 x 10Kg ÷ 6 **= 166,666.6 u/dose**

The recommended calculated safe low and high dose ranges are:

41,666.6 u to 166,666.6 u

Next you need to compare the ordered dose to the calculated safe low and high dose ranges. The physician ordered 250,000 Units IV Q4 hours. **250,000 units** is greater than the 166,666.6 u. This is **NOT A SAFE DOSE.**

When the dose is not safe what should the nurse do?

Double check your calculations and review the pediatric drug reference. The next area to think about is the reason the patient is receiving this drug. Does the patient have a severe infection such as meningitis which requires a very high dose of antibiotic? Has the child been receiving this drug for a period of time with no therapeutic effect? Some children require a higher dose of medicine to maintain a therapeutic level. Is there a recent blood level and what is the level?

If the dose is not safe, validate this information with your instructor, the child's primary nurse, the pharmacist or the physician who wrote the order.

Intravenous (IV)Piggyback Medications Administration

Segment 2: Most parenteral antibiotics or IV antibiotics are premixed by the pharmacy. For example, depending on the recommended dilution of a particular parenteral antibiotic, it can be dispensed in a 25ml, 50ml, or 100 ml minibag. Sometimes, the pharmacist will add the medication additive (fractional dose the minibag). The volume of the medication additive (fractional dose) can be found in the upper right hand corner of the minibag.

Definition of Terms

When administering IV antibiotics there are some definition of terms you need to familiar with. The first term is the:

- **Minibag volume:** Volume in minibag + medication additive (if any has been added).
- **Total volume (TV) to be infused:** This includes the minibag volume (including medication additive) + flush.
- **Flush (20mls):** The flush is always 20ml. This is an additional volume required to completely infuse medication from IV tubing.
- **Intermittent infusion time**: This is the recommended time to administer the medication, for example, the pediatric drug reference book may recommend a medication to be administered over 10-60 minutes.
- **Intravenous flow rate** = The IV flow rate is what you will set you're the IV rate at in ml/hour to deliver IV medication in the specified amount of time.
- **Fractional dose =** how many milliliters of drug to be given.

Step 5. When administering IV medications, the first thing you need to do is to look up the recommended infusion time for the medication: The pediatric drug reference book recommends medication administration by IV intermittent infusion for a specific medication, for example, a medication <u>may</u> be recommended to be infused at least over 10-60 minutes. This means you can safely administer the medication over 10 minutes, 30 minutes, 40 minutes or 60 minutes, as long as it is within 10-60minutes, unless the drug reference book recommends longer administration times.

Step 6. Now that you know recommended intermittent infusion time, next you need to calculate the parental (IV) flow rate (ml/hr). The IV flow rate (ml/hr) is determined on an hourly basis and is always based on the minibag volume. For example, the pharmacist **adds 1.33mls** of the **medication additive** (fractional dose) to a 25 ml 0.9% minibag. **The minibag volume is 1.33ml of medication additive plus 25ml minibag of 0.9%= 26.33mls.**

Now that you know the minibag volume is **26.33** ml you will need to calculate the IV flow rate. The drug reference book recommends that the medication can be administered over 30-60 minutes. As the nurse, you decide to administer the medication over 30 minutes.

To calculate the IV flow rate:

$$\frac{26.33 \text{ ml minibag}}{30 \text{ min}} \quad \frac{X}{60 \text{ min}} = X = 52.67 \text{ml/hr}$$

OR 26.33ml x 60min ÷ 30 min = X = IV flow rate 52.67 ml/hr

Remember, you calculate to the 100^{th} place and, if it is greater than .05, you round up to the tenth place.

You will set your IV flow rate at 52.7 ml/hr. This will to deliver the medication over 30 min.

Step 7. Next, you need to know the **total volume (TV) to be infused**. The average amount of fluid required to flush the intravenous primary tubing is approximately 20 ml depending on where the medication is placed on the line. The purpose of the 20ml flush is to clear the primary tubing of the medication.

The **total volume to be infused (TV)** will always include the 20 ml **flush + minibag volume** (including medication additive). Remember the flush is always 20ml.

The total volume (TV) to be infused **=** 26.33ml minibag + 20ml flush = The TV to be infused is = 46.33 ml. This is what you are going to program into the IV pump as the TV to be infused.

In Review

Next is an example 1:

A child weights: **22lbs**
Physician **orders:** Cefazoline **300mg** IV q 8hrs
The **minibag volume**= 25ml of 0.9% + 3ml medication additive = **28 ml is the minibag** volume.

Step 1: The first thing to do is to convert lb to Kg

22lbs = kg?

$$\frac{1\text{ kg}}{2.2\text{ lbs}} = \frac{X}{22\text{ lbs}}$$

1 x 22lb= 22lb ÷ 2.2lb= 10 Kg

22lb child = 10Kg

Step 2. Now that you know the weight in Kg, the next step is to look up the recommended safe dose range in drug reference book.

The pediatric drug reference book recommends a safe low and high dose range of 50mg - 100mg/ kg / day q 8 hrs.
Remember, whenever the recommended safe dose range is **<u>Kg/day,</u>** you need to do an extra step by dividing how often the medication will be given in a 24hr period. In this

case the MD orders the medication to be given every 8 hrs. This medication will be given 3 times in a 24hr period.

Step 3. Next, you want to do the safe dose calculations

Calculate the recommended safe low dose**:** 50mg x 10Kg ÷ 3 = 166.7mg/dose

This is the calculated safe low dose based on the child's weight.

Next, Calculate the recommended safe high dose : 100mg x 10Kg ÷ 3 = 333.3 mg/dose

This is the calculated safe high dose based on the child's weight

The recommended safe low and high dose ranges based on the child's weight is 166.7mg to 333.2mg.

Step 4. Next you need to compare the ordered dose to the calculated safe low and high dose ranges. Is the 300mg within the calculated low and high safe dose range? Cefazoline 300mg is a safe dose.

Step 5. Next, how much is the minibag volume?

Cefazoline was dispensed in a 25ml of 0.09% **+** 3ml of medication additive= **28 ml minibag volume**

Step 6. The next step is to look at the pediatric drug reference book to see what is the recommended intermittent infusion time?
Drug reference book recommends the medication can be safely administered over 30-60 minutes.
The recommended intermittent infusion time is 30-60 minutes. This gives you a lot of leeway, especially if you have two medications due at the same time. You can safely administer the medication over 30 minutes.

Step 7: Once you know the recommended intermittent infusion time, **the next step** is to calculate the IV (intravenous) flow rate (mls/hr). To calculate the IV flow rate (mls/hr), it is always going to be based on what the minibag volume is.

25ml of 0.09% + 3mls of medication additive (fractional dose) = **28ml minibag volume.**
You can safely administer the medication over 30 minutes (this is within the recommended time range).

$$\frac{28\text{ml}}{30\text{ minutes}} \quad \frac{X}{60\text{ minutes}} \quad = \quad 56\text{ ml/hr}$$

OR 28ml x 60min ÷ 30min= IV flow rate= 56ml/hr

You are going to set your IV flow rate at 56mls/hr to administer the medication over 30 minutes.

Step 8: Next, you need to know what the total volume (TV) to be infused is:

Minibag + medication additive (if any) + flush (is required to flush the IV tubing). The flush is always 20ml.

Total volume (TV) to be infused = 28mls minibag + 20ml flush= **48ml**

Practice Problems

Next is a practice problem. I will give you all of the information you will need to do the calculations. Write on your scratch paper, the relevant information and the questions to be answered.

1. **The physcician orders:** Clindamycin **300 mg** IV q 8hrs

The child weight: 60 lbs.
Minibag volume = 25mls 0.9 % minibag + 5 ml of medication additive (fractional dose) = **minibag volume is 30 ml**
Recommended safe dose ranges are: 25mg-40 mg / kg / day q 8 hr.
Recommended intermittent infusion time: 30-60 minutes.

1. What is the weight in Kg?
2. Calculate the low and high safe dose ranges based on the weight
3. Is this a safe order?
4. What is the recommended intermittent infusion time? The nurse decides to infuse the medication over 30 minutes.
5. What is the minibag volume?
6. Calculate your IV flow rate to administer the medication.
7. What is your total volume to be infused?
8. How much flush is required?

In review

1) What is weight in Kg? You have a 60lb child.

60 lb = Kg?

$$\frac{1k}{2.2\ lb} = \frac{X}{60}$$

1Kg x 60min = 60min ÷2.2 lb = 27.27 kg 60lb =27.27 Kg

Remember in Segment 1, you calculate to the hundredth place and when it is greater than 0.05, you round up to the tenth place. This is greater than 0.05, you round up to the tenth place. The **weight in Kg is 27.3 Kg.**

2) Next, you want to **calculate recommended the safe low and high dose ranges?**

The drug reference book recommends the low safe dose

25mg x 27. 3Kg ÷ 3= 227.5 mg /dose
Based on the child's weight, the calculated safe low dose is 227.5mg/dose

Next, you are going to calculate the recommended high safe dose

40mg x 27. 3 ÷ 3 = 364 mg per dose

Based on the child's weight, the calculated low and high safe dose ranges are:
227.5mg to 364mg. The ordered dose is 300 mg.

3) **Is the dose safe?** You need to compare the ordered dose of 300mg with the calculated low and high safe dose range? 300mg is within the calculated safe dose ranges.
   The dose is safe. Now you can administer the medication.

4) Next, **what is the recommended intermittent infusion time to administer Clindamycin?** Look in the drug reference book the recommended intermittent infusion time. The recommended intermittent infusion time is 30-60 minutes

As the nurse**,** you decide to administer the medication over 30 minutes

5) What is the minibag volume? 25ml 0.9% + 5ml medication additive

The minibag volume is 30ml

6) **What is the IV flow rate (mls/hr)?** The IV flow rate is based on the minibag volume.

$$\frac{30\text{ml}}{30\text{ min}} \quad \frac{X}{60\text{ min}} \quad = \mathbf{60mls/hr}$$

OR 30ml x 60 minutes ÷ 30 minutes = 60 ml/hr. This will deliver the medication over 30 min.

7) How much flush is required? 20ml

The flush will always be 20ml

8) **What is your total volume to be infused?** 30ml minibag+20ml = Total volume to be infused **50mls**

CALCULATION OF FLUID MAINTENANCE
(Minimum 24 hr fluid requirements)

Segment 3: Infants and ill children are not able to tolerate too much fluid and are susceptible to dehydration and fluid overload. As the nurse, you need to closely monitor the amount of fluid the child receives. The fluid a child receives over a 24-hr period is referred as fluid maintenance needs (Giangrasso & Sprimpton, 2010). The amount of fluid maintenance required will depend on the child's weight. When calculating maintenance fluid for 24hrs and 8 hrs, you will need to use this formula. You multiply the **first 10Kg by 100mls**, **then multiply second 10Kg by 50mls** and, **anything above 20Kg you multiply by 20 mls**.

Weight	**ml fluid / 24 hours**
1st 10 kgs	100 ml/kg
2^{nd} 10 kgs	+50 ml/kg
Above 20 kgs	+20 ml/ kg

Examples

Let's start with an example:

If you have a child that weighs 10 kg or less, you multiply the weight in Kg by 100ml. For example, you have a child that **weighs 8 kg**

Step 1. 8 kg x 100 ml/kg/24 hrs. = 800 ml is the calculated 24 hr fluid maintenance

As the nurse, you may be working an 8 hr shift. In that case, you want to calculate the 8 hr fluid maintenance. In order to do that, you would have to calculate the 24hr fluid maintenance first, then you would **divide by 3,** because there are three 8 hr shift in a 24hr period.

Step 2. 800mls ÷ 3 (three 8 hr shifts in 24 hr) = 266.7 ml/8hr fluid maintenance

Let's do a second example: You have a child that **35 Kg.**

Step 1. 1^{st} 10 kg x100ml = **1000**ml/24 hr

Step 2. 2^{nd} 10 kg x 50ml = **500** ml/24 hr

Step 3. 3^{rd} 15 kg x 20ml= **300** ml/24 hr

1000ml + 500 ml + 300= **1800ml**/24 hr fluid maintenance for a child who weighs 35 Kg.

Next, calculate the 8hr fluid maintenance:

Step 4. 1800 ml ÷ 3 = **600 ml/8hr** fluid maintenance

Next is a Practice Word Problem: This is atypical Clinical Scenario you will encounter in the clinical setting. For this practice problem, you will need scratch paper so you can write down all of the relevant information and write down the questions that you need to answer. Show all of your work and circle the answer.

You are working the 1500- 2300 (8hr) shift. Maria weighs 55 lbs. At 1600 Maria's oral intake is 75ml and at 1700 she drinks an additional 150mls. At 1730, Maria receives one antibiotic that is dispensed in a minibag that contains 50ml of O.9 % + 3mls medication additive. The pediatric drug reference recommends an intermittent infusion time of 30 minutes. At 1800 the medication is finished. The student nurse remembers the total volume to be infused must include a 20ml flush so no medication is left in the tubing.

A. **What are Maria's fluid maintenance requirements for:**

24hrs? ______

8hrs? ______

B. **What was her PO intake before 1800?**

C . **What is the total volume to be infused for parenteral secondary (piggyback) medication administration?**

D**. What is the amount of flush required?**

E. **What is the minibag volume?**

F. **What will the student set the IV flow rate (mls/hr) to administer the medication over 30 minutes?**

G. **Once the antibiotic is finished, what will the student nurse set the IV flow rate to meet the 8hr fluid maintenance for the remainder of the shift?**

Answers

The first step is to convert the weight to Kg. You have a child that weighs 55 Lbs.

55lb =kg ?? **Convert weight to Kg.**

$\frac{1kg}{2.2lb}$ $\frac{X}{55\ lb}$

1 x 55 lb ÷ 2.2 lb = 25Kg 55lb= 25Kg

Next, what are Maria's fluid requirements for 24hr and 8hr?

24hr fluid maintenance:

1st 10kgx100mls= 1000 ml
2nd 10Kgx 50mls=500 ml
3rd 5Kg x 20mls = 100ml

1000 ml + 500 ml + 100 ml = **1600 ml/24hr fluid maintenance**

8hr fluid maintenance:

1600 ÷3 = **533ml/8hr fluid maintenance**

Next, what was her PO intake before 1800?

75ml+ 150ml = <u>225mls</u>

Next, what is the minibag volume? 50 mls+ 3mls medication additive **<u>53mls</u>**

Next, what is the amount of flush required? **<u>20mls</u>**

Next, what is the total volume to be infused (for piggyback medication administration)?

50ml medication + 3mls medication additive +**20ml (flush)<u>73 ml</u>**

Next, what will the student set the IV flow rate at to administer the medication over 30 minutes?

$\frac{53ml}{30\ minutes}$ $\frac{X}{60\ minutes}$ **= <u>106 mls/hr</u>**

OR

53ml minibag x 60 minutes ÷ 30 minutes = IV flow rate=106 ml/hr

The IV flow rate will be set at 106ml/hr to deliver the medication over 30 min.

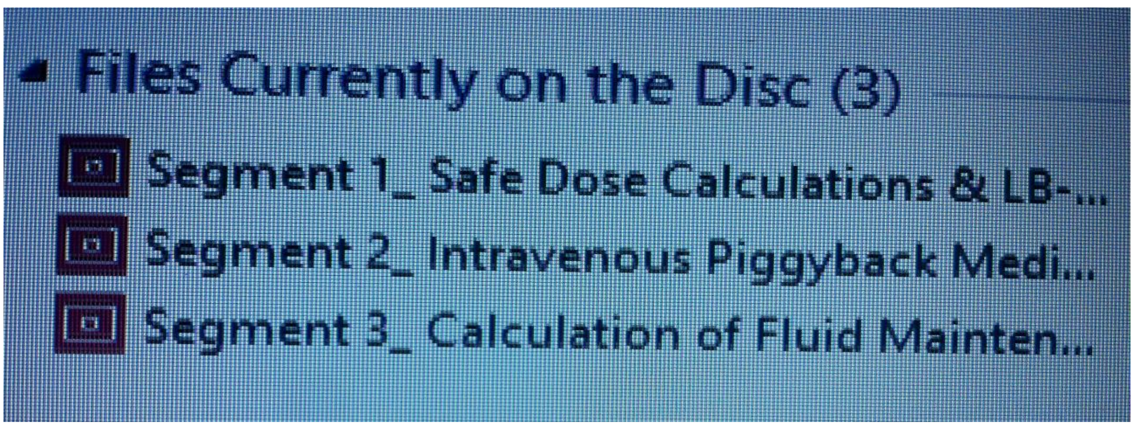
The last question was, once the antibiotic is finished, what will the student nurse set the IV flow rate to meet the 8hr fluid maintenance for the remainder of the shift?
47 mls/hr

To answer this question there are multiple steps and calculations that need to be done.

1. The first thing you need to know is the 8 hr fluid maintenance=533ml
2. Next, you need to know the total IV & PO intake = PO 225ml + IV 73ml (53ml minibag+ 20 flush)= 298ml.
3. The 8hr fluid maintenance is 533ml and the IV and PO intake was 298ml. **Subtract 533ml-298ml = 235ml is left of the 8hr fluid requirements.** All of the PO intake and the medication intake occurred before1800.
4. Next, there are **5 hrs left** in the 8 hr shift.
5. 235ml ÷ 5 hrs, this equals 47 ml/hr. **You are going to set the IV rate at 47ml/hr to deliver the remainder of the 8 hr fluid maintenance.**

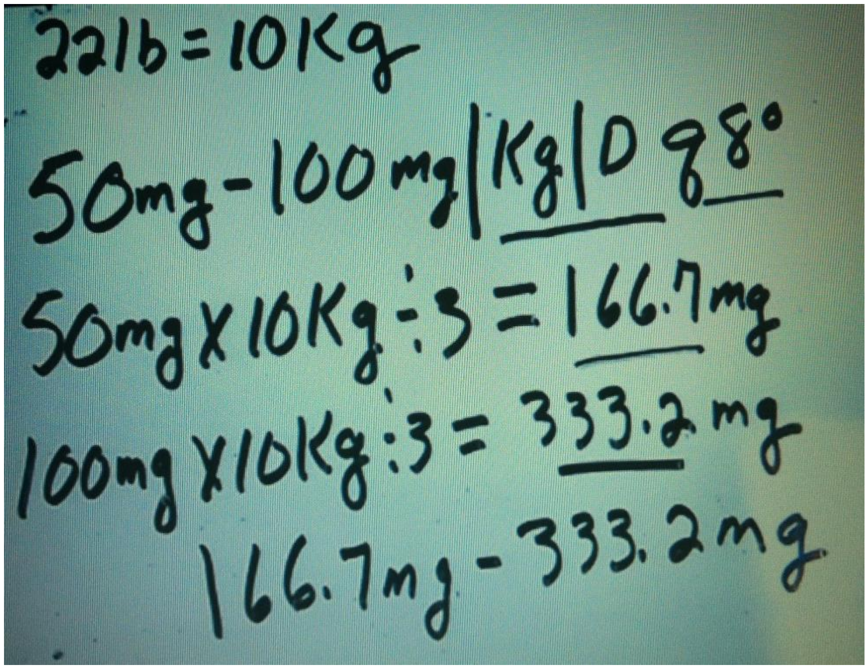
Appendix E

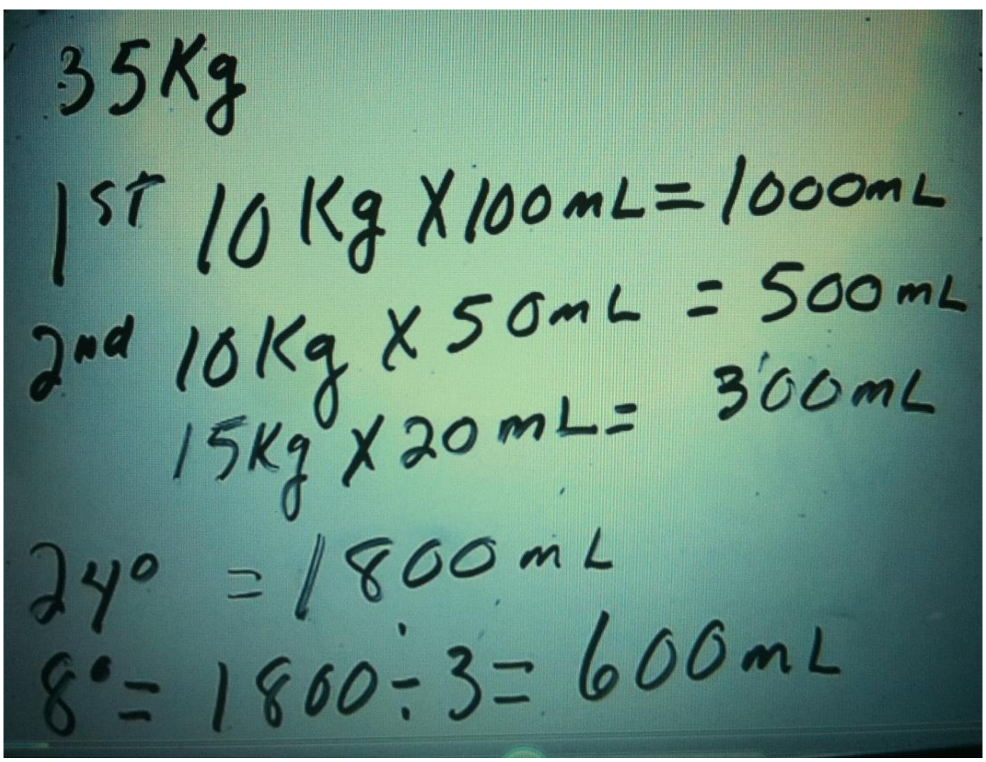
Multimedia Module Screen Shot of Table of Contents


Files Currently on the Disc (3)
Segment 1_ Safe Dose Calculations & LB-...
Segment 2_ Intravenous Piggyback Medi...
Segment 3_ Calculation of Fluid Mainten...

Appendix F

Multimedia Module Screen Shots of Safe Dose And Fluid Maintenance Calculations


22lb = 10Kg
50mg - 100mg | Kg | D q8°
50mg X 10Kg ÷ 3 = 166.7mg
100mg X 10Kg ÷ 3 = 333.2mg
166.7mg - 333.2mg


35Kg
1st 10 Kg X 100mL = 1000mL
2nd 10Kg X 50mL = 500mL
15Kg X 20mL = 300mL
24° = 1800mL
8° = 1800 ÷ 3 = 600mL

Appendix G

Research Study Script

Research Study Script

Hello, my name is ___________. I am a RA for Professor Granados. Professor Granados is conducting research on pediatric medication administration, and she is inviting you to participate because you will be administering medications in the pediatric clinical rotation. Participation in this research involves studying a medication administration module that includes common mathematical computations for medication administration in the pediatric patient, as well as a pediatric medication test. You will be given on hour and 15 minutes to study the medication module and 30 minutes to take the pediatric test. If you agree to participate in the research, your total time commitment will be two hours.

You received an envelope with a reading on the pediatric medication, two consent forms, and a text-based module. If you do not agree to participate, take the article out of the envelope, seal the envelope and at the end of the study return the envelope in the box at the desk. If you do not participate, you can read the article on pediatric medication.

If you would like to participate in the research, there will be two consents, you will be asked to take the consents out of the envelope and sign the written consents, keep one and insert the other into the envelope. You will be instructed to take out the medication module and instructed on how to proceed (text-based module). At the end of one hour and 15 minutes you will insert the module in the envelope and take out the test. You will be instructed to start the test. After 30 minutes, you will be instructed to insert the completed test into the envelope and seal it. The reading is for you to keep. Return the sealed envelope with the consent, module, and test to the box on the desk.

You will be instructed how to navigate through the multimedia module (multimedia module). At the end of one hour, you will be instructed to close the multimedia module and instructed to take the test out of the envelope. You will be instructed to start the test. After 30 minutes, you will be instructed to insert the completed test into the envelope and seal it. The reading is for you to keep. Return the sealed envelope with the consent, module, and test to the box on the desk.