Effective pedagogies for teaching math to nursing students: A literature review

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Summary

Improving mathematical competency and problem-solving skills in undergraduate nursing students has been an enduring challenge for nurse educators. A number of teaching strategies have been used to address this problem with varying degrees of success. This paper discusses a literature review which examined undergraduate nursing student challenges to learning math, methods used to teach math and problem-solving skills, and the use of innovative pedagogies for teaching. The literature was searched using the Cumulative Index of Nursing and Allied Health Literature and Education Resource Information Center databases. Key search terms included: math*, nurs*, nursing student, calculation, technology, medication administration, challenges, problem-solving, personal response system, clickers, computer and multi-media. Studies included in the review were published in English from 1990 to 2011. Results support four major themes which include: student challenges to learning, traditional pedagogies, curriculum strategies, and technology and integrative methods as pedagogy. The review concludes that there is a need for more innovative pedagogical strategies for teaching math to student nurses. Nurse educators in particular play a central role in helping students learn the conceptual basis, as well as practical hands-on methods, to problem solving and math competency. It is recommended that an integrated approach inclusive of technology will benefit students through better performance, increased understanding, and improved student satisfaction.

Introduction

Nursing students have been challenged by mathematical (math) competency for more than 40 years (Brown, 2006). Various teaching strategies have been used to address this challenge. Math dosage calculation has traditionally been taught using paper and pencil and chalkboard examples. More recently PowerPoint and CD-ROM tutorials have been incorporated into undergraduate teaching to address the unique characteristics of technologically-competent millennial learners who prefer active learning, group activities and instantaneous feedback. However, despite these technological advances, undergraduate nursing students continue to struggle with math computation and problem-solving skills. Students who are unable to successfully pass math competency examinations are often forced to withdraw from nursing courses, and are at high risk of never completing the nursing program (Hodge, 1999). In turn, nurse educators are challenged to develop innovative teaching and learning approaches that meet the needs of millennial learners and result in achievement of both the conceptual understanding and practical know-how of solving math problems for medication administration.

Aim

The aim of the literature review was to survey current math computational and problem-solving approaches, identify the challenges faced by undergraduate nursing students in understanding math, and evaluate effective pedagogies for teaching math.

Method

The literature search began using key terms in the CINAHL (Cumulative Index of Nursing and Allied Health Literature) and ERIC (Education Resource Information Center) databases. Key search terms included: math*, nurs*, nursing student, calculation, technology, medication administration, challenges, problem-solving, personal response system, clickers, computer and multi-media. The search range included studies published in English from 1990 to 2011. After an initial review of bibliographies, additional relevant references were obtained. Inclusion criteria included quantitative, qualitative, mixed method research and scholarly discussion articles that focused on the challenges of teaching and learning math computation and problem-solving for medication administration, traditional math teaching methods, and the use of technology for teaching math. Articles excluded from the review consisted of those not published in English, those published prior to 1990, dissertations, and studies that focused on comparisons between traditional teaching approaches, instrument development, cooperative learning, medication errors and the attitudes and practices of registered nurses.
The initial search retrieved 264 articles. Fifty-one articles met the criteria for selection. Articles that met inclusion criteria were analyzed for content and similar concepts. Emerging themes and subthemes were identified and categorized.

Results

Of the 51 articles in the review, an international audience was well represented. Studies were predominantly published in the UK (n = 14) and the US (n = 29), with articles also emanating from Australia (n = 4), Canada (n = 1), Finland (n = 1), Norway (n = 1), and Sweden (n = 1). The majority of articles were research-based (n = 39) with a primary focus on math (n = 48). Only three articles had a technology focus, while six articles addressed both math and technology. The majority of articles were from the nursing literature (n = 47), with the remaining studies coming from the discipline of math (n = 4). Four major themes emerged from the review: student challenges to learning, traditional pedagogies, curriculum strategies, and technology and integrative methods as pedagogy.

Student Challenges to Learning

Several student learning challenges that impact math and problem-solving competency were identified in the literature. Subthemes include: inadequate pre-college math preparation, inability to comprehend problem-solving approaches, test anxiety, and lack of contextual understanding.

Previous math success and innate math ability contribute to student ability to achieve math competency (Hodge, 1999). Success with medication calculation tests have also been linked to students' math scholastic achievement test (SAT) scores, high school algebra grades, and the actual number of high school math courses taken (Costello, 2011). Costello (2011) suggests that students admitted to nursing programs with math SAT scores less than 600 should be provided with math remediation within their first year of school. Students with fewer high school math courses tended to report more stress related to math test performance, thus researchers suggest that greater attention be given to math competency prior to college (Roykenes and Larsen, 2010). In a similar study, Grandell-Niemi et al. (2006) found that students who had more math classes in high school performed better in mathematics, tended to be more positive toward math in general, and were more successful in completing dosage calculations.

A number of researchers investigated student inability to comprehend basic calculation and problem-solving approaches. In several studies students struggled with fundamental skills of numerical ability, converting fractions and decimals, and calculating percentages (Blais and Bath, 1992; Brown, 2002; Johnson and Johnson, 2002; Wright, 2005; Brown, 2006; Wright, 2006, 2007; McMullan et al., 2010). In McMullan et al.'s (2010) study of nursing students and registered nurses, participants were more able to calculate oral and injectable problems, versus solving percentages and intravenous rates of infusion. Measurement errors also occurred in the United States when converting minims (a unit of volume) to milliliters (Blais and Bath, 1992). Whereas, in a few other studies, math calculation errors were attributed to students’ lack of understanding and inability to accurately set-up and calculate medication problems versus a deficiency in basic math skills (Greenfield et al., 2006; Harne-Britner et al., 2006; Jackson and De Carlo, 2011). Likewise, Jukes and Gilchrist (2006) report that students had difficulty with the ratio-proportion section of the math test and performed better on items that dealt with percentages.

In summary, undergraduate nursing student math calculation ability is related to pre-college math experiences. Basic calculation skills and problem-solving approaches are a cumulative process learned over time through the effort of the student. It is essential for students to master basic concepts before learning more advanced concepts. Otherwise, ideas remain disconnected with no underlying theme, which further limits math ability (Fotopes, 2000).

Another student challenge subtheme identified in the literature is anxiety. Anxiety is a factor widely discussed by researchers that negatively impacts student ability to achieve math competency (Pozehl, 1996; Hodge, 1999; Glaister, 2007). Glaister (2007) reports that students with higher negative attitudes and greater test anxiety did not perform as well on a dosage calculation test compared to students with neutral or positive attitudes toward math. Although not statistically significant, Pozehl (1996) found that nursing students scored higher on instruments that measured math anxiety, pre-test state anxiety and computer anxiety than did non-nursing students in an introductory statistics course. Nurse educators must provide an environment that is encouraging and conducive to learning in order to decrease student anxiety and promote positive attitudes toward math (Pozehl, 1996).

One additional subtheme identified as a barrier to math competency is lack of contextual understanding. A theory–practice divide exists between abstract classroom teaching and the real-world of calculating dosages in the clinical setting. In an effort to address the conceptual errors students make, Weeks et al. (2000) hypothesized a constructivist approach for learning. Students often fail to make the semantic connection between the words themselves in the formula and the actual medication orders and doses found in practice. The didactic method of teaching is not effective because the standard recipe approach of setting up math problems does not address the conceptual aspect of problem solving (Weeks et al., 2000). Conceptual errors related to problem set-up also occurred in Blais and Bath’s (1992) study.

According to Krautscheid et al. (2011) acute care clinical students had difficulty applying the medication concepts learned in the practicum laboratory to the quick-paced technologically-driven clinical environment. Challenges to student learning included using a manual medication cart in the university setting versus the technology of electronic medication dispensing systems at the hospital (Krautscheid et al., 2011). It is recommended that educators address conceptual understanding and application of math to the practice setting (Wright, 2006, 2007). Ultimately, the goal of nurse educators is to support real-life scenarios and application of skills to support the transition from classroom to practice (Hall, 2010).

Traditional Pedagogies

Traditional pedagogies is the second theme identified in the literature review. Three pedagogies are used in the classroom to teach math calculation and problem solving. Subthemes include the formula method, dimensional analysis, and the ratio–proportion method. Strengths and weaknesses are identified for each of these methods. The main aspects of the formula method include “remembering the formula; arithmetic skills involving fractions, long multiplication, and division; or calculator skills” (Wright, 2009b, p. 883). According to Wright (2008), the formula method relies heavily on arithmetic and remembering formulas accurately to solve problems, and leaves students with numerical values that lack clinical meaning and conceptual understanding, thus leading to an increased incidence of calculation errors.

The ratio–proportion method is another common approach used to teach math calculation to nursing students (Jackson and De Carlo, 2011). This method requires students to convert all units of measurement into the same system prior to calculating. According to Wright (2009a), the ratio–proportion method is beneficial to student nurses because it maintains practical meaning. An advantage of this method is that volume and weight vary together and ratio–proportion is effective when dosages can be doubled or halved (Wright, 2009a).

Dimensional analysis was the last subtheme that emerged. This method provides a consistent way to set-up and solve math conversions by teaching students to systematically convert units prescribed to units available (Greenfield et al., 2006). Several researchers use
dimensional analysis for their teaching methodology (Rice and Bell, 2005; Greenfield et al., 2006). Rice and Bell (2005) found dimensional analysis to be an effective teaching strategy for teaching medication calculations. In their study, students who used dimensional analysis made fewer errors and were more confident in their ability to solve problems than students who did not use this method. Further, when dimensional analysis was taught to a group of baccalaureate nursing students, researchers found that the students in the experimental group had fewer errors in all areas of conversion and dosage calculation versus the control group which used the formula method (Greenfield et al., 2006). Conversely, Kohltz and Gowda (2010) report no significant difference in math test scores for students who were taught dimensional analysis when compared to ratio–proportion and calculation formula methods.

The use of calculators as a tool to teach math problem-solving is a topic of continued debate in the nursing literature across all three traditional pedagogies (Hutton, 1998; Kapborg and Rosander, 2001; Jukes and Gilchrist, 2006). Kapborg and Rosander (2001) found that student test scores increased significantly with the use of calculators. However, in several other studies researchers discouraged the use of calculators during testing. McMullan et al. (2010) suggest that students initially learn mathematics calculations without the use of calculators. Whereas, Hutton (1998) recommends that calculators be available only when complicated calculations are required.

Curriculum Strategies

The third theme that emerged from the literature review related to curriculum strategies. Analysis of the literature identified three subthemes of curricula focus that impact student learning: method of testing, remediation approaches, and consistency of teaching across courses. Several nursing curricula require repeated math competency testing at the start of each clinical course (Heinzer et al., 1997; Allen and Pappas, 1999). The purpose of recurrent testing is to promote student awareness of the significance of math competency and to provide an opportunity for routine math calculation practice prior to each clinical experience (Allen and Pappas, 1999). Jukes and Gilchrist (2006) recommend that students be tested throughout their nursing programs in order to reinforce math skills in the class and clinical settings.

Students who fail to pass their math tests and meet progression criteria are often assigned to remediation (Pozehl, 1996; Heinzer et al., 1997; Allen and Pappas, 1999; Johnson and Johnson, 2002; Elliott and Joyce, 2005). In Allen and Pappas’ study (1999) remediation included having students spend an average of 4 weeks meeting one-on-one with teachers to learn calculation strategies. A number of students reported the benefit of relieving math anxiety through their ability to understand the “why and how” behind the ability to solve problems. Whereas, remediation in a study by Heinzer et al. (1997) included computer assisted instruction, one-on-one tutoring and the use of laboratory simulations. Several other authors also recommend the use of repeated math calculation practice throughout the curriculum to address the math challenges of nursing students (Polifroni et al., 2005; Walsh, 2008).

Another curricular subtheme was consistency in pedagogical approach to teaching math. It was noted that consistency across the curriculum impacts student learning outcomes. When math is taught in individual clinical courses with no consistency in teaching methods, each course tends to exist in isolation with no opportunity to evaluate overall curriculum proficiency (Elliott and Joyce, 2005). In support of curricular threading across courses, Johnson and Johnson (2002) implemented a 4 C’s method to teach dosage calculation. In this approach, the 4 C’s method (compute, convert, conceptualize and critically evaluate) was adopted by all teachers. Teachers focused on the steps of conceptualization and critical evaluation and were able to institute a simple to complex teaching approach for math calculations to ensure student success early on. These researchers reported a decrease in student test anxiety and an increase in students’ feelings of self-efficacy (Johnson and Johnson, 2002).

Regardless of the pedagogy used to teach math, the literature is clear that nurse educators should agree to select one approach and use the method exclusively across the curriculum (Bath and Blais, 1993; Jackson and De Carlo, 2011). “In order to achieve dosage calculation proficiency, nursing students need supportive faculty, [who use]... innovative teaching methodologies consistently across the curriculum” (Johnson and Johnson, 2002, p. 8).

Technology and Integrative Methods as Pedagogy

The final theme that emerged from the literature included the use of technology and integrative strategies to teach math. The technologies used for teaching math are reported with mixed results. CD-ROMS and video instruction improved student math competency (Jeffries, 2001); however, no significant improvement in math test scores is reported when online multimedia learning tools (Maag, 2004) or online medication dosage assessment tools are used (Hutton et al., 2010). Personal response system (PRS) technology, also known as clickers, was evaluated for its effect on student learning outcomes in an undergraduate algebra course (Butler et al., 2010). Findings indicated no statistically significant differences in scores on final exam, overall exam average, or lab points between sections using traditional teaching approaches and the integration of PRS technology, whereas quiz scores were higher in sections that did not use PRS technology. Researchers conclude that it was not clear if PRS technology was effective for increasing student learning outcomes. Similarly, Liu and Stengel (2011) report mixed results in their study with students in an undergraduate math course. PRS technology is thought to be most effective with problems that can be broken down into one or two clear steps. Complex problems with multiple steps are not well suited to teaching with this technology (Liu and Stengel, 2011). The effect of PRS technology on learning outcomes has also been evaluated in nursing (McCurry and Hunter Revell, 2011) with mixed results; however, the study did not evaluate student learning related to math calculations.

The second subtheme, integrative approaches, includes the use of technology, computerized-learning, and in person activities to teach math (Ellis-Monaghan, 2010). Strategies include: online math tutorial sessions (Wright, 2007; Cummings, 2011; Jackson and De Carlo, 2011), in-class lecture, drug calculation workbooks (Hutton, 1998; Wright, 2004, 2007; Krautschied et al., 2011), and lab practical sessions (Wright, 2005, 2007; Krautschied et al., 2011). Visual prompts aid individual understanding of problem solving and numeracy knowledge should be integrated into clinical practice problems instead of being taught without practical context (Wright, 2009a). Cummings (2011) reports on the benefit of one-on-one tutoring with teachers and weekly professor-led tutorials, which consisted of both on-line and in-class components. An integrative approach should include the use of peer groups (Krautschied et al., 2011) and supportive instructional techniques to enhance students’ comfort level and self-confidence in their ability to solve calculation problems (Glaister, 2005).

Discussion

The literature clearly establishes that many nursing students have difficulty learning math concepts required for professional success (Heinzer et al., 1997; Allen and Pappas, 1999; Polifroni et al., 2003; Brown, 2006; Newton et al., 2009). Student barriers to successful math competency include test-related anxiety and a subsequent feeling that they are not “good at math.” For some, a lack of adequate pre-college mathematics preparation in high school accounts for their college math challenges, while researchers have determined that “other” students lack a conceptual understanding of how to solve math problems. A lack of conceptual understanding leads to errors
in dosage calculations and in turn errors in the clinical setting. Ultimately students lack contextual understanding of how to solve real-world math problems, which reflects the theory–practice divide that exists in nursing education today.

The nurse educator’s role in teaching students is to foster the development of conceptual and contextual understanding of math and problem-solving material. According to Allen and Pappas (1999), millennial students “[require] a multifaceted approach that incorporates student accountability, faculty sensitivity to the source(s) of the problem, and creative interventions” (p. 128). Pedagogies should focus on a constructivist learning approach (Weeks et al., 2001), but also be tailored to the audience of millennials. Students are able to constantly order, classify, and modify knowledge, thereby enabling them to adapt to changes by allowing continuous evolution of mental constructions (Fosnot, 1996). Teaching through a constructivist approach involves fostering the internal process within the student that actively builds understanding and decreases anxiety.

PRS technology provides one example of a pedagogy that can be used by nurse educators to externalize students’ cognitive learning process, making their conceptual linkages visible for evaluation and corrective feedback. There is an abundance of nursing research that supports the integration of PRS technology into the classroom as an effective pedagogy for millennial learners. Researchers have found that PRS technology fosters active learning, and increases student interaction and participation (Berry, 2009; Smith and Rosenkoetter, 2009; Hunter Revell and McCurry, 2010). Thus, by externalizing students’ learning, nurse educators may finally be able to solve the long-standing challenge of achieving math competency in their students.

Nurse educators are encouraged to adopt one approach for teaching math to undergraduate nursing students, and use it consistently across the curriculum. This approach should integrate various teaching strategies including the use of technology to complement the learning styles of students (National League for Nursing – Nurse Educator Competencies, 2005). Successful integration of teaching with technology includes incremental changes over time through pedagogy, curriculum development, and student assessment of learning (Sturdivant et al., 2009).

Conclusions

A need exists for innovative pedagogies to teach math to undergraduate nursing students. Nurse educators are in a pivotal role to assist students with the conceptual understanding and practical know-how of solving math problems. By developing an integrative teaching program that includes the use of technology, it is anticipated that students will improve math performance with better retention, increased confidence, and enhanced student satisfaction because the pedagogy will complement their preference for active engagement with interactive technology. Nurse educators may report improved utilization of didactic instruction time, with enhanced ability to rapidly assess student understanding and identify concepts needing reinforcement.

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References


