Emerging Solutions
in Mathematics Education for Nursing

The University of Texas at Austin
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As the baby boom generation ages, the current shortage of registered nurses in the United States is expected to worsen due to a rising need for nursing services and the retirement of significant numbers of nurses (American Association of Colleges of Nursing, 2017). Hence, nursing professional associations and other experts are increasingly analyzing the real or perceived barriers to entry into and successful completion of nursing programs and examining how to expand access to a wider field of students. While a shortage of nursing faculty continues to be a hindrance on the supply side of nursing education, a consideration on the demand side is whether any program prerequisites or curricular

We provide this brief to inform discussions among mathematics and nursing organizations and national leaders about the mathematics course requirements needed for modern nursing programs and to promote collaboration between the fields.

This brief identifies the relevant mathematics for the nursing major, underscoring the lack of clarity from nursing organizations in the mathematical content knowledge needed for safe practice. We explore the curricular inconsistencies across the country as well as the disconnect between how mathematics is taught and assessed in programs and how it is actually used in practice, focusing on identifying emerging solutions to ensure that mathematics is an effective tool, rather than a barrier, for equitable nursing education.

requirements serve as unnecessary obstacles to nursing degree program entry, progression, or completion. This brief examines the mathematics content and requirements for nursing degrees, as compared with the mathematics used by nurses in the field; considers whether they pose a barrier to access; and offers some emerging solutions suggested or implemented by a variety of agencies, institutions, and states.

Identifying, Teaching, and Assessing the Mathematics Needed for Nursing

A graduate completing an Associate Degree of Nursing (ADN) or a Bachelor of Science in Nursing (BSN) must be licensed in order to practice. To become a Registered Nurse (RN), the individual must pass the National Council Licensure Examination-RN (NCLEX-RN), which is administered by the National Council of State Boards of Nurses (NCSBN), a membership organization for nurse regulatory bodies. The pass rates on the NCLEX-RN are used by nursing regulatory bodies as one of many data points to measure the efficacy of nursing education programs and are included in nursing program accreditation standards. Nursing programs often display their graduates' pass rates on their websites (National League for Nursing Commission for Nursing Education Accreditation, 2016).

The content of the NCLEX-RN is based, by law, on the first year of nursing practice. The test reflects the frequency and importance of nursing care activities that graduates perform during that first year, as determined by both surveys and professional observation. There is some debate among faculty as to whether the NCLEX-RN is an accurate measure of the mathematical skills needed by professional nurses, but the restriction of the topics on the NCLEX-RN to the first year of practice does not seem to be common knowledge. Rather than teaching to the NCLEX-RN, it is important for faculty to keep in mind that nurses use many skills throughout their careers that may not be called on in their first year of practice. Regardless of the scale of the alignment between the overall

curriculum intended to support nurses' numeracy needs in their practice and the contents of the NCLEX-RN, it is imperative that current nursing education programs evaluate whether they are teaching the appropriate skills, in an appropriate way, to ensure effective application in the field, both in the first year of practice and beyond.

The NCLEX-RN Detailed Test Plan (NCSBN, 2018) states that, in the area of mathematics, exam takers must demonstrate their ability to perform the calculations needed for medication administration (intravenous and parenteral therapy is specifically identified) and be able to apply mathematics to client nutrition, both as it relates to BMI and to Total Parental Nutrition. A review guide from another organization recommends understanding the three measurement systems used in pharmacology (the household measurement system, the metric system, and the apothecary system) and being able to quickly and accurately perform conversions between units of measurement. This guide also notes that the examination includes basic areas of math such as fractions, mixed numbers, decimals, ratios, and proportions. The above topics are included in—but do not cover all of—the essential numeracy skills for nursing that were identified in a survey conducted by Young, Weeks, and Hutton (2013). The survey identified the mathematical skills, and the contexts in which they are used by nurses, including estimation skills; measurement skills; whole and negative number arithmetic; use and understanding of fractions, decimals, and percentages; unit conversions; proportional reasoning; the use of formulae, tables, charts and graphs; and an appreciation of statistics as it relates to evidence-based practice. The differences between these lists of topics make it clear that having an explicit set of core math competencies for nursing education is critical to ensure consistent preparation and education of nursing students.

Assuming a list of topics is agreed upon, the next question that arises is how to structure the mathematics instruction within the nursing program. An effective way to develop these competencies in nurses is to "dispense with reductionist approaches that focus on calculation skill development in isolation. Critical to solving this ubiquitous problem is the need to co-locate conceptual, calculation and technical measurement competence development and assessment within a competency model and education structure" (Weeks et al., 2012, p. e30). Hoyles, Noss, and Pozzi (2001) emphasize this need for contextualizing computational instruction after having identified a "disjunction between visible mathematics—whether it is school mathematics or the mathematics introduced in training programs—and what happens in practice" (p. 23) in their ethnographic study of nurses' use of mathematics in a professional setting.

Despite the broad mathematical competencies for nursing, the majority of the current research related to mathematics and nursing education is related to the specific skill and context of drug dosage calculations. There is clear consensus in the nursing education research literature that the ability to correctly calculate drug dosages is an essential skill in the profession, as errors can compromise patients' safety. The literature also expresses significant concern about whether nursing program graduates have mastered this skill. Research going back decades and spanning several continents attempt to examine why and where nursing students have challenges with these types of calculations and how improved curriculum or different pedagogical approaches might address those challenges (see, e.g., Bagnasco et al., 2016; Cartwright, 1996; Elliott & Joyce, 2005; Revell & McCurry, 2013).

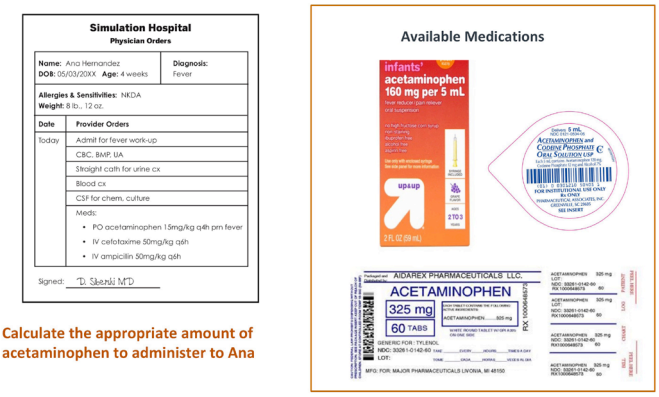
Sample Dosage Calculation Problems

- The order reads "Terramycin 0.75 g. to be taken three times a day." They come in capsules of 250 mg. How many capsules should they take for each dose? (The answer is 3.)
- The label reads "for children weighing 25 kg or less, administer 150 mg/kg/day in four divided doses." The child weighs 44 lbs. How many mg will this be per dose? (The answer is 750.)

While the types of calculations needed to determine appropriate dosages (see sidebar for sample problems) and their corresponding algebraic solutions strategies are a common component of both the instructional and assessment practices in current nursing education, Wright (2007) asserts that "the assumption that written calculation tests and/or numeracy tests represent a measure of students' and nurses' drug calculation skills in

practice neglects to consider the other indicators that are required for successful drug calculations in practice and arguably results in an invalid assessment" (p. 341). According to Wright (2007), there is a need for flexibility in both the instruction and assessment of mathematics for drug calculations because the ways in which professional nurses solve these problems vary and involve a variety of numeracy skills, most of which arise from the context of drug administration rather than from formal arithmetic. Hoyles et al. (2001) support this claim, noting that experienced nurses employ a variety of proportional reasoning strategies in their practice, rather than rely on a single formula or process learned in their formal education.

A Classic Problem – Reconceptualized



Calculate the appropriate amount of acetaminophen to administer to Ana

In addition to questions about what math to teach, how to teach it, and how to asses it once students are in the nursing program, some institutions are implementing mandatory assessments prior to nursing program entry in an attempt to preemptively measure proficiency in mathematics and other academic skills. The Test of Essential Academic Skills (TEAS), administered by Assessment Technologies Inc. (ATI), is one of the most common assessments used in this fashion. The test is designed be a part of the admissions criteria for nursing programs; it "statistically predicts whether or not a person can pass and graduate from a school of nursing."[2] The test is also intended to provide a proxy for understanding and decreasing the rate of student attrition from nursing programs.[3] The TEAS is a timed, multiple-choice examination with a mathematics section that has two subsections covering numbers and algebra, and measurement and data.

It is not clear, however, whether the mathematics content on the TEAS aligns with the math that nurses actually use in practice, nor is it clear that it aligns with how they use that math. While the content includes basic arithmetic operations and conversions, it is generally presented in a decontextualized format; additionally, the TEAS includes other topics (such as solving algebraic equations) that are not necessarily used by nurses in practice. Given the imperative of training and licensing large numbers of new nurses and the fact that the NCLEX tests nurses' knowledge and skills before allowing them to practice, members of the nursing education community have begun to question whether screening tests impose an unnecessary barrier to admission into nursing programs. Consequently, the National League for Nursing (NLN), a longstanding association of nurse faculty and other nurse education leaders, issued the *Fair Testing Guidelines for Nursing Education* (NLN, 2012a). The accompanying publication, *NLN Vision: Fair Testing Imperative in Nursing Education*, expresses NLN's concern with "the prevalent use of standardized tests to block graduation or in some other way deny eligibility to take the licensing exam" (NLN, 2012b, p. 1). The testing guidelines are intended for nurse faculty and administrators who are designing and implementing a sequence of courses and coursework that are ethical and evidence-based. They encourage learning from institutions that have managed to achieve high NCLEX-RN pass rates without having to utilize high stakes testing.

Existing Guidance from Professional Organizations on Mathematics for Nursing

To identify the mathematics courses or quantitative learning outcomes recommended for nursing students, the Charles A. Dana Center reviewed reports from a number of professional associations of nursing, some of which have issued program accrediting standards. In general, we found that while some of these bodies provide guidance for curricular content, mathematics is not a major focus. Instead, professional associations tend to emphasize a broad liberal education along with professional competencies. For example, the National League for Nursing

established the NLN Commission for Nursing Education Accreditation (CNEA), which developed five standards of accreditation (CNEA, 2016). Its guidelines for Standard V, Culture of Learning and Diversity – Curriculum and Evaluation Processes, do not mention mathematics specifically but note the importance of a general liberal arts curriculum:

> The PN/VN and RN pre-licensure and undergraduate curriculum is built upon and incorporates a foundation of nursing arts and sciences into the program of study. Faculty and students can describe how any courses taken to fulfill the general education, basic sciences, social sciences, and/or human sciences curricular requirements of the program support the development of the professional identity of nurses. (NLN, 2016, pp. 25-26)

Similarly, the Accreditation Commission for Education in Nursing (ACEN), a specialized accrediting agency for nursing education programs, does not explicitly discuss mathematical competencies in its updated accreditation manual (ACEN, 2019). One of the six standards for baccalaureate programs, Standard 4 (Curriculum), does state that all end-of-program learning outcomes must be consistent with safe healthcare practice. Given the earlier discussion of the importance of mathematics for dosage calculations, it can be assumed that some mathematical competency is implied, but not directly stated.

Another example comes from the Quality and Safety Education for Nurses (QSEN) Institute at Case Western Reserve University. While QSEN defined quality and safety competencies—along with the corresponding knowledge, skills, and attitudes—that should be developed in nursing education programs, it did not explicitly state specific mathematics content and skills.[4]

QSEN Competency	Selected Knowledge and Skills Related to Mathematics
Evidence-Based Practice	Definition: Integrate best current evidence with clinical expertise and patient/family preference and values for delivery of optimal healthcare. Demonstrate knowledge of basic scientific methods and processes. Describe EBP to include the components of research evidence, clinical expertise and patient/family values.
Quality Improvement	Definition: Use data to monitor the outcomes of care processes and use improvement methods to design and test changes to continuously improve the quality and safety of health care systems. Explain the importance of variation and measurement in assessing quality of care. Use tools such as quality measures and charts.
Safety	Definition: Minimizes risk of harm to patients and providers through both system effectiveness and individual performance. Describe processes used in understanding causes of error and allocation of responsibility and accountability (such as, root cause analysis and failure mode effects analysis)
Informatics	Definition: Use information and technology to communicate, manage knowledge, mitigate error, and support decision making. Information management tools, database management.

The American Association of Colleges of Nursing (AACN) is somewhat more specific in proposing mathematics content for baccalaureate nursing programs. *The Essentials of Baccalaureate Education for Professional Nursing Practice* (AACN, 2008) outlines nine curricular elements considered to be critical for nursing programs. These elements are intended to guide faculty in choosing course content, rather than recommend any specific course. However, some mathematics topics are specified in four curricular elements, as follows (emphasis ours):

AACN Curriculum Element	Mathematics Related Topics
Essential I: Liberal Education for Baccalaureate Generalist Nursing Practice	The sciences to be taught include: • physical sciences (e.g., physics and chemistry), • life sciences (e.g., biology and genetics), • **mathematical sciences**, and • social sciences (e.g., psychology and sociology). Program outcome: "Use skills of inquiry, analysis, and information literacy to address practice issues" (pp. 10-12).
Essential II: Basic Organizational and Systems Leadership for Quality Care and Patient Safety	Program outcome: "Use improvement methods, based on data from the outcomes of care processes, to design and test changes to continuously improve the quality and safety of health care" (p. 14). Sample content includes "overview of QI (quality improvement) process techniques, including benchmarks, **basic statistics**, root cause analyses, and Failure Mode Effects Analysis (FMEA) in the quality improvement process" (p. 15).
Essential III: Scholarship for Evidence-Based Practice	Sample content includes: "overview of qualitative and quantitative research processes" and **"basic applied statistics"** (p. 17).
Essential VII: Clinical Prevention and Population Health	Sample content includes: "the fundamentals of epidemiology and **biostatistics** (distribution, incidence, prevalence, rates, risk factors, health status indicators, and control of disease in populations)" (p. 25).

Our review found that organizations for nursing and nursing program accreditation delineate few recommendations for specific mathematics content and offered no recommendations for mathematics courses. However, when organizations do include mathematics topics in their standards and guidelines, those topics fall under the statistics content area.

Emerging Solutions at the National Level

Perhaps as a result of the sparse guidance on math content and courses, several recent initiatives are addressing this issue. For example, the Dana Center has paired with QSEN and the Mathematical Association of America to form the *High-Quality Mathematical Preparation for Nurses Task Force*.[5, 6] This joint effort works to strengthen the connections between mathematics—curriculum, instruction, and assessment—and clinical practice so that "[a]ll students in nursing programs gain the mathematical knowledge, skills, and attitudes to promote and provide safe, high-quality health care" (QSEN, n.d.). The task force is currently working to identify the core math skills and competencies necessary for safe nursing practice and is seeking funding to investigate the best strategies for implementing their findings in nursing education programs. The task force plans to publish a biannual newsletter to keep the field up to date with its progress.

Other recent initiatives aim to streamline nursing education by improving the progression from ADN to BSN programs, which have implications for required coursework. The Academic Progression in Nursing (APIN) program, originally funded by the Robert Wood Johnson Foundation (RWJF) from 2012 to 2017 is now under the leadership of the Organization for Associate Degree Nursing and the National Forum of State Nursing Workforce Centers (Hassmiller & Reinhard, 2017). APIN explored strategies to create a more highly educated nursing workforce to meet the Institute of Medicine's (2011) call for 80% of the nursing workforce to have a baccalaureate degree.

APIN identified the inconsistencies in prerequisites and credits that often resulted in students' having to repeat coursework when transitioning to BSN programs. A working group was convened to address the issue, first analyzing prerequisite and general education requirements at a sample of both ADN and BSN programs. The group found significant variation not only in the courses required, but also in the number of credits required in particular content areas:

> This analysis led to the conclusion that there is general consistency in the content areas seen in prenursing and general education courses for both baccalaureate and associate degrees in nursing, but a complete lack of consistency exists in how these content areas are applied within the curricula. These inconsistencies become barriers for transferring students or those who are seeking advanced degrees and for nurse educators, particularly in developing consortium or partnership models among multiple schools." (Giddens & Meyer, 2016, p. 375)

As a solution, the working group proposed a set of foundational courses for baccalaureate nursing programs organized into four categories: general education courses, basic sciences, social sciences, and human sciences. The aim was to improve course transferability between RNs' ADN programs and their BSN programs. To this end, the only math course specified by the working group was statistics/logic (which happens to fall under the general education course category).

Alongside this work, the RWJF State Implementation Program funds 21 states to work towards strengthening nursing education generally and academic progression in nursing programs in particular. Some states coordinated nursing curricula across universities and community colleges for students' smooth transition from an associate degree to a BSN program, avoiding repeating coursework.

Emerging Solutions at the State Level

As mentioned above, several states have already taken steps to coordinate their nursing curricula. One example, the Oregon Consortium for Nursing Education (OCNE), has been cited as a model for the coordination of nursing education and progression statewide (Giddens & Mayer, 2016). Now almost 20 years old, the consortium has created partnerships among the state's community colleges and four-year institutions to increase nursing program capacity by coordinating scarce faculty and aligning curriculum. The application process, required prerequisites, and curricula are now standard across the partnering nursing programs. Regarding mathematics, OCNE requires that "[c]ompetency for Intermediate Algebra/Math 95 or higher must be demonstrated prior to matriculation into the nursing program, either by a math placement test or by successful completion of an appropriate course."[7] While Math 95 is not a college-level course, it is a common algebraic prerequisite for gateway college math courses. Statistics/Math 243 is the only college-level mathematics course noted as a mandatory part of the nursing program (OCNE, 2012).

In Washington State, efforts are streamlining the transfer path from ADN to BSN programs with a statewide direct transfer agreement that requires all prerequisite non-nursing credits, as well as nursing credits, to transfer for credit toward the BSN degrees. State legislation also sets guidelines for the content of nursing programs: For baccalaureate and master's programs, legislation mandates the inclusion of "the study of research principles and application of statistics to health care practice and intervention."[8]

Other states have tried similar initiatives, which have improved the consistency of programs to a lesser degree. For example, the Texas Higher Education Coordinating Board approved a Field of Study curriculum—a block of courses in a given program that is guaranteed to transfer from the state's two-year to its four-year colleges—for nursing programs, which includes Elementary Statistical Methods (Math 1342) as the sole required math course.[9] However, while we found that almost all of the baccalaureate-level nursing programs in Texas for 2018–19 do require a statistics course, either Elementary Statistics (Math 1342) or one specific to the nursing program, there is great variation in terms of additional mathematics courses required, from a choice of any general education math course to college algebra and pre-calculus.

Conclusion

This brief raises several questions about the type of mathematics taught in nursing programs, how it is taught, and how it is assessed. There is great focus from both national and state organizations on increasing the number of highly prepared nurses and exploring ways to improve nursing education. While there is extensive literature on whether nursing students are adequately prepared to make accurate calculations of medication dosage, there is still little attention to other mathematics content knowledge and competencies both in the literature and various

current initiatives. Additionally, an increasing body of research indicates that the strategies tested in the licensure examinations do not accurately reflect the ways in which professional nurses use and conceptualize those dosage calculations.

Thus, we conclude that nursing organizations, nursing education experts, and mathematics education experts need to collaborate and delve more deeply into the mathematics required for nursing, and the ways in which it is taught and assessed. How does the math used by nurses in practice differ from the way the math is taught in nursing education programs? In addition to the numerous ways of accurately and efficiently computing dosages, what other mathematics competencies are needed not just for capable but expert nursing? There appears to be an emerging consensus that statistics is the appropriate course to include in ADN and BSN programs, but yet more questions arise: How much statistics should be required? Are the statistics courses designed for social sciences majors appropriate for nursing majors? Is algebra a needed foundation for statistics? Finally, does the mathematics section in the TEAS reflect the math needed by nurses or is the test needlessly screening out students who could be successful in nursing? A national consensus among nursing organizations, accrediting bodies, and mathematics and nursing educators on these issues would greatly help nursing programs provide their students with the best possible education for the field.

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Endnotes

[1] RegisteredNursing.org

[2] https://www.registerednursing.org/teas/

[3] Ibid.

[4] http://qsen.org/competencies/pre-licensure-ksas/

[5] https://www.utdanacenter.org/our-work/higher-education/collaborations/math-for-nurses

[6] http://qsen.org/qsen-task-force-on-high-quality-mathematical-preparation-for-nurses/

[7] http://www.ocne.org/students/Admissions.html

[8] https://apps.leg.wa.gov/WAC/default.aspx?cite=246-840-541

[9] http://www.thecb.state.tx.us/reports/PDF/9829.PDF?CFID=94324479&CFTOKEN=36514078


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In collaboration

This resource was created in collaboration with the Mathematics for Nurses Task force, whose goal is to address how to strengthen the fundamental connections between mathematics curriculum, instruction, assessment, and clinical practice. The task force is a collaboration with the Charles A. Dana Center, Mathematical Association of America, and Quality Safety and Education for Nurses (QSEN) Institute.

https://www.utdanacenter.org/our-work/higher-education/collaborations/math-for-nurses

About this resource

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The Dana Center develops and scales math and science education innovations to support educators, administrators, and policy makers in creating seamless transitions throughout the K–14 system for all students, especially those who have historically been underserved.

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