Essential Mathematics and Statistics Skills and Competencies for Nursing Education

Arkansas Math for Nursing Working Group

The University of Texas at Austin
Charles A. Dana Center

Introduction

Mathematical competency and effective quantitative reasoning skills are essential for safe nursing practice; however, research reveals a lack of consensus on the necessary quantitative learning outcomes for undergraduate nursing programs. The High-Quality Mathematics Education for Nurses Task Force—supported by the Charles A. Dana Center at The University of Texas at Austin, the Mathematical Association of America, and Quality and Safety Education for Nurses—was created in 2017 to build partnerships to work towards the goal that "all students in nursing programs will gain the mathematical and statistical knowledge, skills, and attitudes to promote and provide safe, high-quality health care."

In October 2019, the task force convened leaders from mathematics, statistics, nursing, and education organizations and institutions at the University of Miami. The purpose was to (1) build connections among these communities, and (2) develop a forward-thinking consensus on improving the quantitative education of nurses. The task force then released *Convening Recommendations: Math and Statistics Education for Nurses* (Ozimek et al., 2021), which details areas of consensus from the convening and provides seven recommendations for developing improved quantitative education for nursing practice.

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Among the seven recommendations is the charge for nursing, mathematics, and education faculty and communities of interest to engage in structured conversations to *"Identify the quantitative skills and competencies necessary for quality and safe nursing practice"* (Ozimek et al., 2021, p. 3). Although other inventories of essential quantitative skills for nursing practice have been developed (Pirie, 1987; Roberts, 1990; Young et al., 2013), convening attendees believed these artifacts should be reconsidered given improvements in technology and changes in nursing, mathematics, and statistics education.

Beginning in January 2022, as part of the larger statewide work of aligning programs of study with appropriate math pathways, mathematics and nursing faculty across Arkansas formed a working group to address this recommendation and reach a consensus of the quantitative skills and competencies necessary for quality and safe nursing practice.

Methods

Members of the Arkansas Math for Nursing Working Group (herein referred to as the working group) included representatives from the Arkansas Department of Education, Arkansas Association of Community Colleges, and at least one nursing and one mathematics faculty or staff member from the following institutions.

Arkansas Northeastern College **(ANC)**
Arkansas State University Jonesboro **(ASUJ)**
Arkansas State University Mid-South **(ASUMS)**
Arkansas State University Mountain Home **(ASUMH)**
Arkansas State University Newport **(ASUN)**
Arkansas State University Beebe **(ASUB)**
Arkansas State University Three Rivers **(ASUTR)**
Arkansas Tech University **(ATU)**

Black River Technical College **(BRTC)**
East Arkansas Community College **(EACC)**
Henderson State University **(HSU)**
National Park College **(NPC)**
North Arkansas College **(NAC)**
NorthWest Arkansas Community College **(NWACC)**
Ozarka College **(OZARKA)**
Phillips Community College of the Univ. of Arkansas **(PCCUA)**
South Arkansas Community College **(SACC)**
Southeast Arkansas College **(SEARK)**
Southern Arkansas University **(SAU)**
Southern Arkansas University Tech **(SAUT)**
University of Arkansas Fayetteville **(UAF)**
University of Arkansas Fort Smith **(UAFS)**
University of Arkansas Little Rock **(UALR)**
University of Arkansas Monticello **(UAM)**
University of Arkansas Pine Bluff **(UAPB)**
University of Arkansas Community College Batesville **(UACCB)**
University of Arkansas Community College Cossatot **(CCCUA)**
University of Arkansas Community College Hope–Texarkana **(UACCHT)**
University of Arkansas Community College Morrilton **(UACCM)**
University of Arkansas Community College Rich Mountain **(UACCRM)**
University of Arkansas Pulaski Tech College **(UAPTC)**
University of Central Arkansas **(UCA)**

Stewarded by representatives from the Charles A. Dana Center, the working group collaborated through a series of virtual meetings and completed offline tasks between January and June 2022.

Process

Following a “kickoff” meeting, working group members and additional nursing faculty from participating institutions completed a short survey that prompted them to react to quantitative skills and competencies previously identified in the literature as being necessary for nursing practice or important in the learning of mathematics and statistics (National Governors Association, 2010; National Research Council, 2001; Pirie, 1987; Roberts, 1990; Young et al., 2013). More specifically, individuals were asked to classify each of the items as either “essential,” “not essential, but nice to have,” or “not necessary” for safe nursing practice, which could then be backmapped to identify appropriate content for nursing students. Items included those within content-specific domains as well as those related to mathematical practices, processes, and dispositions (e.g., “Demonstrate a positive attitude towards mathematics/statistics,” “Persevere in solving challenging mathematical tasks"). Survey participants were also encouraged to provide qualitative comments to add context to their responses.

A total of 67 individuals completed the survey, and results were shared with the working group through

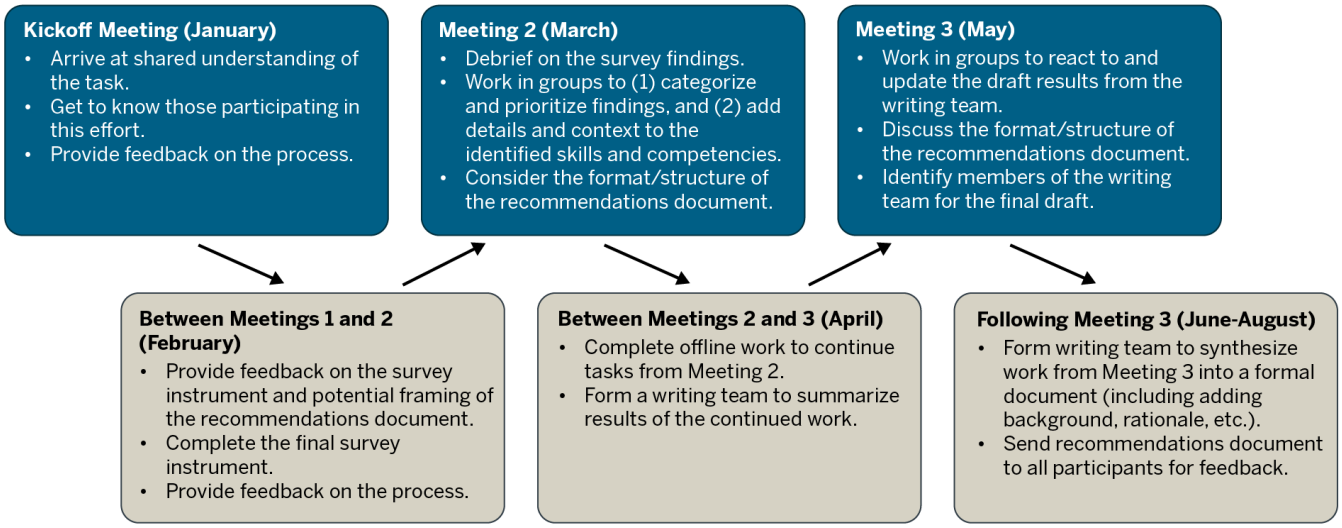
graphical displays that depicted the breakdown of responses for each survey item. Survey items were classified into one of four categories based on the percentage of respondents who identified the item as "essential" for nursing practice (0–25%, 25–50%, 50–75%, 75–100%).

These results served as the basis for discussion for the second working group meeting. In March 2022, participants collaborated in small groups to confirm, organize, and provide context to the items identified by the majority as "essential." The working group also discussed which items might be more appropriate for nursing students at the baccalaureate level.

After this meeting, a small writing team drafted a document that served as the focus for the third and final virtual meeting, where members provided feedback. Another writing team synthesized all of the information into a final draft, which was then shared with the working group for final comments and suggested revisions.

A summary of the process is detailed in the figure below.

Figure 1: The Arkansas Math for Nursing Working Group's process for identifying the quantitative skills and competencies necessary for quality and safe nursing practice.



Results

The following sections represent the findings of the working group. Identified essential skills and competencies for nursing students are organized within six domains: Number and Operation; Measurement; Percentage, Ratio, and Proportion; Probability and Statistics; Practices, Processes, and Dispositions; and Algebra, Functions, and Modeling.

Within most of the domains, the identified skills and competencies are presented in tables: The first column lists the essential skill or competency, and the second column provides examples of contexts and problem situations requiring the associated skill or competency. Additional context is provided for all domains, including implications and points of discussion from virtual working group meetings and asynchronous work.

The examples, problem situations, and additional context in each section are not meant to be an exhaustive list; rather, this content should be viewed as a starting point to build future collaborative efforts among nursing, mathematics, and statistics educators.

Number and Operation

The working group identified five essential skills and competencies and related problem situations within the Number and Operation domain.

Students need to be able to...	In order to...
• Perform arithmetic operations with positive and negative numbers. • Demonstrate a conceptual understanding of positive and negative numbers.	• Understand data presented with positive and negative values when reading reports, such as bone density reports. • Gather, calculate, and interpret results of data in quality improvement/performance improvement measures. • Accurately calculate and interpret fluid volume balance and nutritional status.
• Perform arithmetic operations with rational numbers (fractions, decimals), with the aid of a calculator. • Demonstrate a conceptual understanding of rational numbers (fractions, decimals). • Convert between decimal and fraction representations, with the aid of a calculator.	• Calculate body surface area (BSA) and body mass index (BMI). • Calculate safe dosage for medications when performing conversions between measurement units. • Set up and calculate IV rates involving portions of an hour. • Calculate doses, including rounding when appropriate and necessary, to determine how much of a medication to draw or use. • Assure accuracy of weight-based dosing using fractions of a pound, kilogram, pounds to ounces, and kilograms to grams. • Discuss the precision of instruments, such as syringes, pills, IVs, etc. • Solve problems involving fractional values (e.g., add the fractional portion of two beverages consumed to identify total fluid intake). • Complete conversions in medication dosage problems (converting mcg to mg, mg to gram). • Recognize and discuss rational numbers in context, including those presented in research results. • Perform and teach patients dilution of solutions/mixture problems (e.g., how to prepare 500mL of ⅔ strength solution). • Compare relative differences in dosage (e.g., 50 mg is less than twice 30 mg).

Discussion and Implications

At all levels of nursing education, a functional understanding of numbers and operations is required to complete everyday nursing tasks. In general, and consistent with discussions in the working group meetings, the identified skills and descriptions of how they would be applied in the care of patients suggest that nurses must be able not only to simplify numerical expressions accurately with the aid of

technology, but also demonstrate a deeper and flexible understanding in order to interpret numbers in context and communicate quantitative results to peers and colleagues. Therefore, these skills should be explicitly and purposefully explored and emphasized in any mathematics course that nursing students take.

The working group noted that, although many of the skills and competencies within this domain are foundational in the study of mathematics, students often arrive to their programs underprepared or requiring review to refresh their knowledge of these skills. It is therefore essential that faculty and institutions ensure additional resources are in place to identify and support these students. Institutions should provide opportunities (e.g., corequisite support, guiding students to existing online resources) for students to build and strengthen the necessary skills instead of preventing them from continuing in their programs and pursuing a nursing career.

Measurement

The working group identified three essential skills and competencies and related problem situations within the Measurement domain.

Students need to be able to...	In order to...
• Measure and estimate length, weight, and volume in standard and metric units.	• Measure a patient's height and weight. • Measure lesions, wounds, tumors, pupil dilation, etc. • Measure liquid medications and volume intake/output. • Administer ointment medications by a particular length.
• Demonstrate an understanding of relative sizes of units within and between measurement systems (e.g., mg vs. g vs. oz).	• Estimate U.S. standard units relative to metric units and back. • Recognize when a measurement (e.g., BSA, BMI, temperature) may not be accurate. • Identify calculation errors in practice.
• Convert units within and between systems of measurement with any computational method, such as dimensional analysis or ratios and proportions.	• Calculate dosage and infusion rates. • Calculate intake and output measurements. • Communicate relevant health measurements and instructions to patients and families so that they can be understood and followed.

Discussion and Implications

Everyday nursing tasks require the skills and understanding to measure mass, volume, and length accurately with a variety of instruments. Nurses must also be able to convert between measured units accurately within a variety of contexts, such as when charting intake and output, calculating dosage, and determining infusion rates. While obtaining an accurate solution to a measurement or conversion task is essential for safe practice, nurses' confidence in their ability to communicate quantitative ideas and solution strategies is also important. Additionally, because conversions are commonly completed by a peer or a pharmacy technician, nurses must develop skills in performing accurate estimations and identifying errors in practice. As students progress in their nursing programs, their ability to make medication-specific estimations and understand "reasonable" contextual measurements should be connected to the strategies and their foundational understanding of estimation and accuracy developed in a math course.

A final point of discussion that arose in working group sessions was the "debate" over the most appropriate computation method to complete conversion tasks—formula methods, dimensional analysis, or ratios and proportions. Although specific situations might necessitate one method over another, members of the working group recognized the importance of being able to utilize and make connections between all methods. This skill is especially valuable given the emphasis placed on confirming already completed calculations and communicating quantitative information to patients and their families. The working group recommended that mathematics and nursing educators collaborate to develop materials and strategies that clearly connect the different methods throughout the math and nursing coursework. Further, faculty should allow students to use a variety of effective strategies when appropriate, provided the student is able to explain their reasoning and reach a correct solution.

Percentage, Ratio, and Proportion

The working group identified five essential skills and competencies as well as example contexts within the Percentage, Ratio, and Proportion domain.

Students need to be able to...	In order to...
• Find a percentage of a quantity as a rate per 100.	• Determine amount of oral intake. • Estimate the amount of consumption in intake/output situations. • Calculate percentage of body surface area burned.
• Convert between percentages, fractions, and decimal representations with the aid of a calculator.	• Recognize equivalency of values represented as fractions, decimals, and/or percentages. • Calculate intake and output. • Interpret problems involving percentage increases such as infection control rates.
• Construct ratios and proportions, and describe the relationship between the quantities involved.	• Calculate intake and output. • Calculate dosage. • Complete conversion problems.
• Compute unit rates and use them to address problems.	• Initiate and manage critical care drip medications. • Calculate infusion rates for IV pumps and manual tubing situations. • Convert within and between the Metric System and U.S. Customary System for dosage calculations.
• Reason with ratios, rates, and percentages without the aid of a calculator.	• Interpret vital statistics in context, such as BMI, percent of body surface area burned, or topical medication absorption rates. • Develop critical thinking and reasoning habits of mind to determine if the solution is reasonable in the given context. • Estimate quantities. • Identify errors in practice.

Discussion and Implications

As noted in the previous section, the working group recommended that nursing students utilize ratio/proportion, formula, and dimensional analysis methods to solve problems. While one method may be more intuitive for the student in making most of calculations, there is a need to have an understanding of each of the three methods. The components of each method, as well as the relationships between them, should be explicitly and purposefully explored and emphasized in any math course that nursing students take.

Students should also be comfortable scaling ratios, understanding unit rates and ratios, and deciding in which order a ratio should be presented to be the most useful in a given context. Not only should students understand these concepts, but they must also be confident in their reasoning, able to justify their work to colleagues, and work comfortably with or without a calculator.

Probability and Statistics

The working group identified two essential skills and competencies and related problem situations within the Probability and Statistics domain.

Students need to be able to...	In order to...
• Interpret tables, charts, and graphical displays of summary data.	• Understand publications and reports. • Evaluate clinical contexts to make informed decisions. • Identify misleading charts, tables, and graphics in media, and communicate that information to patients to help improve their understanding.
• Calculate and interpret measures of center (mean, median, midrange) and measures of variation (standard deviation, range) in context.	• Determine if medication needs to be given or adjusted based on the measures and trends. • Determine if a value is within a reasonable range. • Recognize when a patient is outside of the “norm” and communicate that to their PCP. • Communicate percentiles and measures of relative placement to patients and their families. • Calculate weighted averages.

Discussion and Implications

Nurses need to be able to understand and apply concepts related to charts and graphs in many settings, such as in tracking progress, identifying trends, determining if a value or calculation is significant and meaningful in context, and identifying outliers in data. Students should understand how to interpret measures of center and variation as well as how each of these measures are relevant within the nursing context. For example, some medications are adjusted in the critical care settings based on a patient’s mean arterial pressure. Although not all students will go on to practice in the critical care settings, they all will be tested on these concepts in their programs and to some extent on their national exam, the National Council Licensure Examination (NCLEX).

The working group identified some skills in statistics that would be essential in only certain settings. Notably missing from the table are concepts from inferential statistics, statistical design, and probability.

Students would benefit from some basic knowledge of how statistical information is reported in health care reports. For example, t-scores are reported for bone density, where a negative score would indicate a patient is at risk for osteoporosis or has osteoporosis. A nurse should be able to advise on safety and nutrition of high calcium foods.

Additionally, students would benefit from understanding the data reported on infection rates and how to interpret that data for a patient whom they need to educate and encourage to be vaccinated. It would also be helpful for students to have knowledge of other statistical concepts (e.g., conditional probabilities, two-way tables, confidence intervals) to enable them to evaluate publicly available information for accuracy and to help decrease sharing of misinformation on many health issues such as vaccination risks and benefits.

Just as not all students will practice in critical care settings, not all students will pursue a Bachelor of Science in Nursing (BSN) or additional degrees. A BSN student may need more statistical knowledge and skills for research courses and to participate in identifying possible questions to seek evidence-based nursing information. Students completing a BSN program are required to complete a research course where statistical knowledge would support deeper understanding of the concepts in the course. BSN students must also complete population health courses that focus on public health concepts involving infection rates, prevalence, and community health assessments that would include measures reported in statistical terms.

Practices, Processes, and Dispositions

The working group identified essential skills and competencies that are common across all content-specific domains stated above. Many items in this domain are based on the Standards for Mathematical Practice (National Governors Association, 2010) and the strands of Mathematical Proficiency (National Research Council, 2001).

As noted in the previous sections, students need to be able to:

- Identify errors in a peer's arithmetic work and/or mathematical reasoning.
- Assess the "reasonableness" of a calculation and/or solution to a problem.
- Demonstrate an attention to precision.
- Communicate mathematical and statistical information effectively.

The following skills were also identified by the working group as "essential." Students need to be able to:

- Reason abstractly and quantitatively.
- Identify essential and extraneous information in the context of a problem.
- Demonstrate confidence in their mathematical abilities.
- Demonstrate a growth mindset when learning mathematics/statistics and perceive the skills as essential and useful in one's work.

Discussion and Implications

Nursing students must work on becoming competent in many skills to provide safe care for their patients. They need opportunities to practice and develop their abilities to evaluate a peer's work, assess reasonableness and precision of an answer, communicate mathematically, and critically analyze and solve problems.

It is also important to help students realize that multiple distractions in health systems can create the potential for error. Therefore, nurses must be able to filter extraneous information and identify the assessment data or dosage information they need to complete a task. Nurses need to be able to recognize when information is extraneous or necessary to complete a problem, if values need to be converted or modified prior to being used, and explain whether and why each piece of information is needed.

Finally, in keeping with the literature related to students' mathematical learning and persistence, students should be provided with opportunities to develop and practice a growth mindset. Support for a growth mindset aligns with the earlier recommendation to provide additional support for students who are deemed underprepared mathematically to enter the nursing program. A growth mindset better positions students to respond to new tasks that they will inevitably encounter in nursing practice.

Algebra, Functions, and Modeling

The working group did not identify any essential skills or competencies within the Algebra, Functions, and Modeling domain—a significant finding, as many institutions require nursing students to take an algebraically intensive mathematics course such as College Algebra. Although algebra is relevant in

many real-world contexts, the content traditionally included in an algebra course does not align with the specific skills needed for nursing. Institutions should examine and consider requiring other mathematics courses as an alternative to College Algebra for nursing students.

Notably, the working group identified algebraic skills that could be essential depending on the other courses required for nursing students. For example, many BSN programs require additional chemistry and science coursework that might need specific linear, logarithmic, and exponential equation skills.

Implications and Recommendations

The work summarized in this document is a crucial first step in ensuring that nursing students in Arkansas learn the appropriate mathematical and statistical skills for safe practice. It is, however, only the beginning of the work towards consistent and appropriate mathematics alignment within and through the nursing education path.

This section provides additional direction and potential opportunities for Arkansas to continue the collaborative work between mathematics and nursing educators based on the recommendations in *Convening Recommendations: Math and Statistics Education for Nurses* (Ozimek et al., 2021).

- Convening recommendation #2: ***Investigate*** *the most appropriate sequencing of mathematics, statistics, and nursing educational offerings to ensure students acquire essential quantitative skills and competencies for quality and safe nursing practice*.

  Math and nursing faculty in Arkansas should consider the common gateway math courses in the state (College Algebra, Quantitative Reasoning, Statistics) and identify which course contains the best alignment with the topics identified in this document. While there may be no single course that includes all topics, a working group could recommend (1) creating a new course intended to serve students in nursing (and possibly the broader healthcare professions) that includes a majority of the listed topics; (2) requiring an existing course that covers many of the topics and then developing resources and materials to support nursing students in learning the additional topics at appropriate times throughout their programs, as indicated by recommendation #4 below; or (3) doing some combination of both.

  Additionally, a future working group could consider including faculty from departments that offer other STEM courses required for nursing students (e.g., chemistry, anatomy, physiology) to ensure that mathematical skills needed for those courses are also being considered, even if those skills are not specifically necessary for nursing practice.

- Convening recommendation #3: ***Incorporate*** *recommendations and best practices in nursing, mathematics, and statistics education in the design of learning outcomes, instruction, materials, and assessments*.

  Evidence-based strategies and recommendations from national math and nursing education organizations should guide the future development of quantitative educational practices in Arkansas nursing programs. In addition to ensuring that the pedagogical strategies follow the best practices of the mathematics and nursing education fields, the working group may want to provide statewide suggestions for a continuous, improvement-based assessment model for nursing students, in line with recommendation #6 below.

- Convening recommendation #4: ***Integrate*** *learning experiences throughout the nursing curriculum that provide learners an opportunity to develop sound quantitative reasoning, data reasoning, and*

clinical judgment.

The High-Quality Mathematics Education for Nurses Task Force felt that it is important to reject a "once-and-done" mentality about quantitative education in the nursing curriculum. A student's quantitative education should not be defined by passing a mathematics or statistics course; rather, it should include quantitative learning experiences that are explicitly embedded throughout the curriculum.

Now that Arkansas has identified a list of essential skills for nursing students, the conversation about how and when nursing students should be introduced to specific concepts, and when those concepts should be reinforced within the nursing curriculum, should continue. Math and nursing faculty may want to develop lectures, seminars, and activities that can be incorporated into nursing courses, when appropriate, to remind students of skills they learned in prior math courses. These resources should be designed with pedagogical best practices in mind, as indicated in the previous recommendation.

- Convening recommendation #6: ***Incorporate*** *assessment measures that reflect changing licensure/certification requirements, integrate quantitative and data reasoning with components of clinical judgment, and provide learners the opportunity for continuous improvement (rather than serving only as a high-stakes benchmark for academic progression)*.

  To foster a culture of continuous improvement, educators in Arkansas should collaborate to develop and incorporate valid, competency-based assessments, especially those that require nursing students to use critical thinking and psychomotor skills necessary for safe nursing practice. For example, simulations, case studies, and clinical-based activities can provide a safe and controlled environment for learners to build confidence and develop sound quantitative reasoning, data reasoning, and clinical judgment. If math and nursing faculty develop assessment tools collaboratively, they can ensure that the mathematical and nursing skills are represented and assessed in ways that support student learning and continued understanding of the relevance and importance of accurate mathematics in the nursing setting.

- Convening recommendation #7: ***Inform*** *the community through collaborative engagements and professional development opportunities that integrate best practices from nursing, mathematics, and statistics education*.

  The working group acknowledged that some of the recommendations and associated implications in this document may cause discomfort to math and nursing faculty. It is important to identify the needs of math and nursing faculty, develop resources to address those needs, and encourage engagement in state-supported, cross-disciplinary professional learning opportunities. As current and future working groups continue to consider how to improve math education for nursing students, a concurrent consideration should be how to best support faculty in implementing future recommendations.

The collaborative efforts of mathematics and nursing faculty in Arkansas demonstrate how this type of work can be done in other states to ensure that students receive the appropriate quantitative education that supports, rather than "weeds out," future nurses in their safe and effective practice. This document should inform nursing departments as they revise their programs to meet new standards published by regional and national organizations to provide students with the quantitative skills necessary to meet those standards and expectations. Rather than rely on old course definitions and math requirements, this ongoing collaboration and reflection will ensure that nursing students are prepared to enter an ever-changing field that requires new and emerging technical and mathematical skills.

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About this resource

About the Charles A. Dana Center

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.

We focus in particular on strategies for improving student engagement, motivation, persistence, and achievement.

The Center was founded in 1991 at The University of Texas at Austin. Our staff members have expertise in leadership, literacy, research, program evaluation, mathematics and science education, policy and systemic reform, and services to high-need populations.

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