



Dana Center  
**Mathematics**  
PATHWAYS



The University of Texas at Austin  
**Charles A. Dana Center**

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# Mathematics for pre-service elementary (K–5) teacher education:

*Recommendations from professional organizations and requirements from the higher education sector*

## Pre-service elementary teacher education in the United States

The mathematics education of elementary school teachers is a complex and critically important enterprise. Mathematics professional associations and mathematics education organizations, including the Conference Board of the Mathematical Sciences (CBMS), the National Council of Teachers of Mathematics (NCTM) and the National Mathematics Advisory Panel (NMAP), have reached broad consensus on the mathematics content and process standards that educators need to teach mathematics effectively in grades

*We provide these briefs to inform institutional discussions about the modernization of mathematics course requirements.*

*Each brief examines what constitutes relevant math for various majors (thus far, nursing, communications, criminal justice, social work, elementary teacher education, and business) by examining professional organization recommendations and institutional requirements.*



K–5 (CBMS, 2001, 2012; NCTM, 2000, 2006; NMAP, 2008). However, there is wide variation in state standards and institutional practices regarding mathematics courses for elementary teachers (Greenberg & Walsh, 2008; Tatto et al., 2008, p. 20). States and institutions of higher education have not established coordinated systems that align teacher preparation standards with the recommendations

of mathematics professional associations (Center for Research in Mathematics and Science Education, 2010; Greenberg & Walsh, 2008; Greenberg, Walsh, & McKee, 2015).

The mathematics knowledge and skills that students learn in grades K–5 provide an essential foundation for their quantitative literacy and for more advanced mathematics pursuits. According to Dr. Kenneth Gross, a mathematics professor at the University of Vermont, “all of mathematics depends on what kids do in the elementary grades. If you don’t do it right, you’re doing remedial work all the way up to college” (Glod, 2007). Elementary teachers play a critical role in this process, as the teaching that students encounter in school shapes their ability to use mathematics to solve problems and influences their confidence in and disposition toward mathematics (NCTM, 2000, p. 16–17).

Research shows that improving the mathematics knowledge of prospective elementary teachers supports student success in mathematics (Hill, Rowan, & Ball, 2005). Teachers who serve grades K–5 have unique needs for mathematical preparation, which involves a profound conceptual understanding of elementary mathematics (Ma, 1999). Scholarly research in this area has been shaped by Schulman’s (1987) description of three categories of teachers’ knowledge: mathematics content knowledge (fundamental assumptions, definitions, concepts, and procedures), mathematics pedagogy knowledge (insight into how students think about mathematics and teaching skills to influence student understanding), and curricular knowledge (understanding how mathematics topics are arranged across schooling experiences) (Tatto et al., 2008, p. 19). The CBMS (2001) contends that college mathematics courses for pre-service elementary teachers should strengthen these components of teachers’ knowledge by making connections between the content being studied and the mathematics that teachers will deliver.

Recommendations of the mathematics professional associations and the research on which they are based are consistent with the Dana Center Mathematics Pathways (DCMP) model—that institutions of higher education should offer multiple mathematics pathways with relevant and challenging mathematics content aligned to specific programs of study.

This brief explores the question of relevant mathematics for elementary teachers by examining recommendations by professional organizations and requirements from institutions.



## Recommendations from professional organizations of education and mathematics

We reviewed reports by professional associations of mathematics, teacher education organizations, state governments, and scholarly research to identify the recommended structure and content of mathematics courses for elementary teacher preparation. Findings include:

- *Design course structure and content based on expert recommendations.* Current research and professional consensus support the conclusion that elementary teachers need courses that include the following content:
  - *Mathematics content knowledge* – The CBMS (2001, 2012) reports call for a thorough development of basic mathematics content knowledge, which for elementary students includes numbers and operations, algebra and functions, geometry and measurement, and data analysis. In addition to the CBMS (2001, 2012) and the National Research Council (2001, 2010) reports, mathematics faculty interested in deeper understanding of professional recommendations and research on teachers' mathematics content knowledge should review the following: Ball, Lubienksi, and Mewborn, 2001; Ball, Thames, and Phelps, 2008; Milgram, 2005; and Thames, 2006.
  - *Mathematics pedagogy knowledge* – The CBMS (2012) recommends that mathematics pedagogy courses for elementary teachers should develop the habits of mind of a mathematics thinker and problem-solver, “such as reasoning and explaining, modeling, seeing structure, and generalizing, courses should also use the flexible, interactive styles of teaching that will enable teachers to develop these habits of mind in their students” (p. 19). International comparative studies show that the highest performing countries in mathematics teacher education address how teachers should think about mathematics, teaching, and learning (Tatto et al., 2008, p. 20).
  - *Curricular knowledge* – Mathematics courses for elementary teachers should highlight curricular connections between elementary topics and more advanced mathematics that students will encounter in middle school (CBMS, 2012, p. 25). The National Mathematics Advisory Panel (2008) argues that teachers must know in detail and from a more advanced perspective the mathematics content which they are responsible for teaching and the connections of that content to other important mathematics, both prior to and beyond the level they are assigned to teach (p. xxii).
- *Eliminate general education mathematics prerequisites.* Experts recommend that mathematics courses for elementary teachers should not have general education prerequisites such as intermediate algebra, college algebra, mathematical modeling, math for liberal arts, or calculus (CBMS, 2001, ch. 2; CBMS, 2012, p. 32; Greenberg & Walsh, 2008, pp. 25–26). Given the unique nature of elementary mathematics, it is unlikely that teachers can acquire the pedagogical content or curricular knowledge required for effective teaching through courses designed for a general audience.
- *Require 9–12 semester-credit hours.* Pre-service elementary teachers should complete a minimum of 9–12 semester-credit hours of specialized courses in mathematics. The CBMS (2001) and the Massachusetts Department of Education (2007) recommend that pre-service elementary teachers take a minimum of 9 semester-credit hours on the fundamental ideas of elementary mathematics. The CBMS (2012) report revises this recommendation to 12 semester-credit hours and suggests the following distribution of time for specific content areas: 6 hours for numbers and operations treated algebraically, and measurement, data, geometry, and additional algebraic ideas with the remaining 6 hours (pp. 18, 31).
- *Interweave content and methods in mathematics courses.* A goal of professional mathematics associations is for both teachers and students to view mathematics as an integrated, coherent sequence of ideas. Teacher preparation programs should be structured to support this goal and CBMS (2012) recommends that



program designers consider courses that blend the study of content and pedagogy (p. 32). Graham and Fennel (2001) observe that content courses and pedagogy courses are often split between mathematics departments and education departments, respectively, with education department administrators often determining the required mathematics courses (p. 321). Ball and Bass (2000) contend that this splintering in preparation leaves teachers with the challenge of integrating content knowledge with pedagogy in the context of their work (p. 86). The current division in the administration of teacher preparation programs presents an opportunity for mathematics faculty to lead cross-departmental collaboration to design courses that support integrated content knowledge and pedagogy skills.

- *State policy should formalize course-taking requirements.* Massachusetts is a leading example of a state that enacted a robust policy to strengthen the mathematics education of elementary teachers. In 2007, the Massachusetts Department of Education issued guidelines for institutions training elementary teachers based on the recommendations of the NCTM, CBMS, U.S. Department of Education, and Mathematical Sciences Research Institute (MSRI). The state guidelines specify that students should take at least 9 hours of coursework that spend proportional amounts of time on the following core topics: number and operations (45 percent), functions and algebra (25 percent), geometry and measurement (20 percent), and statistics and probability (10 percent) (Massachusetts Department of Education, 2007, p. 4).

*Institutions . . . should offer multiple mathematics pathways with relevant and challenging mathematics content aligned to specific programs of study.*





## Current status of mathematics course requirements for elementary teachers

While professional associations have clear, research-based proposals for content and structure of mathematics courses for elementary teachers, the adoption of these recommendations varies widely at the state, institution, and department levels.

Unlike for most postsecondary majors in which academic departments set course requirements, guidelines for teacher preparation programs are established at the state level through political processes that often involve legislatures, education agencies, boards of education, and professional standards boards. Consequently, there is no consistency among the states regarding the mathematics coursework required for elementary teachers. According to Greenberg and Walsh (2008), 18 states have no requirements pertaining to specific areas of math; 1 state has requirements only for geometry; 3 states have requirements only for foundations of mathematics and geometry; and 29 states have requirements only for foundations of mathematics, algebra, and geometry (p. 35).

At the institutional level, the number of students entering elementary teacher education programs is growing each year. According to the 2010 CBMS survey of mathematics departments, 72 percent of 4-year mathematics departments reported belonging to an institution that offers a teacher certification program for some or all grades in K–8 (Blair, Kirkman, & Maxwell, 2013, p. 48). Enrollments in mathematics courses designed for pre-service elementary teachers increased by 36 percent between 1995 and 2010, with 80,000 enrolled in 2010 (Blair et al., 2013, p. 114).

Two-year colleges also play an increasingly important role in the preparation of math teachers (Coulter & Vandal, 2007; Schuhmann, 2002). Two-year colleges have shown the largest increases in certification programs at the elementary level: 41 percent have programs that allow students to complete their entire mathematics course requirements for certification (Blair et al., 2013, p. 49). From 2000–2010, enrollments in math courses for elementary school teachers at 2-year colleges have more than doubled, from 18,000 in 2005 to 29,000 in 2010 (Blair et al., 2013, pp. 49, 137, 180). Because a significant number of elementary teachers complete their mathematics training at 2-year colleges, the CBMS (2001) calls for increased cooperation between 2-year and 4-year colleges in the mathematics education of teachers.

Finally, analyzing course-level data is complicated because of variation in how teaching certificates are awarded at the state and institutional levels (McCrary & Cannata, 2011, p. 31). For example, the teacher education standards outlined by the professional associations are split into grade ranges K–5, 6–8, and 9–12 to reflect the increasing complexity of algebra-intensive content as students progress through school. However, most states' certification requirements do not follow this pattern. In some states, for example, elementary teachers are certified to teach all subjects for grades K–8, while in other states, elementary generalist certificates are split between lower elementary (grades K–3) and upper elementary (grades 4–6), with distinct course requirements for each grade range.

Evidence indicates that elementary teacher programs do not currently require a sufficient level of semester-credit hours to cover the fundamental ideas of elementary mathematics in sufficient breadth or depth. According to data from the Mathematics Education of Elementary Teachers project at Michigan State University, 30 percent of K–4 teachers take only one mathematics class and 50 percent take two or fewer (MSRI, 2009, p. 11). Survey data further suggest that only 10 percent of teachers complete the equivalent number of courses that cover the core topics (numbers and operations, algebra, geometry, measurement, data analysis) recommended for elementary teachers by NCTM (Banilower et al., 2013, p. 18). A large national survey of institutions that offer specialized math courses for elementary teachers found that “the majority of...institutions are not meeting the recommendations of the Conference Board of the Mathematical Sciences, the NCTM, and the National Center on Teacher Quality for prospective elementary teachers to take at least nine credits of mathematics content designed specifically for them” (Masingila, Olanoff, & Kwaka, 2012, p. 353). These findings suggest that states and institutions of higher education need to work together in reviewing and strengthening mathematics course-taking requirements for pre-service elementary teachers to align with recommendations of professional associations.

## Conclusion

Strengthening the mathematics education of teachers is crucial to address what the CBMS (2001) refers to as a “vicious cycle” in which prospective teachers enter preparation programs with insufficient knowledge of elementary mathematics, receive little instruction grounded in the mathematics they are expected to teach, and finally enter the classroom without the knowledge or skills to prepare the next generation of students (p. 5). The research regarding what mathematics knowledge and skills that elementary teachers should learn is summarized in key documents by professional organizations of mathematics. Mathematics faculty, education faculty, higher education administrators, and state decision makers should coordinate policies and standards that align teacher mathematics preparation with the recommendations of professional organizations, which include at least 9–12 hours of mathematics coursework, with no general education mathematics prerequisites, that integrates content, pedagogy, and curriculum knowledge to strengthen prospective elementary teachers’ mathematics abilities.

## References

- Ball, D.L., & Bass, H. (2000). Interweaving content and pedagogy in teaching and learning to teach: Knowing and using mathematics. In J. Boaler (Ed.), *Multiple perspectives on mathematics teaching and learning* (pp. 83–104). Westport, CT: Ablex Publishing.
- Ball, D. L., Lubienski, S., & Mewborn, D. (2001). Research on teaching mathematics: The unsolved problem of teachers’ mathematical knowledge. In V. Richardson (Ed.), *Handbook of research on teaching* (4th ed., pp. 433–456). New York: Macmillan.
- Ball, D. L., Thames, M. H., & Phelps, G. (2008). Content knowledge for teaching: What makes it special? *Journal of Teacher Education*, 59(5), 389–407.
- Banilower, E. R., Smith, P. S., Weiss, I. R., Malzahn, K. A., Campbell, K. M., & Weis, A. M. (2013). *Report of the 2012 national survey of science and mathematics education*. Chapel Hill, NC: Horizon Research, Inc.
- Blair, R., Kirkman, E. E., & Maxwell, J. W. (2013). *Statistical abstract of undergraduate programs in the mathematics sciences in the United States: Fall 2010 CBMS survey*. Providence, RI: American Mathematical Society. Retrieved from <http://www.ams.org/profession/data/cbms-survey/cbms2010-Report.pdf>.
- Center for Research in Mathematics and Science Education. (2010). *Breaking the cycle: an international comparison of U.S. mathematics teacher preparation*. East Lansing, MI: Michigan State University.
- Conference Board of the Mathematical Sciences. (2001). *The mathematical education of teachers*. Issues in Mathematics Education, Volume 11. Washington, D.C.: American Mathematical Society. Retrieved from [http://cbmsweb.org/MET\\_Document/](http://cbmsweb.org/MET_Document/).
- Conference Board of the Mathematical Sciences. (2012). *The mathematical education of teachers II*. Issues in Mathematics Education, Volume 17. Providence, RI: American Mathematical Society. Retrieved from <http://cbmsweb.org/MET2/met2.pdf>.
- Coulter, T., & Vandal, B. (2007, May). *Community colleges and teacher preparation: Roles, issues and opportunities* (Issue Paper). Denver, CO: Education Commission of the States. Retrieved from <http://files.eric.ed.gov/fulltext/ED496574.pdf>.
- Glod, M. (2007, December 26). Elementary math grows exponentially tougher. *The Washington Post*. Retrieved from <http://www.washingtonpost.com/wp-dyn/content/article/2007/12/25/AR2007122501423.html>.
- Graham, K. J., & Fennell, F. S. (2001). Principles and standards for school mathematics and teacher education: Preparing and empowering teachers. *School Science and Mathematics*, 101(6), 319–327.
- Greenberg, J., & Walsh, K. (2008). *No common denominator: The preparation of elementary teachers in mathematics by America’s education schools*. Washington, DC: National Center on Teacher Quality. Retrieved from [http://www.nctq.org/dmsView/No\\_Common\\_Denominator\\_NCTQ\\_Report](http://www.nctq.org/dmsView/No_Common_Denominator_NCTQ_Report).

- Greenberg, J., Walsh, K., & McKee, A. (2015). *2014 teacher prep review: A review of the nation's teacher preparation programs*. Washington, DC: National Center on Teacher Quality. Retrieved from [http://www.nctq.org/dmsView/Teacher\\_Prep\\_Review\\_2014\\_Report](http://www.nctq.org/dmsView/Teacher_Prep_Review_2014_Report).
- Hill, H. C., Rowan, B., & Ball, D. L. (2005). *Effects of teachers' mathematics knowledge for teaching on student achievement*. *American Educational Research Journal*, 42(2), 371–406.
- Ma, L. (1999). *Knowing and teaching elementary mathematics: Teachers' understanding of fundamental mathematics in China and the United States*. Mahwah, NJ: Lawrence Erlbaum Associates.
- Masingila, J. O., Olanoff, D. E., & Kwaka, D. K. (2012). Who teaches mathematics content courses for prospective elementary teachers in the United States? Results from a national survey. *Journal of Mathematics Teacher Education*, 15(5), 347–358.
- Massachusetts Department of Education. (2007). *Guidelines for the mathematical preparation of elementary teachers*. Malden, MA: Author. Retrieved from <http://www.doe.mass.edu/mtel/mathguidance.pdf>.
- Mathematics Sciences Research Institute. (2009). *Teaching teachers mathematics: Research, ideas, projects, evaluation* (edited by C. Kessel). Critical Issues in Mathematics Education Series, Volume 3. Retrieved from <http://library.msri.org/cime/CIME-v3-TTM-booklet.pdf>.
- McCrorry, R., & Cannata, M. (2011). Mathematics classes for future elementary teachers: Data from mathematics departments. *Notices of the American Mathematical Society*, 58(1) 29–35.
- Milgram, R. J. (2005). *The mathematics pre-service teachers need to know*. Stanford, CA: Author.
- National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*. Reston, VA: Author.
- National Council of Teachers of Mathematics. (2006). *Curriculum focal points for prekindergarten through grade 8 mathematics: A quest for coherence*. Reston, VA: Author.
- National Mathematics Advisory Panel. (2008). *Foundations for success: The final report of the National Mathematics Advisory Panel*. Washington, DC: U.S. Department of Education. Retrieved from <http://www2.ed.gov/about/bdscomm/list/mathpanel/report/final-report.pdf>.
- National Research Council. (2001). *Adding it up: Helping children learn mathematics*. J. Kilpatrick, J. Swafford, and B. Findell (Eds.), Mathematics Learning Study Committee, Center for Education, Division of Behavioral and Social Sciences and Education. Washington, DC: National Academy Press.
- National Research Council. (2010). *Preparing teachers: Building evidence for sound policy*. Committee on the Study of Teacher Preparation Programs in the United States, Center for Education. Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.
- Schuhmann, A. M. (2002). *The community college role in teacher education: A case for collaboration* (Issue Paper). American Association of Colleges for Teacher Education.
- Shulman, L. (1987). *Knowledge and teaching: Foundations of the new reform*. *Harvard Educational Review*, 57(1), 1–23.
- Tatto, M. T., Schwille, J., Senk, S., Ingvarson, L., Peck, R., & Rowley, G. (2008). *Teacher Education and Development Study in Mathematics (TEDS-M): Policy, practice, and readiness to teach primary and secondary mathematics. Conceptual framework*. Amsterdam, The Netherlands: International Association for Educational Achievement (IEA). Retrieved from <http://files.eric.ed.gov/fulltext/ED542390.pdf>.
- Thames, M. H. (2006). *Using math to teach math: Mathematicians and educators investigate the mathematics needed for teaching*. Berkeley, CA: Mathematical Sciences Research Institute.





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