Unlocking Young Children's Potential: Governors' Role in Strengthening Early Mathematics Learning

Executive Summary

Studies find that the mathematics knowledge acquired in early childhood and early elementary grades is a critical foundation for long-term student success. A child's math ability when he or she enters school has proved a better predictor of academic achievement, high school graduation, and college attendance than any other early childhood skill. Early mathematics competency even predicts later reading achievement better than early literacy skills. Finally, high-quality early mathematics instruction supports later learning of the science, technology, engineering, and mathematics (STEM) skills U.S. employers are demanding.

Unfortunately, many students fail to master math skills and concepts during elementary school and develop negative attitudes about their ability to learn mathematics. By fourth grade, only 42 percent of U.S. students score at or above "proficient" levels on the National Assessment of Educational Progress.[1] By age 15, U.S. students score below international averages on standardized mathematics assessments.[2]

There is growing evidence that more and higher-quality early mathematics instruction could reverse these trends. Researchers have found that young children have significant and often untapped potential to understand math skills and concepts such as magnitudes, patterns, shapes, and measurement. State learning standards for preschool-aged children, however, underestimate their ability to master early mathematics concepts and often do not fully capture the emerging research on age-appropriate math skills. In addition, early childhood and elementary teachers often lack the preparation and professional development to effectively support students' math learning.

As governors respond to the need to significantly improve the quality of public education, they should consider incorporating stronger actions to improve mathematics instruction as part of their overall reform agenda. Governors can take the following actions to promote high-quality mathematics instruction for young children:

- Become a champion for improvements in the quality of early math education with legislators, business leaders, educators, parents, and students. Governors may choose to build support for early mathematics education within the context of existing policy priorities, such as pre-kindergarten expansion, early literacy, STEM education, or future workforce preparation.

- Align high-quality mathematics standards through the educational pipeline, and support appropriate use of student assessments to measure results. State leaders could consider raising standards for the math skills and concepts children should learn in their state's early learning guidelines. Revisions should reflect recent research on young children's capacity to learn math and align with kindergarten through grade 12 standards for college and career training readiness. Although high-stakes assessment is not appropriate for young children, state policymakers can support the use of student assessments to measure

[1] U.S. Department of Education, Institute for Education Sciences, *The Nation's Report Card 2013,* http://nationsreportcard.gov/reading_math_2013/#/what-knowledge (accessed September 19, 2014).

[2] U.S. Department of Education, Institute for Education Sciences, National Center for Education Statistics, Program for International Student Assessment, http://nces.ed.gov/surveys/pisa/pisa2012/pisa2012highlights_3_1.asp#table (accessed September 19, 2014).

statewide progress in early mathematics learning and allow teachers to better target student needs.

- Promote changes in policies that improve educator preparation and that support their capacity to teach mathematics to young children. Governors can look for opportunities to strengthen state policies that govern preparation, certification, and professional development for early childhood and early elementary teachers, as well as elementary school principals, to ensure that teachers have the expertise and support they need to effectively teach mathematics to young children.

Introduction

Although most governors are already leading state efforts to improve early literacy, emerging research suggests that they also should focus on improving young students' proficiency in mathematics.[3] In fact, the National Research Council's (NRC) recent report on the topic of early mathematics concludes that basic literacy should be defined to include both reading and math skills.[4] Studies find that children in early childhood and early elementary classrooms have greater potential to acquire math skills and concepts than many educators realize.[5] Moreover, recent studies find that early proficiency in mathematics predicts the long-term success of students better than any other early childhood skill.[6]

Unfortunately, the current approach to mathematics education is not tapping young children's potential. Observational studies of early childhood and early elementary classrooms find that educators often do not spend enough time on mathematics instruction, do not use quality instructional methods, and do not teach appropriately challenging material.[7] Not surprisingly, U.S. students fare poorly on national and international mathematics assessments in early grades and beyond.[8]

Those findings point to the need for greater attention to state policy strategies that can improve early mathematics education and yield long-term improvements in the skills of the U.S. workforce. As part of their larger education reform agendas, governors can lead the move to strengthen early mathematics education through three actions:

- Become a champion for improvements in the quality of early mathematics education with legislators, business leaders, educators, parents, and students;

- Align high-quality mathematics standards through the educational pipeline (from early education through high school), and support appropriate use of student assessment to measure results; and

- Promote changes in policies to improve educator preparation and support their capacity to teach mathematics to young children.

Why Should Governors Incorporate a Focus on Early Mathematics Education in Their Education Reform Agendas?

Early math abilities are a surprisingly important predictor of children's long-term success. Recent studies have found

[3] Kathy Christie and Stephanie Rose, *A Problem Still in Search of a Solution: A State Policy Roadmap for Improving Early Reading Proficiency* (Denver: Education Commission of the States, 2012), http://www.ecs.org/clearinghouse/01/04/41/10441.pdf (accessed September 19, 2014).

[4] Christopher T. Cross, Taniesha A. Woods, and Heidi Schweingruber, eds., *Mathematics in Early Childhood: Learning Paths Toward Excellence and Equity,* (Washington, DC: National Academy Press, 2009).

[5] Douglas H. Clements, Arthur J. Baroody, and Julie Sarama, *Background Research on Early Mathematics* (Washington, DC: National Governors Association, 2013).

[6] Greg Duncan and Katherine Magnusson, "The Nature and Impact of Early Achievement Skills, Attention Skills, and Behavior Problems," in *Whither Opportunity? Rising Inequality, Schools, and Children's Life Chances,* Greg Duncan and Richard Murnane, eds. (New York: Russell Sage Foundation, 2011), 47–70.

[7] See, for example, Douglas H. Clements and Julie Sarama, *Learning and Teaching Early Math: The Learning Trajectories Approach,* 2nd ed. (New York: Routledge, 2014); and Mimi Engel, Amy Claessens, and Maida Finch, "Teaching Students What They Already Know? The (Mis)Alignment Between Mathematics Instructional Content and Student Knowledge in Kindergarten," *Educational Evaluation and Policy Analysis* 35 no. 2 (2013): 157–178.

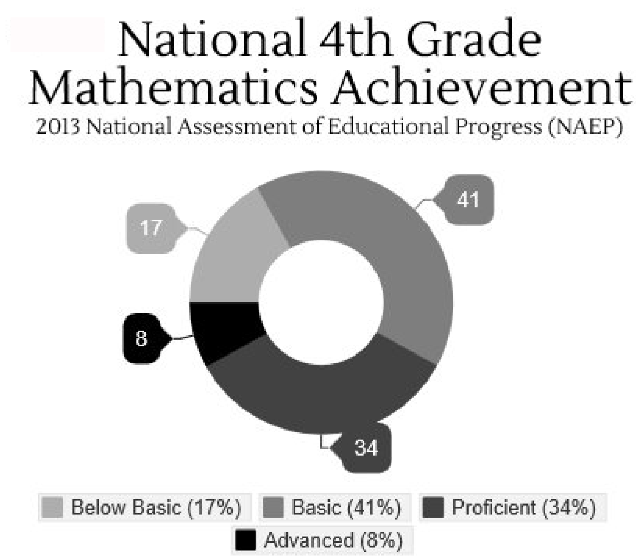
[8] See, for example, U.S. Department of Education, Program for International Student Assessment.

that a child's math ability when he or she enters kindergarten predicts academic achievement in elementary school, high school graduation, and college attendance better than any other early childhood skill. Math skills have even been shown to predict later reading achievement better than early literacy skills.[9] (See page 6 for more information about these findings.) Although researchers do not yet fully understand why early mathematics is so important, studies find that mathematics learning is closely tied to students' executive function skills—a set of cognitive processes, including problem solving, reasoning, working memory, and task flexibility—that supports student achievement across academic subjects.[10]

Unfortunately, U.S. students are not demonstrating proficiency in mathematics during early childhood or beyond. By fourth grade, only 42 percent of students score at or above "proficient" levels on the National Assessment of Educational Progress[11] (see Figure 1). Studies also find a significant achievement gap in mathematics learning by race, ethnicity, and family income as early as kindergarten and growing by fifth grade.[12]

In addition, Americans score low on international mathematics assessments compared with their peers in other countries. That trend has been documented for children as early as three to five years of age and worsens by the time they are in high school.[13] In 2012, U.S. 15-year-olds ranked 26th out of the 34 countries in the Organization for Economic Cooperation and Development (OECD) on the mathematics portion of the Program for International Student Assessment.[14] It is not surprising, then, that a different OECD study focused on adults (ages 16–65) finds that Americans lag behind international averages in

Figure 1. Early Mathematics Competency Predicts Later Success



[9] Duncan and Magnusson, "The Nature and Impact of Early Achievement Skills," 2011.
[10] John R. Best, Patricia H. Miller, and Jack A. Naglieri, "Relations Between Executive Function and Academic Achievement from Ages 5 to 17 in a Large, Representative National Sample," *Learning and Individual Differences* 21 no. 327 (2011): 327–336.
[11] U.S. Department of Education, *The Nation's Report Card 2013.*
[12] Douglas H. Clements, *Background Research on Early Mathematics*.
[13] Ibid.
[14] U.S. Department of Education, Program for International Student Assessment

Early Mathematics Competency Predicts Later Success

Researchers at the University of California, Irvine and the University of Wisconsin analyzed six large population-based data sets in an effort to understand which student attributes at school entry best predict later achievement, regardless of students' demographic backgrounds. Researchers looked specifically at the effect of early reading and mathematics competency, attention skills, and behavior problems. Key findings of that research include:

- Of all student measures at school entry, early mathematics competency is by far the strongest predictor of mathematics achievement in later elementary and middle school. Surprisingly, early mathematics competency also predicts later reading achievement more accurately than early literacy competency.[15]

- Early math abilities are the strongest predictor of high school graduation and college attendance. For example, children exhibiting persistent problems understanding mathematics in elementary school are 13 percent less likely to graduate from high school and 34 percent less likely to attend college than those who have stronger early mathematics abilities. Persistent problems learning to read in elementary school are less predictive of later outcomes[16] (see Figure 2 on page 5).

both numeracy and problem-solving skills.[17]

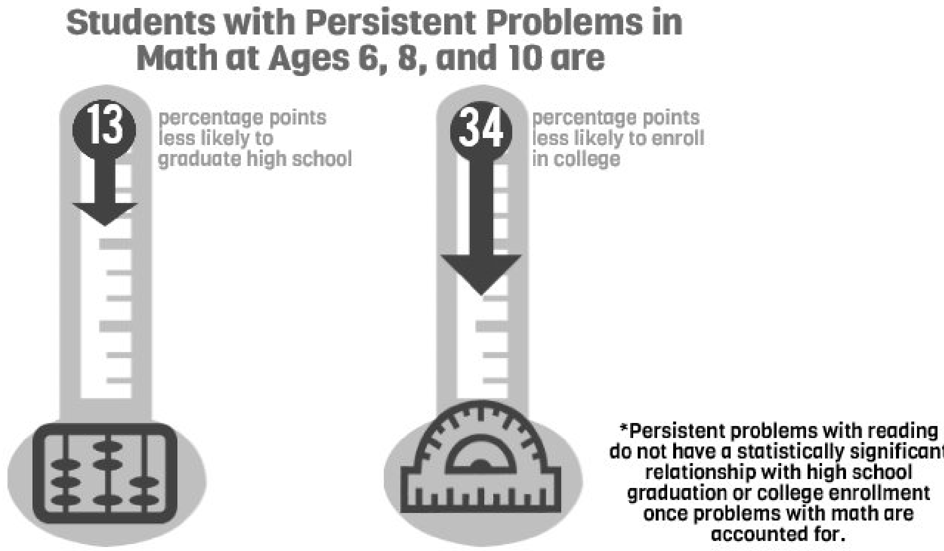
Finally, strengthening young children's competence in mathematics can help build students' science, technology, engineering, and mathematics (STEM) knowledge needed to sustain long-term growth and innovation in the U.S. economy. Many governors have STEM initiatives focused on older students, but students should be provided engaging and effective mathematics education as early as possible. Most young children report that they "like math," and a majority think that they are excellent or very good at it. Those measures slip considerably by seventh grade, with many students developing negative attitudes about their mathematics abilities.[18] A comprehensive state STEM agenda should include efforts to engage young children in early learning and elementary settings to help them develop positive attitudes about mathematics and an interest in pursuing more in-depth study of the subject.

Young Children Have the Capacity to Master More Rigorous and Complex Mathematics Concepts and Skills, but Current Policies and Practices Fail to Tap Their Potential

Research shows that young children have the potential to learn math skills and concepts beyond what many

[15] Duncan and Magnusson, "The Nature and Impact of Early Achievement Skills." This article summarizes findings from studies conducted on six longitudinal data sets by Duncan et al. (2007) and Duncan and Magnusson (2009).
[16] Ibid.
[17] Madeline Goodman et al., *Literacy, Numeracy, and Problem Solving in Technology-Rich Environments Among U.S. Adults: Results from the Program for the International Assessment of Adult Competencies 2012,* U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, http://nces.ed.gov/pubs2014/2014008.pdf (accessed September 19, 2014); and Organization for Economic Cooperation and Development, *United States: Adult Skills (Survey of Adult Skills, PIAAC),* http://gpseducation.oecd.org/CountryProfile?primaryCountry=USA&treshold=10&topic=AS (accessed September 19, 2014).
[18] PROMISE research, Phase 2 (June 2010)—see Douglas H. Clements, *Background Research on Early Mathematics*.

Figure 2. Students Who Have Persistent Problems in Mathematics Are Less Likely to Complete High School and Less Likely to Attend College



Source: *Whither Opportunity? Rising Inequality, Schools, and Children's Life Chances*

educators believe is possible. Young children can learn to compare magnitudes; understand patterns, shapes, and measurements; and count objects.[19] Researchers have found that even infants and toddlers can distinguish different numbers of items and that preschool-aged children are capable of estimating proportions as well as basic addition and subtraction.[20] Teachers working with young children, however, tend to underestimate their students' math abilities. For example, in one study, educators consistently misjudged how many students in their preschool classes could count nine marbles and how many students could complete a basic subtraction problem.[21]

There is evidence that high-quality and appropriately challenging mathematics instruction can help young children realize their math potential. (See page 6 for the key components of high-quality early mathematics education.) Two evidence-based curricula—Building Blocks and The Numbers World—significantly improve preschoolers' math abilities when used by trained educators.[22] For example, one study found that use of The Numbers World curriculum with a group of children from mixed-income backgrounds, starting in kindergarten, effectively closed the achievement gap in mathematics skills over three years.[23]

Unfortunately, most young children currently are not exposed to high-quality mathematics education. More than half of 3- and 4-year-olds in the United States do not attend any preschool program and have only informal mathematics learning experiences.[24] For

[19] Douglas H. Clements, *Background Research on Early Mathematics.*
[20] See, for example, Rochel Gelman, "Logical Capacity of Very Young Children: Number Invariance Rules," *Child Development* 43; Herbert Ginsburg and Amnon Rapparot, "Children's Estimates of Proportions," *Child Development* 1 (1967): 205–211; and Kelly S. Mix and Susan Cohen Levine, "Early Fraction Calculation Ability," *Developmental Psychology* 35 (1999): 164–174.
[21] See, for example, M. Van den Heuvel-Panhuizen, "Realistic Early Childhood Mathematics Instruction and Tests," in K.P.E. Gravenemijer, M. Van den Heuvel-Panhuizen, and L. Streefland, eds., *Context Free Productions Tests and Geometry in Realistic Mathematics Education* (Utrecht, The Netherlands: OW&OC, 1990).
[22] Julie Sarama and Douglas H. Clements, "Building Blocks for Early Childhood Mathematics," *Early Childhood Research Quarterly* 19 no. 181 (2004): 181–189; and Douglas H. Clements and Julie Sarama, "Experimental Evaluation of the Effects of a Research-Based Preschool Mathematics Curriculum," *American Educational Research Journal* 45 no. 443 (2008): 443–494.
[23] Douglas H. Clements and Julie Sarama, "Early Childhood Mathematics Intervention," *Science* 333 no. 6045 (August 2011): 968–970.
[24] U.S. Department of Education, United States Education Dashboard, http://dashboard.ed.gov/statechart.aspx?i=a&id=1&wt=0 (accessed September 19, 2014).

students in preschool classrooms, studies find that educators typically do not spend enough time on mathematics. A review of pre-kindergarten programs funded by states, for example, found that educators allocate an average of 8 percent of learning activity time to mathematics compared with more than 20 percent of time on literacy-based activities.[25]

Early elementary educators spend more time on mathematics than preschool teachers—about three hours per week in kindergarten—but that still trails the amount of time spent on literacy by two hours per week.[26] Moreover, elementary mathematics instruction is lacking in quality. Mathematics education is often integrated into other learning goals and activities (for example, discussing math while playing with blocks or counting during snack time). Although those activities can have value, an NRC analysis finds that they do not improve students' math abilities unless they are paired with more intentional mathematics instruction.[27]

Recently released studies find that, regardless of their background, young elementary school students would benefit from more challenging mathematics education.[28] For example, a 2013 study of kindergarten classrooms found a disparity between mathematics curriculum and students' abilities: Teachers spent significant time on concepts, such as counting and shapes, which most students had already mastered.[29] Although decisions about curriculum and use of class time are made at a local level, the gap between what young students can do and what they are offered underscores the need for state leadership in setting and implementing appropriate standards for what children should know and be able to do at each age and developmental stage. That creates an opportunity for states to help districts identify and implement effective curricula in their schools and professional development for their teachers.

High-Quality Early Mathematics Education: What the Research Shows

Research shows that high-quality mathematics instruction in early childhood and early elementary settings has the following characteristics:

- It uses a research-based curriculum that follows an intentional sequence of developing math skills in which children master one skill, and then another that builds on the preceding skill;
- It is taught through a mix of teacher-led direct instruction and student-centered exploration and practice;
- It focuses on building an understanding of mathematics concepts and skills;
- It includes engaging play-based activities with "teachable moments" about mathematics;
- It promotes family engagement and helps parents support children's mathematics learning; and
- It offers assessment and differentiated support for children who have learning disabilities in mathematics.[30]

[25] Diane Early et al., *Prekindergarten in Eleven States: NCEDL's Multi-State Study of Pre-Kindergarten and Study of State-Wide Early Education Programs (SWEEP)* (Chapel Hill, NC: University of North Carolina Press, 2005).
[26] Anna E. Bargagliotti, Cassandra M. Guarino, and William M. Mason, Mathematics Instruction in Kindergarten and First Grade in the United States at the Start of the 21st Century, California Center for Population Research, 2009.
[27] Christopher T. Cross, *Mathematics in Early Childhood*.
[28] Amy Claessens, Mimi Engel, and F. Chris Curran, "Academic Content, Student Learning, and the Persistence of Preschool Effects," *Academic Educational Research Journal* 51 no. 2, 2014: 403–434.
[29] Mimi Engel, "Teaching Students What They Already Know?"
[30] Summarized from Douglas H. Clements, et al, *Background Research on Early Mathematics*.

Finally, the poor quality of early mathematics instruction stems in part from early educators' lack of training and confidence to teach math skills and concepts effectively. Experts find that training programs for teachers often fail to model and support high-quality mathematics education in early childhood and early elementary classrooms.[31] Early childhood educators report that they find mathematics a difficult subject to teach, do not think that mathematics education is as necessary or appropriate as other skills, and feel underprepared by their training and preservice programs.[32] The research makes it clear that any state strategy to boost the quality of early mathematics instruction needs to include a focus on building the capacity of early educators to effectively teach mathematics. A state can do that through its authority over teacher certification and accreditation of teacher preparation programs as well as its policy and budgetary influence over teachers' professional development.

State Policy Recommendations

As governors explore options to strengthen early mathematics education in their states, they should focus on three key strategies:

- Become a champion for improvements in the quality of early mathematics education;
- Align high-quality mathematics standards through the educational pipeline, and support appropriate use of student assessments to measure results; and
- Promote changes in policies to improve educator preparation and support to build teachers' capacity to teach mathematics to young children.

Become a Champion for Improvements in the Quality of Early Mathematics Education

Governors have an opportunity to use the "bully pulpit" to start conversations with legislators, business leaders, educators, parents, and students about the importance of early mathematics learning as a foundation for long-term student achievement. Governors have been an important voice in recent years for expanding early learning opportunities and bolstering reading proficiency by third grade. Guided by research on early brain development as well as the return on investment from early learning programs, governors have raised awareness of early learning, championed new programs and increased budgets, and strengthened the role of private-sector partners. Depending on the existing state policy context, governors may choose to embed a message about the importance of early mathematics into existing policy priorities, such as expanding early learning opportunities, improving early literacy, or improving students' STEM skills.

Many governors are already pursuing an expansion of opportunities for high-quality early learning. In their 2014 State of the State addresses, for example, 22 governors highlighted plans to expand access to high-quality pre-kindergarten and full-day kindergarten.[33] As those governors work with state legislators on concrete policy proposals, they can make access to high-quality mathematics instruction for young children a priority. For example, state policies can require evidence-based mathematics curricula and related professional development, sufficient time spent on mathematics instruction, and use of assessments that measure math skills.

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[31] Douglas H. Clements, et al, *Background Research on Early Mathematics.*

[32] See, for example, Joon Sun Lee and Herbert P. Ginsburg, "Preschool Teachers' Beliefs About Appropriate Early Literacy and Mathematics Education for Low- and Middle-Socioeconomic Status Children," *Early Education and Development* 18 no. 1 (2007): 111–143; Kimberly Brenneman, Judi Stevenson-Boyd, and Ellen C. Frede, *Preschool Policy Brief: Math and Science in Preschool: Policies and Practice,* Rutgers Graduate School of Education, National Institute for Early Education Research, http://nieer.org/resources/policybriefs/20.pdf (accessed September 19, 2014); and Juanita Copley and Yolanda Padrón, "Preparing Teachers of Young Learners: Professional Development of Early Childhood Teachers in Mathematics and Science," in *Dialogue on Early Childhood Science, Mathematics, and Technology Education* (Washington, DC: Project 2061, American Association for the Advancement of Science, 1999).

[33] National Women's Law Center, "Governors' 2014 State of the State Addresses: Mentions of Early Care and Education" (May 2014), http://www.nwlc.org/sites/default/files/pdfs/2014stateofthestateaddresses.pdf (accessed September 19, 2014).

Governors who are already focused on strengthening early literacy may consider broadening their goals to include early mathematics proficiency. For example, Governor Tom Corbett of **Pennsylvania** is currently promoting a state goal to ensure that all children are "ready by third grade," meaning that they have the foundational skills to succeed across academic content areas in upper grades. Pennsylvania has defined readiness as proficiency in both reading and STEM skills. In 2013, Governor Corbett hosted a statewide governor's symposium to bring together state and district leaders in early childhood and elementary education to discuss strategies for reaching that goal. The governor recently allocated $100 million in new state funding for the 2014–2015 fiscal year for a Ready to Learn block grant to support innovative district approaches for boosting early literacy and numeracy. Although policymakers may at times face tradeoffs in allocating resources to improve early literacy or mathematics education, Governor Corbett's approach demonstrates how a governor can integrate both priorities into a state policy agenda.

Finally, many governors are leading public–private initiatives to improve student engagement and proficiency in STEM skills that employers in their states need. Those initiatives have thus far largely focused on secondary and postsecondary education, but with a slight expansion of their agenda, governors could build a stronger foundation by including early mathematics education. Governors can, for example, invite policy leaders in early education to be part of an existing STEM council or prompt council leaders to include early education in their strategic planning efforts.

In 2009, Governor Deval Patrick of **Massachusetts** signed an executive order establishing a STEM Advisory Council, charged with increasing student engagement and achievement in STEM fields, with a focus on addressing the entire educational pipeline from birth through postsecondary education. The advisory council includes leaders who represent all relevant state educational agencies, each of whom supports the implementation of strategies aligned with state STEM goals. As part of this effort, the Massachusetts Department of Early Education and Care (EEC) has recently adopted early learning standards in STEM subjects, created new professional development opportunities for early educators, and implemented strategies to increase engagement with community members. With support from Governor Patrick, EEC has made targeted investments of state dollars and federal Race to the Top–Early Learning Challenge funding to support these efforts.[34]

Align High-Quality Mathematics Standards through the Educational Pipeline, and Support Appropriate Use of Student Assessments to Measure Results

State policymakers have an opportunity to use learning standards in mathematics to set a clear vision of the math skills and concepts students should have at different developmental stages and grades and to guide effective practice. States and districts use learning standards in a variety of ways, including guiding curricula and assessment as well as informing professional preparation and development. All states have standards for college and career training readiness in mathematics in kindergarten through grade 12 (K–12) schools, with most states having adopted or in the process of implementing the Common Core State Standards (CCSS) in mathematics or their equivalent. According to an independent study, the CCSS in mathematics is clearer and more rigorous than the prior math standards in 39 states and "too close to call" in another 11 states.[35]

In addition, all states have early learning guidelines

[34] Massachusetts STEM Advisory Council, "A Foundation for the Future: Massachusetts Plan for Excellence in STEM Education, Version 2.0: Expanding the Pipeline for All" (November 2013), http://www.mass.edu/stem/documents/2013-11MassachusettsSTEMPlan2.0.pdf (accessed September 19, 2014).

[35] Sheila Byrd Carmichael et al., "The State of State Standards—and the Common Core—in 2010," Fordham Institute (July 2010), http://edexcellence.net/publications/the-state-of-state-of-standards-and-the-common-core-in-2010.html (accessed September 19, 2014).

(ELGs) that lay out the foundation of what children should know and be able to do before entering kindergarten. The states' more rigorous college- and career training–ready standards have prompted states to review and in many cases revise their ELGs to ensure an aligned set of expectations for students from early childhood through the K–12 system. Those revisions can provide an opportunity to strengthen the quality of ELGs in mathematics. ELGs in most states cover infancy through preschool and include skills and abilities in a range of development and learning areas for each developmental stage.[36] Each state has developed its ELGs independently, with input from educators and early learning experts.[37] As states consider revisions, they have an opportunity to review recent research on child development and learning and to ensure that educators working with young children understand the progression of skill development into the more rigorous K–12 standards and that the expectations set out in a state's ELGs push students to achieve their full potential.

According to an analysis published in 2012, state ELGs have uneven and often insufficient coverage of age-appropriate math skills. Twenty-four states have a separate mathematics content area in their ELGs, and other states include mathematics content under a category such as "cognition" or "general knowledge." In 19 states, the ELGs do not describe any specific mathematics concepts; in many others, too few indicators of specific math skills are mentioned, raising concern that states are not paying enough attention to the importance of early math skills.[38] Many state ELGs were found to have insufficient content on topics such as understanding numbers (for example, counting, understanding, and comparing different quantities), mathematical processes, and understanding of shapes and dimensions, all of which are necessary to prepare students for the higher expectations in kindergarten. States such as **Pennsylvania**, which has standards that cover several specific math skills and include examples of how a young child would demonstrate proficiency, may be a model for states considering revision. Pennsylvania has recently revised its ELGs to ensure alignment with its recently adopted, rigorous K–12 mathematics standards and recent research on mathematics learning.[39]

When high-quality standards are in place, state leaders should consider which assessments are needed to measure how young students progress toward meeting those expectations. Although high-stakes assessments are not appropriate for young children because of the unreliability of results, high-quality student assessments that are aligned to state standards can help state leaders measure aggregate student growth in early math skills and help teachers better support struggling students. At the same time, because implementing such assessments can be costly and may place new burdens on teachers, state leaders should carefully consider whether new tools are needed to support policy and practice and whether the benefits outweigh the costs.

For example, **Florida** has launched a standards-based mathematics progress monitoring tool in its state pre-kindergarten programs, and **Mississippi** has developed a statewide mathematics assessment in early elementary classrooms. Both are intended to strengthen instruction, meet individualized student needs, and collect data on students' early mathematics achievement that can inform state and district policies. In addition, the cross-state Partnerships for Assessment in Readiness for College and Career Readiness consortium is developing new CCSS-

[36] Sarah Daily, Mary Burkhauser, and Tamara Halle, "A Review of School Readiness Practices in the States: Early Learning Guidelines and Assessments," *Early Childhood Highlights* 1 no. 3 (2010), http://www.childtrends.org/wp-content/uploads/2013/05/2010-14-SchoolReadinessStates.pdf (accessed September 19, 2014).

[37] Catherine Scott-Little, Sharon Lynn Kagan, and Victoria Stebbins Frelow, "Inside the Content: the Depth and Breadth of Early Learning Standards," SERVE (2005), http://projects.fpg.unc.edu/~eco/assets/pdfs/insidecontentes.pdf (accessed September 19, 2014).

[38] Catherine Scott-Little, Sharon Lynn Kagan, J.L. Ried, and E. Castillo, "Early Mathematics Standards in the United States: Understanding Their Content," Heising-Simons Foundation.

[39] These standards are available online at http://www.pakeys.org/pages/get.aspx?page=Career_Standards (accessed September 19, 2014).

aligned diagnostic assessment tools that states can choose to use in early grades.[40]

Finally, many states are already developing statewide kindergarten entry assessments (KEAs)—tools that measure a wide range of academic skills and indicators of child development when children start school. A KEA is typically used to inform instruction and assess how students are faring at school entry, over time, and by geographic area. For states already using a KEA, the tool provides another opportunity to measure the state's success in improving early mathematics skills and to weigh the costs and benefits of any changes in standards or practice. For example, **Washington**'s kindergarten readiness assessment, first launched in the 2012–2013 school year, found that only 54 percent of incoming kindergarteners in the state's highest-poverty schools demonstrated readiness to carry out age-appropriate math skills, but more than 70 percent of those students demonstrated readiness in all other areas.[41] Those data have prompted the state to focus on improving early mathematics instruction in its state pre-kindergarten program and increase professional development for kindergarten and pre-kindergarten teachers in mathematics instruction.[42]

Promote Changes in Policies around Educator Support and Preparation to Build Educators' Capacity to Teach Mathematics to Young Children

Many states are already making comprehensive reforms to their professional development and preparation policies to ensure that teachers and principals have the skills to improve student outcomes across the educational continuum. As part of those efforts, policymakers can look for opportunities to strengthen the capacity of early childhood and elementary educators to teach mathematics. Governors can act to promote high-quality professional development for existing educators in early mathematics education and can also consider efforts to improve pre-service preparation for future educators.

Strengthen Professional Development for Existing Teachers and Principals

Leaders in several states are looking for opportunities to support evidence-based approaches to professional development for teachers and principals by redirect existing public funds or providing additional funding. Professional development is a critical part of a larger talent-management system in which educator evaluations produce actionable information about needs and professional development that matches with their needs.

As state leaders revamp systems of professional development, they should pay attention to critical needs to improve early educators' expertise in teaching mathematics. New talent-management systems should help teachers assess and address their own lack of confidence in teaching mathematics and provide support not only for the content of early mathematics education but for methods of teaching this content to young children.[43] Depending on the state policy context, professional development might also be needed to help teachers effectively use new diagnostic assessments or KEAs and implement curricula that are aligned to new standards. Finally, professional development should also be offered to elementary school principals to help them support and evaluate high-quality mathematics teaching.

A few states have acted to strengthen professional development in mathematics through legislation. In 2011, **Washington** passed legislation that allowed for district–university partnerships designed to foster

[40] For more information, see "Non-summative Assessments" at http://www.parcconline.org/non-summative-assessments (accessed September 19, 2014).
[41] *Math readiness* is defined according to the Teaching Strategies GOLD kindergarten entry assessment tool, used in multiple states.
[42] Washington Office of the Superintendent of Public Instruction, Washington State Report Card, http://reportcard.ospi.k12.wa.us/WaKidsDetailPage.aspx?year=2012-13 (accessed September 19, 2014).
[43] Deborah Loewenberg Ball and Hyman Bass, "Interweaving Content and Pedagogy in Teaching and Learning to Teach: Knowing and Using Mathematics," in Jo Boaler, ed., *Multiple Perspectives on the Teaching and Learning of Mathematics* (Westport, CT: Ablex, 2000): 83–104, http://www-personal.umich.edu/~dball/chapters/BallBassInterweavingContent.pdf (accessed September 19, 2014).

new professional development opportunities in mathematics. **Florida** passed a law in 2013 focused on early education that requires the state's Office of Early Learning to develop a plan to provide appropriate professional development and training for pre-kindergarten teachers in early mathematics.

More recently, a public–private taskforce in **Illinois**, called the Early Math Advisory Committee, has developed a comprehensive plan to improve professional development in mathematics for early childhood and early elementary educators. The committee proposes an inventory of existing professional development and resources that are available to better identify gaps and opportunities to use existing resources. In addition, the committee recommends that the state pilot test and evaluate multiple models of professional development with various populations (for example, early childhood teachers, K–3 teachers, and administrators), different levels of intensity, and modes of delivery. The committee recommends building a train-the-trainer model to spread the reach of effective practices.[44] Research on professional development suggests that inservice professional development is most effective when educators receive ongoing feedback, coaching, and support connected to their day-to-day practice as opposed to isolated workshops or training.[45] Illinois is already piloting an early mathematics train-the-trainer initiative as part of a larger effort to improve professional development. The taskforce is currently working with public and private leaders to consider how to fully implement these recommendations and how much these strategies would cost.

Improve Educators' Pre-Service Training in Early Mathematics Education

To make a longer-term investment in quality teaching, many state leaders are considering changes to pre-service preparation requirements for new teachers and principals. State policymakers have the authority to strengthen pre-service requirements through accreditation requirements for higher education and certification standards. In that context, state leaders have another opportunity to strengthen the capacity of early childhood and elementary educators to teach mathematics more effectively. States can begin by assessing their current preparation systems in three key areas: pre-service curriculum, requirements for teachers to demonstrate mastery, and the option of certifying mathematics specialists.

First, state policymakers can assess the effectiveness of current coursework and student teaching requirements for educator certification and make changes through their program approval process, if needed. Experts report that accredited teacher preparation institutions should but often do not offer interdisciplinary courses focused on how to teach early math skills. Such coursework would integrate mathematics content with strategies for teaching math skills to young children and knowledge of child development.[46] In addition, experts find that preparation programs currently focus on K–12 mathematics methods and should include more coursework on preschool mathematics education.[47] Finally, state leaders can consider whether current student teaching requirements provide aspiring teachers with sufficient time observing and practicing high-quality teaching of mathematics to young children. For states considering changing preparation requirements, state leaders can also consider providing opportunities for institutions of higher education to develop model courses or share best practice as well as determine what, if any, tradeoffs with other requirements would be implied.

[44] Sally Beneke, *Early Math in Illinois: Recognizing and Raising the Profile*, 2013.

[45] U.S. Department of Education, National Center for Education Evaluation and Regional Assistance, *Reviewing the Evidence on How Teacher Professional Development Affects Student Achievement* (2007), http://ies.ed.gov/ncee/edlabs/regions/southwest/pdf/rel_2007033.pdf (accessed September 19, 2014).

[46] Douglas H. Clements et al., "State Early Childhood and Pre-K Policies and Practices for Early Mathematics" (Washington, DC: National Governors Association, 2013).

[47] Sharon Ryan, Marcy Whitebrook, and Deborah Cassidy, *Strengthening the Math-Related Teaching Practices of the Early Care and Education Workforce: Insights from the Experts,* Center for the Study of Child Care Employment, 2014.

As one example, **Illinois** is currently launching a new early childhood endorsement for educators teaching children from early childhood through second grade. Although the rules for this new endorsement are still being finalized, a public–private early mathematics advisory group has helped to develop standards focused on mathematics education. Draft standards would require that aspiring teachers take coursework that integrates mathematics content with methods of mathematics instruction and knowledge of how young children develop and learn. The advisory committee has also recommended a three-year plan to support higher education institutions in developing these new course offerings. The committee proposes holding higher education symposia to share best practices and offer pilot grants for attendees to use what they learn at the symposia to develop new coursework.[48]

Efforts are underway to implement Illinois' plan with public and private funding. The state hosted a forum for higher education faculty in 2014 focused on strengthening coursework in early mathematics. In addition, the state has allocated $1 million in federal Race to the Top–Early Learning Challenge funding to support selected higher education institutions in revamping early educator preparation programs, with early mathematics as one of three priority areas. State leaders expect that grantees will develop high-quality programs that will serve as models for other institutions.

Similarly, state leaders can examine program approval requirements for principal preparation institutions to ensure that elementary school principals have the capacity to support high-quality mathematics teaching. Through a past legislative effort, Illinois revamped its principal certification process, now requiring that all preparation programs offer curricula that address student learning and school improvement relevant to literacy and numeracy in preschool through 12th grade.[49]

It is important to be aware that many educators in early childhood programs are not required to be certified teachers or to have a bachelor's degree. Many educators working in child care and preschool settings instead receive credentials offered at community colleges. State policymakers could consider similar strategies to embed high-quality content on teaching mathematics to young children in those preparation programs. A statewide analysis in Illinois found that 22 percent of community colleges in the state do not offer mathematics methods coursework accessible for aspiring early educators, and only 2 percent offer courses focused on how to teach early mathematics.[50]

In addition to reviewing pre-service coursework requirements, state leaders can consider whether teachers are required to demonstrate mastery of relevant skills to become certified. For example, if a mathematics exam is required as part of teacher certification, state leaders should ensure that the skills tested are directly related to teaching mathematics to young children.

Finally, state policymakers might consider offering a "math specialist" certification if their state does not already do so. Currently, only 20 states license mathematics specialists, but all 50 states license reading specialists. Mathematics specialists are experts on mathematics education who can mentor teachers, provide individualized support to students, or directly teach math skills to groups of students.[51] Studies have shown that those specialists can play an important

[48] Sally Beneke, *Early Math in Illinois.*
[49] Amanda Szekely, "Leading for Early Success: Building School Principals' Capacity to Lead High-Quality Early Education" (Washington, DC: National Governors Association Center for Best Practices, 2013).
[50] Erika Gaylor, Donna Spiker, Jana Fleming, and Jon Korfmacher, *Illinois Preschool for All (PFA) Program Evaluation,* http://www.erikson.edu/wp-content/uploads/PFA-Evaluation-Final-Report-June-2012.pdf (accessed September 19, 2014).
[51] Patricia Campbell, "Empowering Children and Teachers in the Elementary Mathematics Classrooms of Urban Schools," *Urban Education* 30 (1996): 449–475; and Patti Brosnan and Diana Erchick, "Mathematics Coaching and Its Impact on Student Achievement," in *Proceedings of the Psychology of Mathematics Education—North America,* Patti Brosnan, Azita Manochehri, and Doug Owens, eds. (Columbus, OH: PME-NA, 2010).

role in improving student learning.[52] **Washington**'s 2011 law on mathematics education created such an endorsement and put into statute specific knowledge and skills required to earn that endorsement. In doing so, this law has the potential to create a pool of mathematics specialists whom districts can hire to improve mathematics education in their schools.

Regardless of the path states take to improve the quality of the early childhood and K–3 educators, strong data systems are important. Data systems can help link the performance of teachers back to their preparation programs and professional development provider both to help programs improve and to enable states to hold teacher preparation programs accountable if they are not preparing their graduates well. That is an important role for states if districts across the states expect to hire better prepared teachers and have stronger training for teachers already on the job. Strong data systems can, of course, be costly, but well-functioning systems throughout the educational pipeline can be a valuable tool for improving student achievement.[53]

Conclusion

A growing body of research demonstrates that early math skills are a strong predictor of later achievement and that high-quality instruction can help more young students build foundational math skills. Although governors are already strong proponents of early reading initiatives, they have an opportunity to become champions for improving early mathematics instruction in their states, as well. Many of the actions described in this brief require no or minimal new state funding and can help lay the groundwork for a state's focus on high-quality early mathematics teaching and learning. As state leaders explore this area in more depth, they should weigh the costs and benefits of making new investments, particularly in educator training and supports, to yield long-term gains in student achievement.

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[52] Douglas H. Clements, et al, *Background Research on Early Mathematics.*
[53] Data Quality Campaign, "Leveraging the Power of State Longitudinal Data Systems: Building Capacity to Turn Data into Useful Information" (2011), http://www.dataqualitycampaign.org/files/1303_DQC-Research%20capacity%20May17.pdf (accessed September 19, 2014).