Early Grades: STEM

Annotated Bibliography

While literacy has long led the early grades policy agenda, early math skills also are vital to success in school. In fact, these skills are more predictive of later achievement than early literacy or social development. Math skills are only part of a broader developmental equation. National attention has recently shifted to a set of competencies that economists project as key to future careers — science, technology, engineering and math (STEM). States must ensure more students graduate from high school ready for these critical jobs by promoting equitable access to high-quality STEM learning. Evidence from Texas pinpoints promising early grades STEM policies. To sufficiently prepare tomorrow's workforce, high-quality STEM content must start early to narrow achievement gaps that are evident at school entry.

The following studies highlight recent research on policy topics with nationwide applicability.

It's more than counting: Math and science success has a deep foundation.

1. **Mulligan, G., McCarroll, J., Flanagan, K., & Potter, D. (2016). *Findings From the Third-Grade Rounds of the Early Childhood Longitudinal Study, Kindergarten Class of 2010-11*. Washington, DC: U.S. Department of Education, National Center for Education Statistics.**

   Researchers compiled the latest findings from the national Early Childhood Longitudinal Study (ECLS) for this brief. Data tables comprise the bulk of the brief. However, short narrative pieces provide analysis of major findings. For instance, male third-graders tend to score higher in math than females. There is no statistical difference in science test scores between genders. Also, as parental educational attainment increases, so does math and science achievement for all third-graders. Data also indicate that science and math achievement varies for students based on their race, household income and home language. These results mirror earlier findings from the first- and second-grade ECLS, drawing attention to early achievement gaps that continue to grow over time if not addressed through high-quality instruction and intervention.

2. **Friedman-Krauss, A.H. & Raver, C.C. (2015). Does School Mobility Place Elementary School Children at Risk for Lower Math Achievement? The Mediating Role of Cognitive Dysregulation. *Developmental Psychology* (51.12), 1725-1739.**

   This study addresses the impact of school mobility, an income-related risk factor, on the math achievement of students from low-income households. Researchers followed a sample of these students in Chicago from preschool through fourth grade, noting the number of times these children switched schools by the end of third grade. After comparing this data to fourth-grade test scores, they determined that school mobility negatively affects math test scores. Students who frequently switched schools — those who attended more than three schools during the five-year period — score on average over 8 months behind their peers who did not frequently move. The study also found that frequently mobile children are more likely to experience low levels of cognitive self-regulation, such as shortened attention spans and difficulty following directions, in the third grade. These findings highlight the important role of non-cognitive skills in math success, as well as the need for school-based social services and math intervention in the early grades.

3. **Ramirez, G., Gunderson, E.A., Levine, S.C., & Beilock, S.L. (2013). Math Anxiety, Working Memory, and Math Achievement in Early Elementary School. *Journal of Cognition and Development* (14.2), 187-202.**

   In this early grades study, scientists build on past research that found many middle and high school students suffer from anxiety that lessens their math ability. Starting earlier, they assessed the math and memory skills of first- and second-graders and measured the level of math anxiety exhibited by the students a few days later. Data show that young students with strong-working memories — the brain function that supports

concentration and problem solving — are negatively affected by anxiety during math exercises. Students with weak-working memories are not hindered by math anxiety. While high-working memory is an academic advantage, it can lessen a student's math ability if instruction and assessments are overly stressful.

Sparking interest in STEM in the early grades matters.

4. **Morgan, P.L., Farkas, G., Hillemeier, M.M., & Maczuga, S. (2016). Science Achievement Gaps Begin Very Early, Persist, and Are Largely Explained by Modifiable Factors. *Educational Researcher* (45.1), 18-35.**

   Using a large national data set, this study investigates the origin of and contributing factors to science achievement gaps. A longitudinal analysis identified statistically significant differences in science knowledge at kindergarten entry. The researchers found that the gaps are correlated to numerous contributing factors, including family income, demographics, parenting quality, school quality, self-regulation skills and reading knowledge at school entry. Data show these science gaps continue through the early grades. Sixty-two percent of kindergarteners with low levels of science knowledge continue to struggle on third-grade science assessments. Of the contributing factors studied, first-grade general science knowledge is the strongest predictor of performance on state science assessments in third through eighth grade. Academic preparation before school entry and in the early grades are important to fix the leaky STEM pipeline.

5. **Schoenfeld, A. & Stipek, D. (2011). *Math Matters: Children's Mathematical Journeys Start Early.* Retrieved from www.earlymath.org**

   This conference report summarizes research and data on early math development. For example, children who enter school behind in math rarely catch up. Also, not enough structured instructional time is devoted to math, even though increased time spent on math leads to higher math and literacy outcomes. The report recommends ways to better align policy and practice from preschool through third grade with the evidence base. Recommendations include: align academic content, curricula and professional development with the science of early math development; develop teacher preparation and credentialing practices that promote math expertise; create incentives, such as scholarships and loan forgiveness, for talented math students who enter the early grades teacher workforce; and make early math a priority in state education plans.

6. **Carnevale, A.P., Smith, N., & Melton, M. (2011). *STEM*. Washington, DC: Georgetown University, Center on Education and the Workforce.**

   This study looks at the economic future of STEM careers in the U.S workforce. Through statistical analysis and job projections, the researchers agreed with previous studies — a STEM worker shortage is coming. However, they found the shortage will be less about job growth in STEM fields and more about increasing competition from high-paying, non-STEM careers that use the same core competencies. This so-called diversion attributed to only a quarter of talented math and science K-12 students going on to pursue post-secondary STEM majors. Of the students who graduated with a STEM postsecondary degree, 43 percent did not enter a STEM career. About half of the remaining STEM graduates left the field within 10 years. The study reaffirms that most STEM jobs are filled by white and male postsecondary graduates. It also stresses the importance of STEM-subject achievement and engagement in K-12 and the need to incentivize and support students — especially females and minorities — to continue into STEM career paths.

7. **Maltese, A. & Tai, R.H. (2010). Eyeballs in the Fridge: Sources of Early Interest in Science. *International Journal of Science Education* (32.5), 669-685.**

   This report takes a qualitative look at the early sources of students' interest in science. Relying on 116 interviews with chemistry and physics graduate students and career scientists, the authors analyzed the reported catalysts for science interest. Sixty-five percent credited experiences before the middle grades with their interest. Males were more likely to develop an early science interest from hobbies and self-initiated activities, while females tended to credit school-related activities. The authors concluded that an increased emphasis on STEM subjects in preschool and the early grades, as well as more school-based initiatives to engage young girls in STEM learning, are necessary policy tools to attract more students to STEM fields.

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It all adds up: Early math skills lead to algebra success in later grades.

8. **Watts, T.W., Duncan, G.J., Siegler, R.S., & Davis-Kean, P.E. (2014). What's Past Is Prologue: Relations Between Early Mathematics Knowledge and High School Achievement. *Educational Researcher* (43.7), 352-360.**

   In this study, researchers explored if math development prior to school entry predicts math achievement in high school. They used longitudinal data to compare the early math skills of prekindergarten-age children to their future high school math test results. This analysis reveals that early math skills are related to math achievement through age 15. Math gains made from pre-K to first grade are a statistically significant predictor of later success. In fact, a student's math growth in kindergarten and first grade is just as predictive of math test scores at age 15 as of math achievement in third grade. This study underscores the significance of school readiness to later achievement and the need for high-quality early learning programs.

9. **Education Commission of the States. (2013). Math in the Early Years: A Strong Predictor for Later Success. *The Progress of Education Reform* (14.5).**

   This policy brief synthesizes years of study findings on the effect of early math development on later school success. It notes that early math skills predict later reading achievement better than early language and literacy skills. Yet, math instruction in the early grades often is repeated content since teachers tend to underestimate students' skill mastery. In summary, the authors urged states to develop a preschool-through-third-grade strategy that focuses on high-quality math instruction, aligned standards and content, high-quality educators with specialized early math preparation, and specialized, on-going professional development in early math best practices.

10. **National Mathematics Advisory Panel. (2008). *Foundations for Success: The Final Report of the National Mathematics Advisory Panel*. Washington, DC: U.S. Department of Education.**

    In 2006, President George W. Bush assembled education experts as part of the National Mathematics Advisory Panel. The panel was charged with identifying the best policy and practice to ensure more students are ready for algebra in the middle grades. This subsequent report emphasizes alignment, stating that math content from pre-K through the middle grades should be streamlined to reduce repetition and fill gaps in instruction. It details numerous instances of content misalignment. For example, fraction mastery is the least developed competency of all of the foundational skills for later algebra success. The report stresses the central role of highly prepared teachers in early math development. In total, the report contains 45 policy recommendations to raise math achievement. The recommendations focus on curriculum and content, pedagogy, instructional practice and materials, teacher quality and preparation, assessment and research. The panel's findings on math content still serve as a foundation for early grades math policy and practice.

Engaging instruction and high-quality educators are cornerstones of strong STEM policy.

11. **Pasnik, S. & Hupert, N. (2016). *Early STEM Learning and the Roles of Technologies.* Waltham, MA: Education Development Center, Inc.**

    This report indicates that exposure to the STEM content areas and technology in preschool can help mitigate the large science and math skills gap found at school entry. It reports that technology and digital devices promote learning by exposing young children, especially those from low-income families, to new concepts that they otherwise would not experience. The authors warned that technology use must be developmentally appropriate, such as part of small group lessons with active teacher oversight. Overall, they found that too few young children have sufficient opportunities to build STEM skills before entering school. The report recommends that states include high-quality STEM content in early childhood academic standards, prepare early childhood teachers to use technology in an engaging and developmentally appropriate way, and promote equitable access to technology and quality STEM learning for all children.

12. **Szekely, A. (2014). *Unlocking Young Children's Potential: Governors' Role in Strengthening Early Mathematics Learning*. National Governors Association. Retrieved from www.nga.org**

    The author of this report synthesized research and state-specific examples to guide policymakers as they work to raise statewide early grades math achievement. Overall, the report showcases the foundational role of early math skills in the long-term educational and economic outcomes of students. For instance, research indicates that early math skills at school entry are more predictive of high school graduation and college attendance than any other readiness skill. The report concludes with three action steps for policymakers: set early grades math development and learning as a state education priority; align high-quality, evidence-based math standards, curricula and assessments from pre-K through 12th grade; and raise teacher preparation standards to ensure all early grades teachers have the skills for effective math instruction.

13. **Morgan, P.L., Farkas, G., & Maczuga, S. (2014). Which Instructional Practices Most Help First-Grade Students With and Without Mathematics Difficulties?. *Educational Evaluation and Policy Analysis*, 1-22.**

    This study addresses effective early math practice by comparing student outcomes from student-centered instruction with those from teacher-driven instruction. In an analysis of nationally representative data, student-centered instruction in first-grade classrooms included calculator work and interactive movement exercises while teacher-driven practice was more explicit with time for guided practice. While first-graders without math difficulties benefited from both techniques, struggling first-graders gained significantly more over the school year from teacher-driven instruction. Specifically, practice and drilling math problems were the instructional practices most associated with test score gains. Conversely, they found that teachers with many struggling math students tended to use student-centered instructional techniques. The findings underscore a disparity between evidence and practice that may worsen existing math achievement gaps.

14. **National Research Council. (2011). *Successful K-12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics*. Retrieved from www.nap.edu**

    This book — a result of the National Research Council's Committee on Highly Successful Science Programs for K-12 Science Education — delves into the components of a successful K-12 STEM program. The council set three overarching goals for effective programs: increase participation for students, particularly women and minorities, in STEM degrees and careers; ensure more students graduate with the STEM skills needed for future jobs; and raise STEM literacy for all K-12 students, regardless of their postsecondary or career path. Focusing on science and math, the council compiled research and identified best practices from effective STEM K-12 school models. Throughout, the book offers rich case studies, including successful STEM elementary schools. Successful early grades STEM programs exhibit strong leadership, prepared and informed teachers, family and community engagement, and offer a student-centered learning setting. The book serves a blueprint for policymakers and practitioners as they lead schools to meet the three goals.

Evaluations of early grades STEM initiatives in SREB states

Texas

Young, V., House, A., Wang, H., Singleton, C., & Klopfenstein, K. (2011). *Inclusive STEM Schools: Early Promise in Texas and Unanswered Questions.* Retrieved from www.nationalacademies.org

In this study, researchers investigated the academic benefits of attendance at one of Texas' 51 inclusive STEM schools. These schools were created as part of the state's T-STEM initiative. They focus on college readiness and use small class sizes and data-driven instruction. And, most of these schools are located in high-needs urban settings. The researchers found that students in ninth and 10th grades who attended inclusive STEM schools outperformed their peers at comparable schools on Texas' science and math assessments. Also, inclusive STEM participants were less likely to miss school and more likely to take advanced course work as compared to students not enrolled in inclusive STEM schools.

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