SEEFORUMS
Scientific Evidence in Education Forums

ResearchLink May 2009

ResearchLink is a publication series produced by the Scientific Evidence in Education (SEE) Forums.

In This Issue

Setting the Stage

The growth of scientific and technology-related jobs and the increase in computerized aspects of once purely service or manual jobs have underscored the importance of mathematics skills in the 21st century economy. However, as the most recent National Assessment of Educational Progress shows, at all of the grades tested (4th, 8th, and 12th), many U.S. students fail to meet the level of "proficient" and, depending on the grade, between 18 to 29 percent of students fall in the "below basic" level (Grigg, Donahue, & Dion, 2007; Lee, Grigg, & Dion, 2007). Additionally, by the fourth grade, significant differences exist in performance among students from different racial/ethnic and socioeconomic backgrounds, demonstrating a critical need for effective mathematics instruction in the early grades.

The Federal No Child Left Behind (NCLB) education legislation highlights the importance of the acquisition of mathematics skills beginning in the early grades. NCLB requires schools to make adequate yearly progress (AYP) in mathematics (and reading) starting in the third grade and, by 2014, to ensure that all their students reach or exceed the State's proficiency standard for these subjects. At the same time, however, there has been little rigorous research available on, specifically, the instructional materials being used to teach mathematics. One research review (Slavin & Lake, 2007) found only two studies of mathematics curricula that had used an experimental design and thus were capable of providing the type of strong evidence needed to judge their impacts on student learning. Similarly, the What Works Clearinghouse (WWC) reviewed more than 200 studies of school mathematics curricula and found only five curricula that had strong research and that only one of those showed a positive impact on student achievement.

It is within this context that the Institute of Education Sciences (IES) commissioned a major study of elementary mathematics curricula to provide educators with information to help them evaluate curricula, improve students' mathematics knowledge and skills, and meet AYP requirements. This article summarizes the recently released report on the first year of this rigorous study. Conducted by Mathematica Policy Research, Inc., and SRI International, this study is the first large-scale evaluation of elementary mathematics curricula to use an experimental design and provides important preliminary evidence about the relative effects of different curricula on students' achievement (Agodini et al., 2009).

Which curricula were studied?

Using a competitive selection process, the research team identified four curricula for inclusion in the study. The curricula were selected because they are widely used, have promise for improving student achievement (i.e., they are based in research), and represent a range of instructional approaches commonly used in U.S. classrooms. The four curricula are: Investigations in Number, Data, and Space (Investigations); Math Expressions; Saxon Math (Saxon); and Scott Foresman-Addison Wesley Mathematics (SFAW). Market share data confirm the widespread use of these curricula: Investigations, Saxon, and SFAW (the three curricula for which data exist) are among the seven most widely used curricula in K–2 in the United States and together represent about one-third of the curricula being used by educators in these grades. Figure 1 provides an overview of the four curricula selected for the study.

Understanding differences and similarities in the curricula is important in developing an understanding of the study's results. For example, differences in factors such as the degree of ease of implementation (e.g., degree of scripting) or time investment (e.g., for training or implementation) may have an impact on results and also may affect results differently over time (e.g., as teachers or students become more familiar with the curricula). One interesting difference that was pointed out in the study was that the teachers using Saxon, one of the curricula the studied showed as having relatively stronger effects, provided about 1 hour more of mathematics instruction per week than teachers using the other curricula, who tended to provide about 5 hours of instruction per week.

How was the study conducted?

The study was designed to provide information on two key research questions: (1) what are the rela-

Figure 1: The Curricula Studied

- ***Investigations in Number, Data, and Space*** uses a student-centered approach to learning that encourages metacognitive reasoning and draws on constructivist learning theory. The lessons focus on understanding, rather than on "correct answers," and build on students' knowledge and understanding—and, as such, this is considered by some to be the most "reform" curriculum of the four. Students are engaged in thematic units of 3 to 8 weeks in which they first investigate, then discuss and reason about problems and strategies. Students frequently create their own representations.
- ***Math Expressions*** is a relatively new curriculum that blends both student-centered and teacher-directed approaches to mathematics. Students question and discuss mathematics, but are explicitly taught effective procedures, and each lesson focuses mostly on new material. There is an emphasis on using multiple specified objects, drawings, and language to represent concepts, as well as an emphasis on learning with real-world situations.
- ***Saxon Math,*** which has been in use nearly 20 years, is a scripted curriculum that blends teacher-directed instruction of new material with daily distributed practice of previously learned concepts and procedures. The teacher introduces concepts or efficient strategies for solving problems. Students observe and then receive guided practice, followed by distributed practice. Students hear the correct answers and are explicitly taught procedures and strategies. Daily routines and student monitoring are extensive and emphasize practice of number concepts and procedures and use of representations.
- ***Scott Foresman-Addison Wesley Mathematics*** is a curriculum that focuses on the fundamentals of mathematics and combines teacher-directed instruction with a variety of differentiated materials and instructional strategies. Of the curricula studied here, it is considered to be the most typical of those curricula in use at the elementary level. Teachers select the materials that seem most appropriate for their students and often have access to a wide variety of ancillary or supplemental materials in addition to the textbook. The curriculum is based on a consistent daily lesson structure, which includes direct instruction, hands-on exploration, the use of questioning, and practice of new skills.

tive effects of the different curricula on students' mathematics achievement, and (2) are there differences in effects for students in different subgroups and school/instructional contexts?

The research team recruited districts to participate in the study on the conditions that they had schools receiving Title I funds (i.e., schools that had a high percentage of low-income students) and—across the sample—represented different geographic regions. Districts needed to have at least four schools interested in participating, so that all four curricula could be compared within each district. Four districts from four States in three different regions of the country participated in the study. These districts included two urban, one suburban, and one rural district.

Within each district, schools interested in participating in the study were divided into blocks based on characteristics such as size and income, with each block containing four to seven schools with similar characteristics. Within each block in each district, schools were then randomly assigned to the four curricula. This randomized block design was used to minimize chance differences in school characteristics and sample sizes across curriculum groups, increasing face validity and improving statistical power. Analyses confirmed that the four groups of schools were similar in terms of student, school, and teacher characteristics.

The first cohort of students—the subject of the report and this article—included 1,309 first-grade students in the 2006–07 school year in a total of 39 schools, an average of about 325 students in 33 classrooms in 10 schools for each curriculum. Analyses were based on a random sampling of 10 students from each participating classroom. Figure 2 provides an overview of the key features of the study.

Were there differences in student achievement with the different curricula?

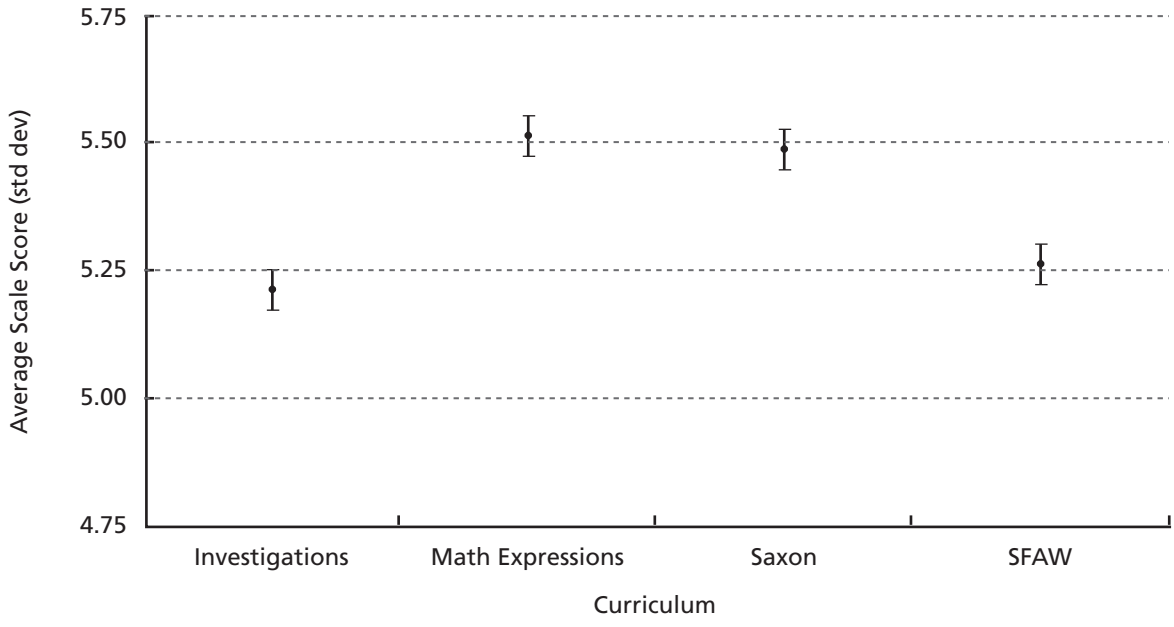
The study used hierarchical linear modeling (HLM) techniques to calculate the relative effects of the curricula on mathematics achievement, as measured by the standardized, nationally normed assessment developed for the Early Childhood Longitudinal Study–Kindergarten (ECLS–K). The HLM techniques accounted for the nested structure of the data (i.e., students within classrooms, classrooms within schools) and student, teacher, classroom, and school variables that could have influenced the results, such as students' baseline mathematics scores on the ECLS–K.

Key Features of the Study	
Curricula	◆ Investigations in Number, Data, and Space ◆ *Scott Foresman-Addison Wesley Mathematics* ◆ *Saxon Math* ◆ *Math Expressions*
Target population and subgroups	First-grade students By district, baseline achievement, free and reduced-price lunch eligibility, teacher education, teacher experience, and teacher pedagogical/content knowledge
Selection/ eligibility criteria	Districts that: ◆ Have schools receiving Title I funding ◆ Represent diverse geographic areas of the United States ◆ Have at least four schools interested in participating in the study
Scope	1,309 students in 131 classrooms, 39 schools, 4 districts
Data collection tools	Teacher survey on background characteristics and curriculum implementation Assessment of teacher content/pedagogical knowledge Assessment of student mathematics (assessment developed for the Early Childhood Longitudinal Study–Kindergarten) Student data from class rosters

Student mathematics achievement was significantly higher in schools assigned to Math Expressions and Saxon than in schools assigned to Investigations and SFAW. The average HLM-adjusted spring mathematics scores for students receiving Math Expressions and Saxon was 0.30 standard deviations higher than those for students receiving Investigations, and 0.24 standard deviations higher than those for students receiving SFAW. Because the backgrounds and conditions of the students in the four different curriculum groups were similar across groups,[1] the study can say with confidence that the observed differences are due to the curricula, not preexisting differences between students. For a student at the 50th percentile in mathematics achievement, these findings mean that the student's percentile rank would be 9 to 12 points higher if the school used Math Expressions or Saxon instead of Investigations or SFAW. These results are summarized in figure 3.

The study also examined whether the curriculum effects differed for different subgroups of students. The research team created 15 subgroups based on which district students were in and on a number of school and teacher characteristics. For example, there was a subgroup for each of the four districts; one for students in high-poverty schools; one for students in low-poverty schools; one for students whose teachers were experienced; and one for students whose teachers were inexperienced. Analyses found that in 8 of the 15 subgroups, there were statistically significant differences in student mathematics achievement between curricula. The significant curriculum differences ranged from 0.28 to 0.71 standard deviations, and all of the significant differences for subgroups—like the findings overall—favored Math Expressions or Saxon over Investigations or SFAW. There were no subgroups for which Investigations or SFAW showed a statistically significant advantage.

Figure 3: Average HLM-Adjusted Spring Mathematics Score With Confidence Interval, by Curriculum (in standard deviations)



Note: The dots in each symbol represent the average HLM-adjusted spring mathematics score (in standard deviations) for each curriculum, and the bars that extend from each dot represent the 95 percent confidence interval around each average. Curricula with non-overlapping confidence intervals have significantly different average scores at the 5 percent level of confidence.

[1] There was one exception: teacher race. Analyses adjusted for this difference.

How were the curricula implemented?

In addition to looking at achievement effects, it is also important to look at issues related to how each curriculum was implemented. For example, did teachers receive similar levels of training; did they implement their assigned curricula as directed and to completion; or how were the curricula similar and different in terms of the content covered or what they require of the implementing schools and teachers? The study provides some data for answering these questions.

Using self-report data collected from teachers in the fall and spring of the 2006–07 school year, the study found that nearly all teachers received the initial and followup training required, although the amount varied by curriculum, ranging from 1.4 to 3.9 days. The data also showed that nearly all teachers reported using their assigned curriculum as their core mathematics curriculum, although about one-third supplemented the curriculum (frequently with self-designed materials) for reasons such as remediation or enrichment. A great majority of teachers also reported completing at least 80 percent of their assigned curriculum by the end of the school year.

The study also looked at the degree to which teachers adhered to essential features of the curricula with the frequency expected by the curriculum designers. Data showed a great range in the percentage of teachers adhering to the various features for each of the four curricula, with some features implemented more uniformly and others more selectively. Generally speaking, teachers using Investigations showed the greatest adherence, with 72 percent of teachers adhering to most of the features, compared with 59, 63, and 55 percent for Saxon, Math Expressions, and SFAW, respectively. Finally, the study examined the math-

Other Resources for Research on Mathematics Education

The latest IES **Practice Guide** focuses on actions that may be key to helping students who are struggling with mathematics. The eight recommendations in the guide, rated by the level of evidence supporting them, are designed to help teachers, principals, and administrators use Response to Intervention for the early detection, prevention, and support of students struggling with mathematics. For example, those recommendations with the strongest evidence are:

- That mathematics instruction should be explicit and systematic. It should provide models of proficient problemsolving, verbalization of thought processes, guided practice, corrective feedback, and frequent cumulative review
- That interventions should include systematic, explicit instruction on solving word problems, based on the problem's underlying structure

More detail on these and the other six recommendations can be found in the report, online at http://ies.ed.gov/ncee/wwc/pdf/practiceguides/rti_math_pg_042109.pdf.

The **National Mathematics Advisory Panel** was created by Executive order in 2006 to provide guidance on how to advance the teaching and learning of mathematics in the United States based on a review of the best scientific evidence available. The panel issued its policy recommendations for mathematics education in the United States in a final report in March 2008, which can be found at http://www.ed.gov/about/bdscomm/list/mathpanel/index.html.

The **What Works Clearinghouse** (WWC) reports on the evidence of effects of various elementary school mathematics interventions for students in grades K–5 focused on improving mathematics achievement. Users can search for individual intervention reports or summary documents at http://ies.ed.gov/ncee/wwc/reports/topic.aspx?tid=04.

Similarly, the **Best Evidence Encyclopedia** (BEE) provides summaries of scientific reviews of research evidence produced by many authors and organizations on various education topics, as well as links to the full texts of each review and information to for users to evaluate the strength of evidence. Information on elementary mathematics can be found at http://www.bestevidence.org/math/elem/elem_math.htm.

ematics content that was covered by teachers in each curriculum and whether coverage differed by curriculum. The study showed that although the curricula had significant overlap of topics and similarity of coverage, on 8 of 20 topics examined, there were significant differences in the average number of lessons per topic among the curricula. Differences such as these need to be taken into account when interpreting the achievement results for the various curricula.

What are the next steps for the study?

An additional 71 schools participated in the second year of the study (school year 2007–08), in both the first and second grades. The next study report will present results for all 110 participating schools in both the first and second grades. The second-year report also will incorporate data from classroom observations to provide additional insight into issues of curriculum implementation and will provide data on Spanish versions of the curricula implemented in Spanish-only classrooms. A third report will focus on expansion in the third year of the study to third-grade students.

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ResearchLink is produced to accompany each Scientific Evidence in Education (SEE) Forum. The SEE Forums is a project of the American Institutes for Research (www.air.org), a nonpartisan not-for-profit organization that conducts behavioral and social science research and delivers technical assistance domestically and internationally in the areas of education, health, and workforce productivity. The project is sponsored in part through a grant from the Institute of Education Sciences of the U.S. Department of Education. To offer comments or request further information, contact: info@seeforums.org.

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