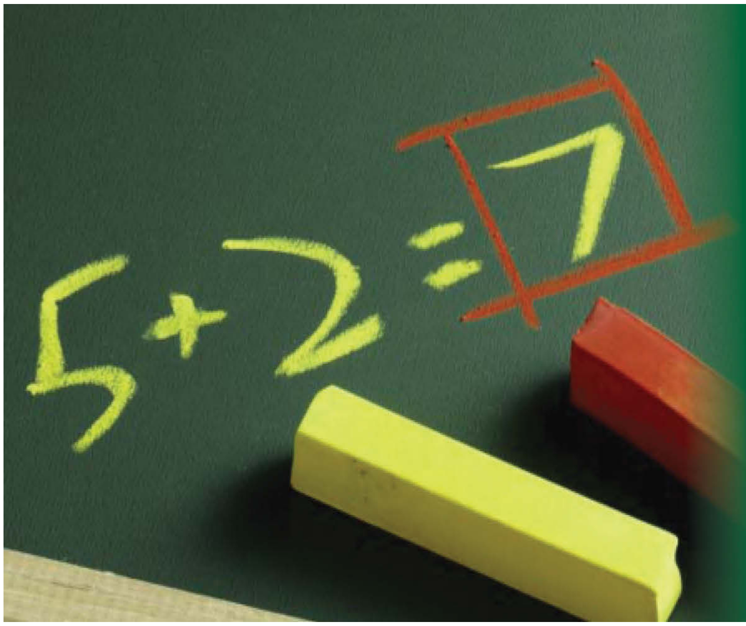
IES NATIONAL CENTER FOR EDUCATION EVALUATION AND REGIONAL ASSISTANCE
Institute of Education Sciences

AFTER TWO YEARS, THREE ELEMENTARY MATH CURRICULA OUTPERFORM A FOURTH



Which math curriculum should I use?

This brief aims to help educators understand the implications of math curriculum choice in the early elementary grades by presenting new findings from a study that examined how four math curricula affect students' achievement across two years—from 1st through 2nd grades.[1] The four curricula were (1) Investigations in Number, Data, and Space (Investigations); (2) Math Expressions; (3) Saxon Math (Saxon); and (4) Scott Foresman-Addison Wesley Mathematics (SFAW), which the developer revised and renamed enVision Math (enVision) during the study. These curricula are widely used and differ in their approaches to teaching and learning. Within districts, we randomly assigned one of the four curricula to each school that participated in the study. After one year (by the end of 1st grade), students taught with Math Expressions and Saxon made greater gains in achievement than students taught with Investigations and SFAW. After two years (by the end of 2nd grade), Investigations students continued to lag behind Math Expressions and Saxon students, while SFAW/enVision students caught up to Math Expressions and Saxon students. Therefore, Math Expressions, Saxon, and SFAW/enVision improved 1st-through-2nd-grade math achievement by similar amounts, and all three outperformed Investigations. Our findings also suggest that switching between some of the study's curricula does not harm student achievement and can even be beneficial.

The selection of a math curriculum affects the nature of mathematics instruction and, ultimately, the opportunities for students to learn mathematics. According to the National Research Council (2001), "Opportunity to learn is widely considered the single most important predictor of student achievement." Research confirms this important connection between curricula and achievement. For example, at the elementary level, previous findings issued by this study indicate that some curricula improve the average student's percentile rank in math by as much as 12 points more than other curricula during the first year of implementation (Agodini et al. 2009, 2010).

The choice of curriculum is particularly critical for elementary schools because they tend to use one math curriculum in several grades, thus affecting students for multiple years. However, little is known about how these curricula affect students over time. This is a key issue because curricula differ in important ways that could have implications for students' learning over time and, therefore, their effects may differ from those found after a single year. For example, differences between curricula in the sequencing of concepts, the extent of review of previously learned skills, or the alignment with student assessments in different grades could lead to achievement effects that vary from year to year. Also, some curricula place higher cognitive demands on students, by having them figure out important mathematical ideas that typically are not immediately apparent. This practice helps students develop conceptual understanding of math that could improve gradually over several years (Hiebert and Grouws 2007). Finally, some curricula are clearer about the objectives of the lessons and provide better teacher supports for implementing the lessons (Stein and Kaufman 2010), which could in turn lead to differing effects across years and grades.

To help educators more fully understand this issue, we expand on previous findings from this study by examining how four math curricula affect students' achievement across two years—from 1st through 2nd grades: (1) Investigations in Number, Data, and Space (Investigations); (2) Math Expressions; (3) Saxon Math (Saxon); and (4) Scott Foresman-Addison Wesley Mathematics (SFAW), which the developer revised and renamed enVision Math (enVision) during the study.[2] These curricula are widely used in the early elementary grades[3] and, as described below, differ in their approaches to mathematics instruction.

When making curricular decisions, it is important to consider not only the potential effects of the new curriculum, but also the implications of switching from one curriculum to another. Because many districts make their own curricular decisions, and some districts let schools choose their own curriculum, students who move from one district or school to another could switch curricula. This issue is of particular concern for disadvantaged students, who are more likely to transfer between schools (Rumberger 2003). Switching curricula also could be an issue for students who do not transfer between schools because many districts review their elementary math curriculum every several years and often adopt a new one at that time, resulting in a large fraction of students experiencing more than one math curriculum during their elementary years.[4] For example, California, Florida, and Texas are among 22 states with a textbook adoption process that every six years or so determines a selection of math texts that districts can purchase with state funds, and districts in these states tend to follow this curriculum adoption schedule.[5] Our study also provides evidence that helps educators understand the effects on student achievement of switching from one curriculum to another.

This brief addresses three questions:

1. Do some of the study's curricula improve 1st-through-2nd-grade student math achievement more than others?
2. How do these curriculum-group differences in achievement after two years (by the end of 2nd grade) compare with the curriculum-group differences after one year (by the end of 1st grade)?
3. How does switching curricula (instead of staying with the same one) affect student achievement during the first year a new curriculum is used?

In the remainder of this brief, we provide an overview of the study design, including the selection, description, and assignment of study curricula. Next, we examine curriculum implementation to place the student achievement effects in context. We then present our findings on the achievement effects of elementary math curricula after one and two years, along with the effects of switching curricula. Finally, we conclude with a discussion and suggestions for future research.

Study Design

To set up the study, we (1) selected the curricula to be included, (2) documented the key ways in which the programs differ, and (3) randomly assigned the curricula to schools that agreed to participate in the study.

Selecting the Curricula

We used a competitive process to choose our curricula. Developers and publishers of math curricula for early elementary school were invited to submit proposals to have their curricula included in the evaluation. The goal of this process was to select curricula that represented varied approaches to instruction and learning and were likely to improve student achievement more than other curricula. To meet this objective, we used six criteria to review the submissions: (1) research support for the curriculum's conceptual framework, (2) empirical evidence of effectiveness, (3) teacher practices and skills that comprise the curriculum, (4) quality of training and materials, (5) institutional capacity to train the number of teachers in the study, and (6) appropriateness of the curriculum for early elementary students in Title I schools. An independent panel of experts in math and math instruction reviewed the submissions and recommended curricula they believed were suitable for the study. In-person meetings were held with publishers whose curricula were considered strong candidates, after which IES selected the four curricula mentioned above.[6]

Important Differences Between the Curricula

To summarize the differences between the curricula, we conducted a comparative analysis that was framed using research on effective mathematics instruction. This research has found that three aspects of curricula are likely to have a strong influence on instruction (that could affect student achievement): (1) mathematical emphasis, (2) instructional approach, and (3) supports for teachers.[7] For each aspect, our review of curriculum materials revealed substantial variation across the four curricula, as expected. Below is a summary of the differences, and more detail is provided in the appendix.

Mathematical emphasis concerns the kinds of mathematics that students had opportunities to learn and how those opportunities were structured. To assess this feature, including the ways in which the curricula address conceptual understanding and procedural fluency, we examined three components: (1) the cognitive demand of the tasks[8]; (2) regular routines that provide opportunities for engagement with concepts, facts, and procedures; and (3) repeated practice of skills and procedures to develop procedural fluency.[9] *Cognitive demand* refers to the extent to which the mathematics tasks involved connections between concepts, procedures, and facts and provided potential opportunities to struggle with mathematics.[10] High-demand tasks are intellectually and conceptually challenging, whereas low-demand tasks focus on routine and procedural elements without connections to concepts.

As Table 1 shows, nearly all (95 percent) of Investigations' and Math Expressions' tasks are high demand, compared with 65 percent for Saxon and 57 percent for SFAW/enVision. Looking at daily routines and use of repeated practice, we found that Saxon and, to a lesser extent, Math Expressions both emphasize procedural fluency more than Investigations and SFAW/enVision do.

Table 1. Summary of Key Curriculum Differences

	Investigations	Math Expressions	Saxon	SFAW/enVision
Mathematical Emphasis				
Cognitive Demand of the Primary Tasks in Each Curriculum	DM – 40% PWC – 55% PWOC – 5% M – 0%	DM – 30% PWC – 65% PWOC – 0% M – 5%	DM – 0% PWC - 65% PWOC – 35% M – 0%	DM – 0% PWC – 57% PWOC – 40% M – 3%
Frequency and Length of the Routine	Daily 10 minutes	Daily 5-10 minutes	Daily 20 minutes	Optional Length Unspecified
Frequency and Length of Repeated Practice	Regularly[a] 10 minutes	Daily 5-10 minutes	Daily 10-15 minutes	Optional Length Unspecified
Instructional Approach				
Teacher's Role	Facilitate student production of ideas	Explain, model, facilitate production of ideas	Explain, demonstrate, guide	Explain, demonstrate, guide
Classroom Interactions	Teacher-Student (Student-Student)	Teacher-Student (Student-Student)	Teacher-Student	Student-Text
Pathway for Learning	Between students and teacher	From teacher to students, and between students	From teacher to students	From text to students
Supports for Teachers				
How the Text Guides Teachers	BLEND: Descriptive scripts guide teacher actions, with selective explicit scripts containing exact words to use	BLEND: Detailed descriptive scripts and explicit guidance of teacher actions (rarely scripts teacher's words)	EXPLICIT: Fully scripted lesson; detailed description of teacher actions and room arrangements	DESCRIPTIVE: Minimal description of teacher actions

Note: The technical appendix further details the curriculum differences; DM=doing mathematics, PWC=procedures with connections, PWOC=procedures without connections, and M=memorization. DM and PWC are high-demand tasks; PWOC and M are low-demand tasks.

[a]Repeated practice in Investigations occurs at regular intervals at least once a week, but does not necessarily occur daily.

Instructional approach refers to the teacher's role during instruction, the types of activities in which students are expected to engage, and the nature of the classroom interactions. Investigations, Math Expressions, and Saxon have students and teachers interact with one another as they work on activities and concepts (Table 1). Investigations and Math Expressions also emphasize student-to-student interactions and provide opportunities for students to work together and communicate their mathematics knowledge. With SFAW/enVision, in contrast, the predominant classroom interaction is between the student and the worksheet, workbook, or other curriculum materials.

Supports for teachers concern the types of implementation guidance provided to teachers, including *how* each curriculum provides guidance and the *topics* of the guidance. The curricula provide guidance through either explicit scripts, descriptive scripts, or both. Explicit scripts specify what teachers should say. Descriptive scripts guide teachers' and students' actions or dialogue by describing what should be said, written, visually demonstrated, or done; or by providing both explicit and descriptive scripts. The topics of the guidance can include directing teachers' actions, helping teachers understand student thinking, providing subject-specific content support, and clarifying curriculum designers' rationale or intent.

Investigations blends descriptions of teacher actions with selective explicit scripts of questions the teacher should ask or ways to respond to students (Table 1). Math Expressions is even more detailed in its descriptive script but less frequently specifies what the teacher should say. Unlike the other three, Saxon provides a fully scripted lesson containing almost everything the teacher should say, along with a detailed descriptive script. SFAW/enVision's guidance is more minimal and general than that of the other curricula.

In terms of topics, both Investigations and Math Expressions provide guidance on a variety of teaching components, including mathematical concepts, student thinking, and ways to adapt a lesson for specific students. SFAW/enVision provides guidance on few topics, as does Saxon, which primarily focuses on classroom organization and management.

Assigning the Curricula to Schools

After selecting the curricula, we recruited schools to participate in the study. A total of 111 schools from twelve districts enrolled in the study and agreed to participate for at least one year.[11] Of the 111 schools, 58 agreed to participate for a second year; the analyses presented in this brief are based on the 58 schools (from seven districts) that participated for two years.

Though not a representative sample of all elementary schools in the United States, the 58 schools included in these analyses are dispersed geographically and in areas with various levels of urbanicity. The participating schools also serve a higher percentage of students eligible for free or reduced-price meals than the average U.S. elementary school.

At the outset of the study, we randomly assigned one curriculum to each school. The random assignment ensures that the four curriculum groups are similar in other ways and, therefore, any differences in classroom practices and student achievement can be attributed to differences in the effect of the curricula. The random assignment was conducted separately in each district, so each district implemented all four curricula. After random assignment, we introduced the school staff to the publishers of their assigned curriculum. Publishers then worked with the schools to deliver curriculum materials before the school year began and to schedule training for teachers.

How Teachers Implemented Their School's Assigned Curriculum

The differences between the curricula described above indicate how they differ when implemented *as intended*. But teachers and publishers may not always implement the curricula perfectly, which could influence the effect of the curricula on student achievement. To help shed light on this important issue, we analyzed implementation data collected by the study team through teacher surveys and classroom observations.

The survey data indicated that nearly all teachers (at least 96 percent) in each curriculum group used their assigned program as their core curriculum. In addition, at least 70 percent of the teachers implemented a majority of the curriculum features as intended.[12] According to the survey data, the amount of time spent on math instruction did not differ across the curriculum groups among 1st-grade teachers. In 2nd grade, however, Saxon teachers spent one more hour per week on math instruction than did teachers using the other three curricula (6.1 hours versus 5.1 hours).[13] The appendix presents more information about implementation based on the survey data.

Our classroom observation data show how well teachers implemented three aspects of the instructional approaches underlying the curricula, including the way teachers question students, respond to student answers, and guide practice. For each of these aspects, our observation data contain two to three related measures.

For these aspects of the instructional approach, we found that teachers did what was expected for their assigned curriculum, with only two unexpected findings, both of which involve Math Expression, Saxon, and SFAW/enVision. First, based on our review of the curriculum materials, we expected Math Expressions teachers to ask fewer closed-ended questions and more open-ended questions than Saxon and SFAW/enVision teachers, but the classroom observation data do not show these patterns. Instead, as shown in Table 2, all three groups (Math Expressions, Saxon, and SFAW/enVision) asked similar numbers of closed-ended questions, and Math Expressions teachers asked as many or fewer open-ended questions compared with Saxon and SFAW/enVision teachers. Second, we expected Math Expressions teachers to be less likely than Saxon and SFAW/enVision teachers to immediately indicate whether a student's answer was correct; instead, all three groups were equally likely to respond in this manner.[14]

Curriculum Effects

To measure the effects of the curricula, we administered the math assessment from the Early Childhood Longitudinal Study-Kindergarten (ECLS-K) Class of 1998–1999 study. The ECLS-K assessment is an individually administered, adaptive, and nationally normed test that measures student achievement both within and across grades and meets accepted standards of validity and reliability (Rock and Pollack 2002).[15] The assessment includes both open-ended and multiple-choice questions designed to measure conceptual understanding, procedural knowledge, and problem solving in five math content areas: (1) number sense, properties, and operations; (2) measurement; (3) geometry and spatial sense; (4) data analysis, statistics, and probability; and (5) patterns, algebra, and functions.[16]

Table 2. Implementation of Three Aspects of the Curricula in First- and Second-Grade Study Classrooms[17]
(average number of times each behavior occurred during one day of math instruction)

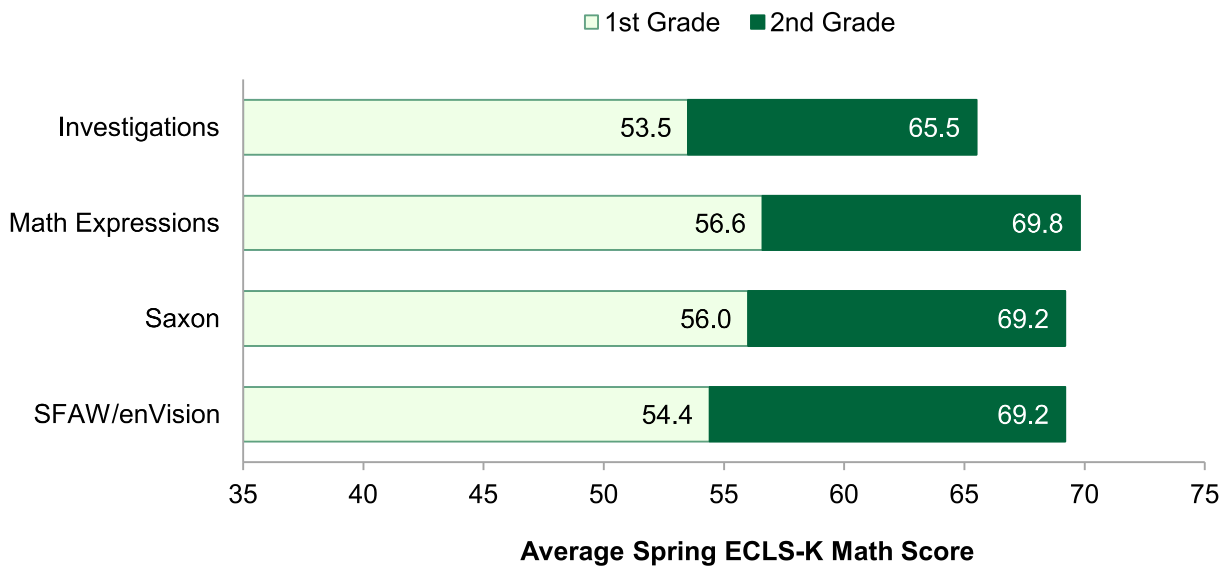
Observation Item	Investigations	Math Expressions	Saxon	SFAW/ envision
1. Teacher Questions				
Teacher asks closed-ended questions for which only one answer is acceptable	18.2	20.1	21.0	20.4
Teacher poses open-ended questions that have more than one correct answer	9.6	4.3	7.6	4.8
Teacher probes for reasoning or justification in response to student work/answer	6.8	4.9	3.5	4.7
2. Teacher Responses to Student Answers				
Teacher repeats student answer in a neutral way without indicating correctness	4.2	0.3	1.2	1.6
Teacher states whether student answer is correct without elaborating	16.9	19.8	20.2	18.7
3. Types of Practice				
Number of problems on which the teacher guided practice	5.2	6.8	10.8	11.6
Number of problems focused on review of previously learned material	2.6	6.0	15.3	4.4

Note: The classroom observations were conducted by the study team using a protocol designed to distinguish differences between the curricula. The observation included an entire day of math instruction, including the math lesson and any morning meeting or calendar time, and the behaviors in the table had a possible range of 0 to 21. The appendix further details the observation effort. All measures differ significantly across the curriculum groups at the 5 percent level of confidence. Statistics are based on 334 classroom observations conducted in 1st- and 2nd-grade classrooms.

Two years of a curriculum. Among students who were taught using their school's assigned curriculum for two years (in the 1st and 2nd grades), Math Expressions, Saxon, and SFAW/enVision improved math achievement by similar amounts. All three improved math achievement more than Investigations by statistically significant amounts (Figure 1).[18] Specifically, after being taught with their school's assigned curriculum in 1st and 2nd grade, Math Expressions, Saxon, and SFAW/enVision students had an average spring 2nd-grade ECLS-K math score of 69.4, compared with 65.5 for Investigations students. Dividing this nearly 4-point difference by the 18-point standard deviation of the second-grade score indicates that Math Expressions, Saxon, and SFAW/enVision students scored an average of 0.22 standard deviations higher on the ECLS-K math test than Investigations students. This 0.22 difference (also known as an "effect size") means that a study student at the 50th percentile in math would score 9 percentile points higher as a result of being taught in 1st and 2nd grade with Math Expressions, Saxon, or SFAW/enVision instead of with Investigations.[19]

One year of a curriculum. Using the same set of districts and schools that participated in the study for two years, we examined the one-year effects students experienced by the end of 1st grade (Figure 1). The comparison of one- and two-year effects helps us understand whether the different teaching and learning approaches underlying the four curricula have implications for students' learning over time.[20]

Figure 1. Math Expressions, Saxon, and SFAW/enVision improved 1st-through-2nd-grade math achievement by similar amounts, and all three outperformed Investigations



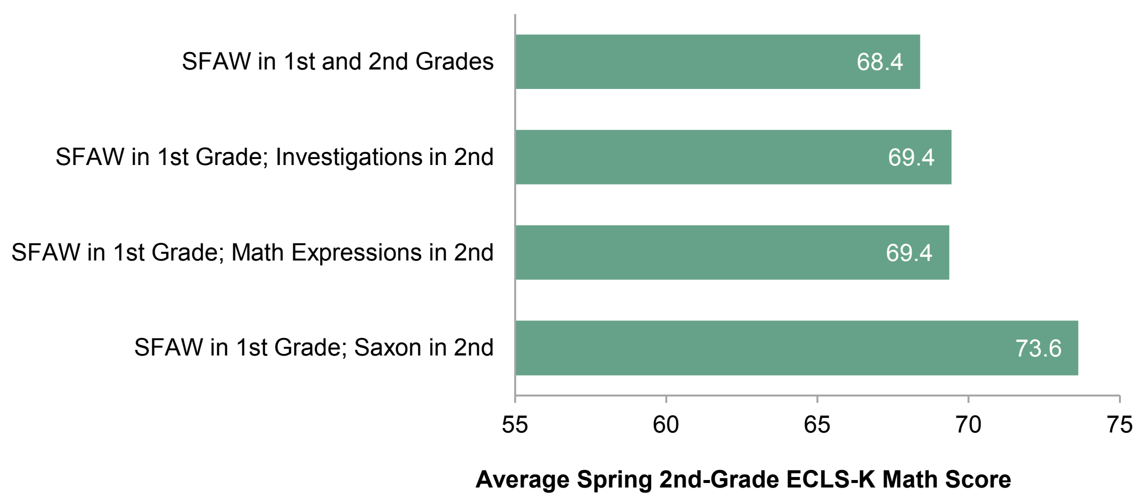
Note: The students included in this analysis entered the study at the beginning of 1st grade, at which point their school was randomly assigned to use one of the study's four curricula. The starting point of 35 for the horizontal axis represents average math achievement of students at the beginning of 1st grade—that is, when they entered the study. The standard deviations of the spring 1st and 2nd grade scores equal 17 and 18, respectively.

After one year (by the end of 1st grade), the achievement differences between Investigations, Math Expressions, and Saxon students were similar to the differences after two years (by the end of 2nd grade). In contrast, after one year, SFAW students scored 2.2 points *lower* than Math Expressions students on the ECLS-K test—a difference that is statistically significant. Dividing this 2.2 point difference by the 17-point standard deviation of the 1st-grade score indicates that SFAW students scored an average of 0.13 standard deviations, or 5 percentile points lower than Math Expressions students. But, after the second year, achievement of SFAW and Math Expressions students was nearly equal. The effectiveness of SFAW/enVision therefore increased as study students gained experience with this curriculum.[21]

Switching curricula. Among the 111 schools that agreed to participate in the study for at least one year, 71 implemented their assigned curriculum in the 2nd grade during the first year of the study. Nearly all of these schools also implemented their curriculum in the 1st grade during the first study year. Our evidence about the effects of switching curricula is based on second graders in 37 of the 71 schools because these 37 schools reported using either Saxon or SFAW before the study. As such, the year before the study, the first graders in those schools were taught with either Saxon or SFAW. The next year, when these schools entered the study, they were randomly assigned to either continue using their pre-study curriculum (Saxon or SFAW), or switch to one of the other study curricula. As a result, the second graders in those schools either continued to be taught with one of the study's curricula (Saxon or SFAW) or were taught with a different curriculum in the 2nd grade. We compared 2nd-grade achievement of students who did and did not switch from Saxon or SFAW to another study curriculum after 1st grade, to understand how switching curricula affects students during the first year a new curriculum is used. The appendix provides more details about these analyses.[22]

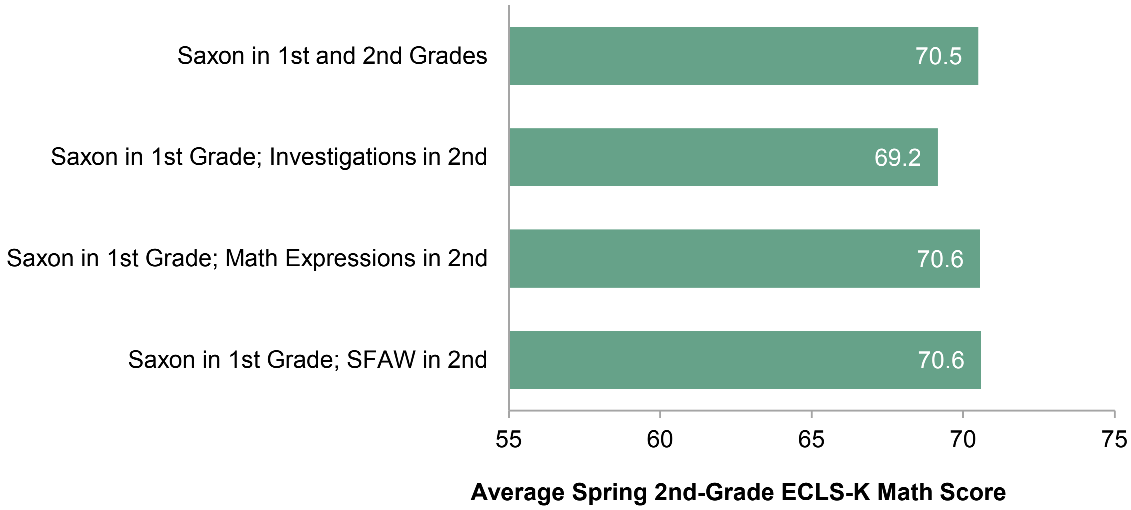
This evidence suggests that switching between some of the study's curricula does not harm student achievement and can even be beneficial. Students in the 7 schools who switched from SFAW to Saxon after 1st grade had an average 2nd-grade math score of 73.6, compared with 68.4 for those (in 6 schools) who stayed with SFAW—a difference that is statistically significant (Figure 2). This effect is equivalent to moving a study student from the 50th to the 64th percentile in math achievement. The other types of switching we examined had no effect on student math achievement. Students in the 12 schools who switched from SFAW to Investigations or Math Expressions after 1st grade had similar 2nd-grade math scores: 68.4 for those who stayed in SFAW and 69.4 for those who switched to Investigations or Math Expressions (Figure 2). Similarly, students using Saxon for an additional year rather than switching to another curriculum had similar 2nd-grade math scores: 70.9 for students in 3 schools who stayed with Saxon versus 70.4 for students in 9 schools who switched to another curriculum (Figure 3).[23]

Figure 2. Average 2nd-Grade Math Achievement: Students Who Stayed with SFAW Through 2nd Grade and Those Who Switched to Another Study Curriculum After 1st Grade



Note: The students included in this analysis entered the study at the beginning of 2nd grade, at which point their school was randomly assigned to either continue using SFAW (their pre-study curriculum) or switch to another study curriculum. The starting point of 55 for the horizontal axis represents average math achievement of students at the beginning of 2nd grade—that is, when they entered the study. The standard deviation of the spring 2nd-grade score equals 15. The difference in average math achievement of students who stayed with SFAW through 2nd grade versus those who switched to Saxon after 1st grade is statistically significant at the 5 percent level; all other differences between students who stayed with SFAW versus those who switched are not significant.

Figure 3. Average 2nd-Grade Math Achievement: Students Who Stayed with Saxon Through 2nd Grade and Those Who Switched to Another Study Curriculum After 1st Grade



Note: The students included in this analysis entered the study at the beginning of 2nd grade, at which point their school was randomly assigned to either continue using Saxon (their pre-study curriculum) or switch to another study curriculum. The starting point of 55 for the horizontal axis represents average math achievement of students at the beginning of 2nd grade—that is, when they entered the study. The standard deviation of the spring 2nd-grade score equals 15. There were no statistically significant differences (at the 5 percent level) between the four groups.

Discussion and Looking Ahead

Many policymakers and education experts agree on the need for education reform and are focusing much of their attention on approaches to improving school governance, staffing, and content standards. Some research suggests that these approaches may have promise for increasing student achievement, but other studies show that an entirely different approach—changing a school's curriculum—could lead to larger increases in student achievement at a much lower cost (Whitehurst 2009).

In our study, one of the first to rigorously examine curriculum effects over multiple years, we compared the two-year effects of four math curricula that are widely used in the early elementary grades and differ in their approaches to teaching mathematics. Our results indicate that Math Expressions, Saxon, and SFAW/enVision improved 1st-through-2nd-grade math achievement by similar amounts, and all three outperformed Investigations.

Although these results help confirm that curricula can be an effective policy lever for improving student achievement in math, educators need at least three more pieces of information to help them use this lever successfully. First, researchers should look at the impacts of curricula on other assessments of student achievement that, like the one administered in this study, were designed to measure knowledge and skills that mathematicians and math educators feel are important for students to develop in early elementary school.[24] Given that about 44 states intend to implement new math assessments in response to the adoption of the Common Core State Standards, it is important to know how the curricula affect these new accountability assessments.

Second, researchers should examine curriculum effects beyond two years, along with the effects on students in other grades and subjects. The findings from this research may also be useful for certain states that limit the use of state funds for purchasing curricula. More comprehensive evidence about curriculum effects could be useful for these states' decisions about which curricula to support.

Third, educators need to know which features of curricula drive the effects we observed in our study. As mentioned in our descriptions of the study's curricula, each program has key differences. For example, Investigations has higher demand tasks than Saxon, whereas the Saxon scripts are easier to use. Given that Saxon improved student achievement more than Investigations did, it is possible that Saxon balances task demand with ease-of-use more effectively than Investigations does. Of course, these features are only two important aspects of the curricula; other features also may play a role in curriculum effects. Knowing these features can help teachers select the right curriculum for their classrooms and implement it successfully.

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ENDNOTES

[1] Previous study reports examined how the curricula affected students' achievement during one year (Agodini et al. 2009, 2010).

[2] The publisher of SFAW revised and renamed the SFAW curriculum during the study. The new name of the curriculum is enVision. This change did not affect three of the seven districts that participated in the study for two years because their two years of participation preceded this change; however, it did affect the other four districts because it occurred halfway through their two years of study participation. We examined the implications of the SFAW-enVision change by comparing results based on students from all seven districts with those from the three districts that were not affected by the change. The pattern of results is similar across the two sets of districts; therefore, we report results based on the larger sample of seven districts. More details about these analyses are provided below and in the appendix.

[3] According to a 2008 survey (Resnick et al. 2010), Investigations, Saxon, and SFAW make up 32 percent of the curricula used by K–2 educators. Math Expressions is a newer curriculum and, therefore, its market share was not available in the 2008 survey.

[4] When a district/school adopts a new curriculum, it is typically implemented in each elementary grade at the same time. These whole-school curriculum changes every several years mean that a large fraction of students experience two math curricula during their elementary years. For example, if a K–5 school changes its math curriculum every six years, only students who are kindergarteners during the year of a curriculum adoption experience the same curriculum throughout their elementary years; students in grades 1 through 5 experience two curricula. Specifically, in these schools, about 17 percent of students experience the same curriculum throughout their elementary years; the other 83 percent experience two curricula.

[5] The following websites (accessed on May 13, 2013) provide information about California's, Florida's, and Texas's math curriculum adoption processes, respectively: http://www.cde.ca.gov/ci/ma/im/,
http://ritter.tea.state.tx.us/textbooks/adoptprocess/adoptioncycle.pdf,
http://www.fldoe.org/bii/instruct_mat/pdf/cycle.pdf.

[6] Nine submissions were received; curricula submitted for consideration but not selected are not disclosed because proposals were confidential.

[7] According to the National Research Council (2001), "Opportunity to learn is widely considered the single most important predictor of student achievement." The goal of our analysis was to characterize the potential opportunities to learn mathematics available in each curriculum program. Traditionally, opportunity to learn (OTL) referred to the specific topics covered in the classroom and the time devoted to each (Floden 2002). Hiebert (2003) argued that you must also consider the nature and quality of that time, as well as the supports and structures that frame engagement with given tasks. Drawing on these perspectives, we identified three analytical

categories to focus our analysis: (1) mathematical emphasis, (2) instructional approach, and (3) supports for teachers. Our analysis does not include other aspects of instruction that research has found are important (such as formative assessments) because they were outside the scope of this study.

[8] Stein, Grover, and Henningsen (1996) developed a scheme for categorizing tasks based on the extent to which they emphasize connections among concepts, procedures, and facts and their potential to engage learners with mathematical ideas. There are two types of high-demand tasks—"doing mathematics" and "procedures with connections"—and two types of low-demand tasks—"procedures without connections" and "memorization." The appendix contains information about their prevalence in the curricula based on a sample of lessons from each program.

[9] Procedural fluency is one of the five components of mathematical proficiency proposed by the NRC (2001). It is defined as skill in carrying out procedures flexibly, accurately, efficiently, and appropriately (pp. 116).

[10] Hiebert and Grouws (2007) elaborate on the term "struggle with mathematics" by stating that it is "the opposite of simply being presented information to be memorized or being asked only to practice what has been demonstrated" (pp. 387–388).

[11] The 111 schools enrolled in the study beginning in either the 2006-07 or 2007-08 school year.

[12] There is some risk that teachers overstated their implementation because they knew they were supposed to implement the curricula, but there is no reason to believe that the magnitude of inflation would be notably different among the four curricula.

[13] The differences in math instructional time in 2nd grade are consistent with the publisher recommendations for instructional time.

[14] Although these results provide evidence that teachers used the curriculum assigned to their schools and implemented some aspects of the instructional approach as expected for their assigned curriculum, not all aspects of the instructional approach are measured with our data. For example, our observation data do not contain measures of how the teacher attends to student thinking and understanding. In addition, the data do not contain measures of the mathematical emphasis or the way in which the teachers utilized the supports available in their assigned curriculum.

[15] During the test selection process, members of the panel who reviewed the curriculum submissions also reviewed the tests under consideration to assess whether the tests provided an unfair advantage to one or more curricula, because we did not want to use an assessment that was biased toward some curricula; however, the review panel did not assess the tests for their alignment with the instructional objectives of the math curricula. The ECLS-K was considered to be the best option among the alternatives.

[16] On the 1st-grade test, about three-quarters of the items can be classified as number sense, properties, and operations; the remaining items are predominantly related to data analysis; statistics and probability; and patterns, algebra, and functions. On the 2nd-grade test, about half of the test is composed of items pertaining to number sense, properties, and operations; the other half is predominantly related to measurement; geometry and spatial sense; and patterns, algebra, and functions. Specific items included on the assessment are not provided because it is copyrighted. Rock and Pollack (2002) provide more details about the assessment, and the appendix of this brief provides more details about the process used to score the tests and information about test reliabilities.

[17] The items presented in the table are a subset of the items on the observation protocol. The items selected for the table were considered by the study team to be those that most closely align with the aspects of the curricula examined through the comparative curriculum analysis.

[18] As mentioned earlier, the participating schools serve a higher percentage of students eligible for free or reduced-price meals and a higher percentage of non-Hispanic black students than the average U.S. elementary school. More details about the study schools are provided in Table A.8 of the appendix.

[19] The results for the SFAW/enVision curriculum group are difficult to interpret because some students in that group were taught with SFAW in both 1st and 2nd grades, whereas others were taught with SFAW in 1st grade and enVision in 2nd. To better understand the two-year effects of SFAW, we calculated results for the three districts that were not affected by the SFAW-enVision change, as mentioned above. In these districts, students in schools assigned to SFAW experienced that curriculum in both 1st and 2nd grades. These subgroup results are similar to the results based on the full sample—that is, after two years, Math Expressions, Saxon, and SFAW improved math achievement by similar amounts, and all three improved math achievement more than Investigations. Because the subgroup and full-sample results are similar, we report results based on the larger sample of seven districts, as mentioned above. The appendix provides more details about these results, along with a description of the enVision curriculum.

[20] Previous study reports examined one-year effects during 1st grade (Agodini et al. 2009, 2010), but those results included students from other districts we did not include in this report because they did not participate in the study for two years. Therefore, to provide an accurate understanding of how the two-year effects in Figure 1 compare with the one-year effects in Figure 2, we calculated the one-year effects for the students who were actually taught their assigned curriculum for two years.

[21] Some teachers who taught the students in these analyses also gained experience implementing their school's assigned curriculum as part of the study. Specifically, 23 percent of the teachers who taught the study students implemented their school's assigned curriculum for a second year; all teachers who gained experience were 2nd grade teachers. Whether teachers gained experience is a function of the grades in which their school implemented the curricula in

the first and second years of study participation. See Table A.7 for more information about the grade levels of implementation in each year of the study.

[22] First graders in some of the study schools also may have experienced a curriculum switch after kindergarten; however, we do not examine the effects of switching curricula between kindergarten and 1st grade because kindergarten math curricula are often less structured or defined.

[23] Because some curricula may be more effective in some grades than others, it would be useful for future research to examine the effects of switching curricula between other grades to assess whether our evidence is robust across grades. It also would be useful for future research to examine the switching-staying issue for Investigations and Math Expressions. Our study does not support these examinations because (1) too few schools were using Investigations before joining the study and they were assigned to continue using Investigations, and (2) no school was using Math Expressions before joining the study.

[24] Recent evidence suggests that, under certain circumstances, the effects of mathematics curricula on student achievement at the middle school level are sensitive to the type of test examined. Tarr et al. 2008 examined curriculum effects on two tests: the Balanced Assessment in Mathematics (BAM) and TerraNova Survey (TNS). The test mattered only when measuring the effects of an NSF-funded curriculum when the curriculum was paired with moderate or high levels of a standards-based learning environment. The evidence is based on a quasi-experimental design, so it could be worthwhile to examine whether the outcome measure matters with a more rigorous approach.

For more information on the full study, please visit:

http://ies.ed.gov/ncee/projects/evaluation/math_curricula.asp

To read the technical appendix, please visit:

http://ies.ed.gov/ncee/pubs/20134019/pdf/20134019_app.pdf

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