Evidence on Effectiveness of Curricula

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Purpose

To review and summarize the evidence needed for choosing a curriculum. It answers the question: "On current evidence, which widely available curricula best enable teachers to help their students to deeper understanding of, and better performance in, mathematics?"

Summary

Choosing a curriculum for classroom use is always difficult. This is especially the case in mathematics, where there have been major controversies, sometimes called the “math wars.” The first question is, what do you want students to learn? This is controversial – different states have different standards, focusing on everything from the traditional curriculum (which focuses on the mastery of fundamental skills and understandings) to “reform” or “standards-based” curricula (which have a broader range of goals covering skills, concepts, and problem solving). Once you decide on fundamental goals for instruction the question is, “What works?” What evidence is there that any particular curriculum or group of curricula is more or less effective at having students learn the desired skills? Our purpose in producing this tool is to describe the controversies, identify the relevant curricula and resources for evaluating them, and summarize the (relatively small but clear) body of evidence comparing traditional and standards-based curricula. Overall, the evidence suggests the following. When you test for basic skills, there is likely to be little statistical difference in the performance of students from traditional or reform curricula –[It’s mixed in the Senk & Thompson volume – many of the reform curric give lower skills scores, but not statistically lower. Overall, the best you can say is that it’s a wash. However, when you test for conceptual understanding or problem solving performance, students from standards-based (reform) curricula are likely substantially to outperform students from traditional curricula.

Background and Context

For a variety of reasons, there were significant changes in U.S. mathematics curricula starting in the early 1990s. One reason was an “economic imperative.” The economy was faltering and U.S. students had done very poorly on international comparisons such as the 2nd international mathematics and science study (SIMS). See, e.g., McKnight, Crosswhite, Dossey, Kifer, Swafford, Travers, & Cooney, 1987; McKnight, Travers, & Dossey, 1985). A very influential document,. “A Nation at Risk, declared that things had to change:

> *“Our Nation is at risk. Our once unchallenged preeminence in commerce, industry, science, and technological innovation is being overtaken by competitors throughout the world.... The educational foundations of our society are presently being eroded by a rising tide of mediocrity that threatens our very future as a Nation and a people....*
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> *“If an unfriendly foreign power had attempted to impose on America the mediocre educational performance that exists today, we might well have viewed it as an act of war. We have, in effect, been committing an act of unthinking, unilateral educational disarmament.” (National Commission on Excellence in Education, 1983, p. 1)*

The second reason for change was that research conducted in the 1970s and 1980s indicated that “thinking mathematically” was much more complex than had been realized.

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[1] This document draws heavily from Schoenfeld (2002; in press-a; in press-b).

For most of the 20th century, the dominant perspective on learning in most fields, and specifically in mathematics, was that learning is the accumulation of knowledge; that practice solidifies mastery; and that knowledge is demonstrated by the ability to solve particular (well-studied) classes of problems. Starting in the 1970s, as a function of the "cognitive revolution" (Gardner, 1985) that overly simple notion of learning was replaced by more complex, and more robust, theories of mathematical competency. Evidence mounted that a wide range of other skills and understandings were central to effective mathematical performance. Those included:

- having a solid knowledge base, much as would be expected in the traditional curriculum;
- being able to employ a range of problem solving strategies;
- being able to reason effectively using mathematical ideas, and to communicate one's reasoning effectively, orally and in writing;
- being able to make effective use of the various resources, including the knowledge and time at one's disposal (this arena is called "metacognition");
- having a productive set of beliefs and dispositions about the nature of the mathematical enterprise.

(See, e.g., De Corte, Greer, & Verschaffel, 1996; Schoenfeld, 1985, 1992.)

More recent volumes may vary in what they stress, but the core aspects of mathematical competence are much the same. For example, NTCM's (2000) *Principles and Standards for School Mathematic*s delineates five important content areas (number and operations; algebra; geometry; measurement; data analysis and probability) and five important mathematical processes (problem solving; reasoning and proof; making connections; oral and written communication; uses of mathematical representation). The National Research Council volume *Adding It Up* (2001) describes five interwoven strands of mathematical proficiency:

- *conceptual understanding* – comprehension of mathematical concepts, operations, and relations
- *procedural fluency* – skill in carrying out procedures flexibly, accurately, efficiently, and appropriately
- *strategic competence* – ability to formulate, represent, and solve mathematical problems
- *adaptive reasoning* – capacity for logical thought, reflection, explanation, and justification
- *productive disposition* – habitual inclination to see mathematics as sensible, useful and worthwhile, coupled with a belief in diligence and one's own efficacy.

(National Research Council, 2001, p. 5)

All of the above are often combined and summarized in the three categories of **skills, concepts, and problem solving.** It is generally agreed that these are the dimensions of mathematical performance that are essential to teach and to assess.

History of the development of curriculum resources

Research on mathematical thinking and problem solving influenced the National Council of Teachers of Mathematics' very influential curriculum document, the 1989 *Curriculum and Evaluation Standards for School Mathematics.* The *Standards,* as they are known, called for a broad set of goals for mathematics instruction (including, for example, mathematical literacy as a component of literate citizenship and in preparation for the workplace, as well as in preparation for more advanced mathematics). In line with current research, they emphasized mathematical processes such as problem solving and reasoning, making connections, and communicating with mathematics.

Since 1989, a number of very different “reform” or “standards-based” curricula have been developed, some with major funding from the National Science Foundation. Most of these curricula differed in significant ways from traditional curricula. Some focused heavily on applications. Some made extensive use of group work. Some used “manipulatives” and other “hands on” materials. And some of them sparked significant controversy, which has been labeled the “math wars” (Schoenfeld, 2004). These curricula, in line with contemporary research on mathematical thinking and problem solving, tend to have much broader goals than the traditional curriculum.

Here are some general resources providing information about reform and traditional curricula. The Mathematics Forum at <http://forum.swarthmore.edu> offers numerous links to resources in mathematics education, including web sites from both pro- and anti-reform groups. A list of NSF-supported curriculum projects can be found at <http://forum.swarthmore.edu/mathed/nsf.curric.html>. The National Science Foundation has established four centers devoted to the support of standards-based curricula: the K-12 mathematics curriculum center available at <http://www.edc.org/mcc>, an elementary grades curriculum center at <http://www.arccenter.comap.com>, a middle grades center at <http://showmecenter.missouri.edu>, and a high school center at <http://www.ithaca.edu/compass>. *Standards* and other related information can be downloaded from NCTM at <http://www.NCTM.org>. The most prominent anti-reform web site, with links to many others, can be found at <http://www.mathematicallycorrect.com>.

What the Data Say

Let us now turn to the evaluation of both traditional and reform curricula. As noted above, reform or standards-based curricula have just recently entered the mainstream. Generally speaking, polished versions of the curricula became available in the mid- and late 1990s. Relatively small numbers of students have worked their way through any full reform curriculum.

Due to their recent emergence, there are scant data regarding the effectiveness of reform curricula – either on their own merits or in comparison with traditional curricula. On the positive side, the evaluations of reform curricula do tend to take into account the broad set of mathematical performance goals, including problem solving, that are deemed central by research. Thus the emerging data do tend to capture student performance on relevant aspects of performance: the knowledge base, conceptual understanding, and problem solving. Ironically, comparable data are extremely rare for the traditional curriculum, despite its near-universality for many years. The dimensions of mathematical performance deemed central by current research were not explicitly highlighted or measured as the traditional curriculum evolved and stabilized. Generally speaking, exemplars of the traditional curriculum have only been examined along those dimensions when they have been compared with “reform” curricula.

In sum, there are no definitive findings regarding the effectiveness of either traditional or reform curricula on the spectrum of mathematical competencies that are now understood to be central to the effective understanding and use of mathematics (NRC panel report, 2004). But, there are strong hints. And, there are strong lessons to be learned regarding assessment as well. What you test is very important, in terms of the judgments you make about individual students and about curricula as a whole.

Consider, for example, a study by Ridgway, Crust, Burkhardt, Wilcox, Fisher, and Foster (2000). The study compared students' performance at grades 3, 5, and 7 on a standardized high-stakes, skills-oriented test (The California STAR test) with their performance on a much broader standards-based test (The Balanced Assessment test). Scores on each test were divided into two simple categories: "proficient" or "not proficient." From 70-75% of the students at each grade level scored equivalently (either proficient or not proficient) on both tests. However, fewer than 5% of the students scored proficient on standards-based test and not proficient on the skills-oriented test, while more than 20% of the students were deemed proficient on the skills-oriented test but not proficient of the standards-based test. That latter group of students, nearly 1/4 of the student population, was deemed "proficient" by the State on the basis of the STAR test, but only because of the narrowness of the test. Those students' low scores on the Balanced Assessment tests suggest that the "proficient" ratings on the STAR tests may be "false positives." That is, the students' proficiency is called into question when measures reflecting contemporary research are employed. You can also imagine "false negatives" with regard to curriculum evaluations. Suppose Curriculum A enables students to do well at skills, concepts and problem solving, while Curriculum B enables students to do well at skills only. If you used the STAR test, both curricula would look the same – "no differences." If you used the Balanced Assessment exams, you would see significant differences. So, what you test for makes a very important difference.

Estimates are that *Standards*-based curricula account for about 10-15% of the current textbook adoptions. Overall, the evidence in favor of well-designed curricula aligned with the research-driven view embodied in the *Standards* is compelling. As noted above, most of the test results are preliminary. But they are quite consistent.

Senk & Thompson (2003) provide the first comprehensive review of "reform" curricula in mathematics, with chapters describing evaluations of each of the major curricula and summary chapters providing across-the-boards commentary. The results described have to be taken with a grain or two of salt, for many of the studies reported were conducted by the curriculum developers in "beta testing" environments rather than in regular field conditions. Nonetheless, many of the studies included comparisons with traditional curricula, and the pattern of findings is clear. Putnam (2003) summarized the results of the elementary curriculum evaluations of *Everyday Mathematics, Investigations, Math Trailblazers, and Number Power* as follows:

> Students in these new curricula generally perform as well as other students on traditional measures of mathematical achievement, including computational skill, and generally do better on formal and informal assessments of conceptual understanding and ability to use mathematics to solve problems. These chapters demonstrate that "reform-based" mathematics curricula can work. (Putnam, 2003, p. 161).

Analogously, Chappell discusses the evaluations of three middle school reform curricula (*Connected Mathematics, Mathematics in Context, and STEM)*:

> Collectively, the evaluation results provide converging evidence that *Standards*-based curricula may positively affect middle-school students' mathematical achievement, both in conceptual and procedural understanding…. They reveal that the curricula can indeed push students beyond the 'basics' to more in-depth problem-oriented mathematical thinking without jeopardizing their thinking in either area (Chappell, 2003, pp. 290-291).

The story is the same at the high school level, according to Swafford's discussion of reviews of *Core Plus, IMP, Math Connections, SIMMS, and UCSMP Secondary*:

> Taken as a group, these studies offer overwhelming evidence that the reform curricula can have a positive impact on high school mathematics achievement. It is not that students in these curricul[a] learn traditional content better but that they

> develop other skills and understandings while not falling behind on traditional content. (Swafford, 2003, p.468.)

An intensive series of studies in the city of Pittsburgh, PA, indicates that when Standards-based curricula are implemented in consistent ways (that is, where curriculum, assessment, and professional development are all aligned), the “performance gap” between whites and underrepresented minorities can be narrowed. (See Briars, 2001, Briars & Resnick, 2000, Schoenfeld, 2002). A series of comparison studies in Massachusetts, using the statewide assessment as the measure of performance shows that fourth and eighth graders using reform texts “outperformed matched comparison groups who were using a range of textbooks commonly used in Massachusetts…. These performance gains… remained consistent for different groups of students, across mathematical topics and different types of questions on the state test. (Riordan & Noyce, 2001, pp. 392-393)

In the largest study conducted to date, the ARC Center, an NSF-funded project, examined reform mathematics programs in elementary schools in the states of Massachusetts, Illinois, and Washington. The study included more than 100,000 students, comparing schools implementing *standards-based curricula* with comparison schools using traditional curricula that were rigorously matched by reading level, socioeconomic status, and other variables.

> Results show that the average scores of students in the reform schools are significantly higher than the average scores of students in the matched comparison schools. These results hold across all racial and income subgroups. The results also hold across the different state-mandated tests, including the Iowa Test of Basic Skills, and across topics ranging from computation, measurement, and geometry to algebra, problem solving, and making connections. The study compared the scores on all the topics tested at all the grade levels tested (Grades 3-5) in each of the three states. Of 34 comparisons across five state-grade combinations, 28 favor the reform students, six show no statistically significant difference, and none favor the comparison students. (See <http://www.comap.com/elementary/projects/arc/tri-state%20achievement.htm>.)

In summary, while the evidence is far from conclusive, it provides the strong suggestion that students who takes courses from “reform” or “standards-based” curricula will do at least as well on tests of skills as those students who take courses from “traditional” curricula, and that students in the reform or standards-based courses will do much better on tests of conceptual understanding and problem solving. When high standards, curriculum, assessment, and professional development are aligned, one can expect even greater benefits from the newer curricula.

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