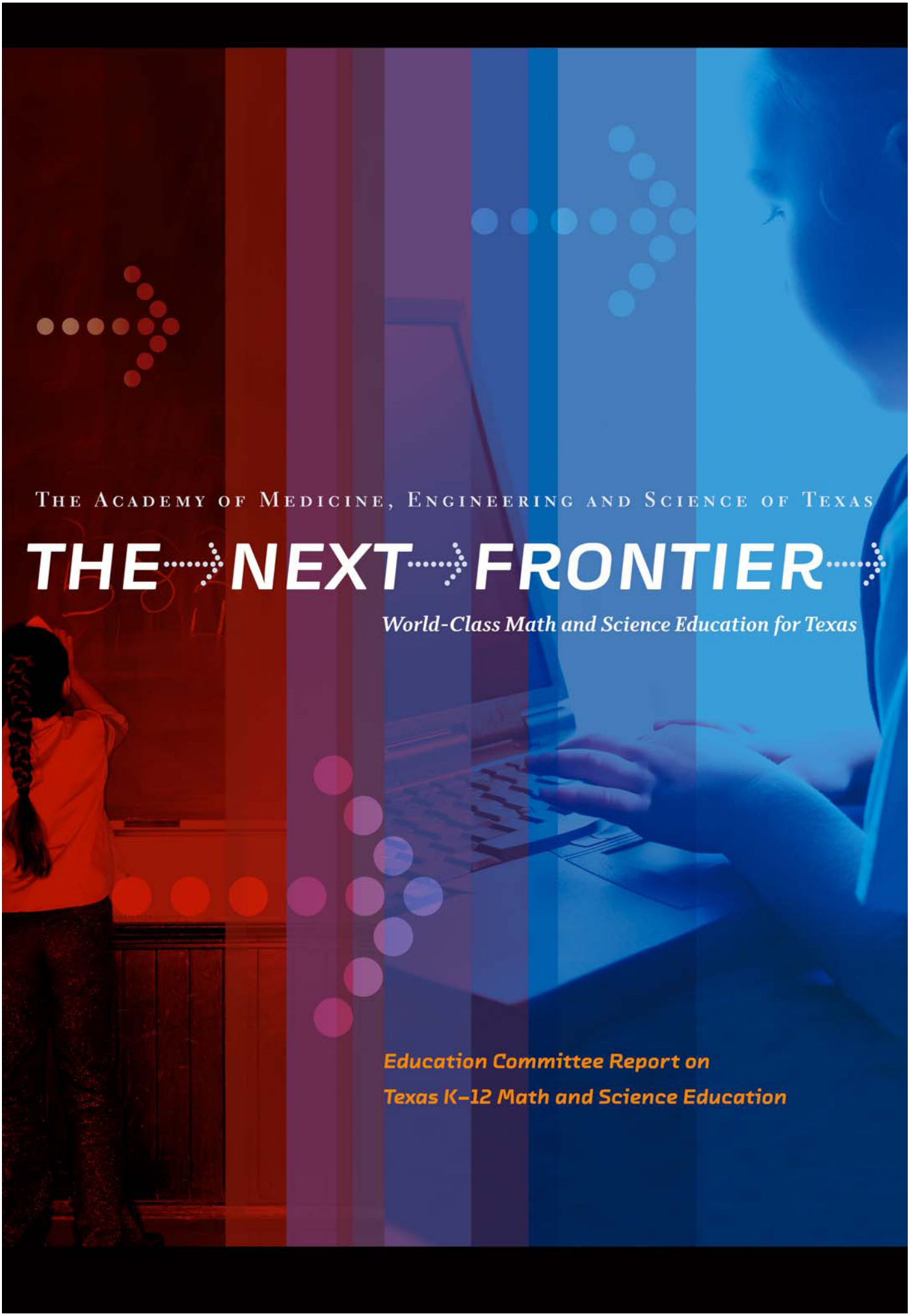


THE ACADEMY OF MEDICINE, ENGINEERING AND SCIENCE OF TEXAS

THE NEXT FRONTIER

World-Class Math and Science Education for Texas

Education Committee Report on
Texas K–12 Math and Science Education

Alexander R. Khachatryan: My work—and the work of the nonprofit organization I direct, Reasoning Mind—has been in the area of mathematics curriculum development. Many studies, including the Third International Math and Science Study (TIMSS), have shown that there are certain attributes shared by curricula used by nations with high mathematics achievement. Therefore, while it is certainly not the only thing that must be done to improve our educational system, it seems that without a reform of our nation's current curriculum practices, we are unlikely to succeed in our goal of significantly boosting the mathematics achievement of our students.

There has been a good deal of research to identify the qualities common to the curricula of nations that do well in mathematics. In particular, it has been recognized that these curricula are coherent, in the sense that they lead students through a sequence of topics and concepts over the grades in a way that reflects the logical and sequential structure of mathematical knowledge. This seems to be a simple concept, but in reality this is not the way mathematics is taught in many U.S. schools. Unfortunately, the average curriculum used in our schools is a haphazardly selected collection of topics, taught either in isolation or in an unnatural order (Schmidt et al., 2002; Schmidt, 2003).

For example, it is a common practice to teach decimals before common fractions in fifth grade, yet it is very difficult for students to make sense of decimals if decimals are not presented as what they really are—a special case of common fractions. Even more strange, some schools teach arithmetic grouped by operation. First, children learn to add whole numbers, common fractions, and decimals; then they learn how to subtract all of these numbers, then multiply, and finally divide. It is not surprising that children taught in such a way will not develop an understanding of the structure of numbers. To them subtraction will be no more than a collection of algorithms to be followed rather than a natural, logical operation.

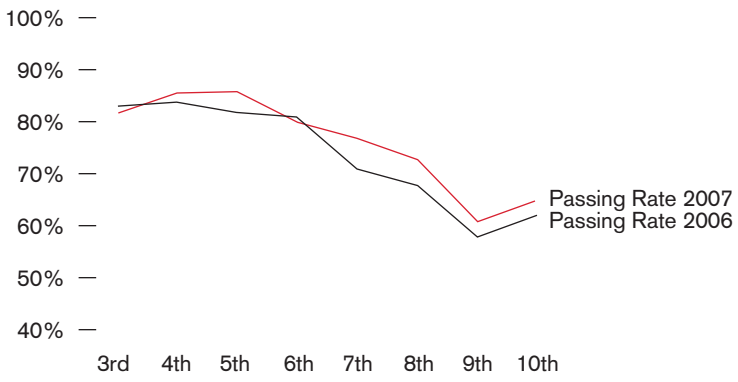
But taking a step back, it is important to recognize that a curriculum is much more than just a sequence of topics or even a textbook. Simply changing the sequencing and textbooks used by a school would be unlikely to affect the instruction children receive: a curriculum comprises not only materials, but also approaches taken by the teacher, alternative ways of explaining concepts to students, knowledge on what problems should be given in a certain situation and in what order and many other things. In short, the knowledge of teachers is an important part of a curriculum in the broad sense of the word. This is why curriculum reform is such a challenging endeavor.

If we look at test scores by year (see Fig. 5.1), we will notice that by any measure—whether it's the TAKS test, the Stanford or the TIMSS—our children are doing well in the early grades. But by 5th and 6th grade, their performance begins to drop, and this slide continues throughout their education. I am in no position to offer a list of reasons for this drop and argue that this list is exhaustive; however, something that has certainly been established by numerous studies—including *Rising Above the Gathering Storm*—is that a major contributing factor is our failure to prepare children in the lower grades for success in middle school. This is exactly this issue of curriculum alignment and coherency.

The idea of the Reasoning Mind project is to use computers to reform our curriculum practices, introducing a coherent mathematics curriculum. It's important to understand that in a Reasoning Mind classroom, not all instruction is provided directly through computers; the teacher not only controls the computer-based portion of the instruction, but also spends a significant amount of time working with students in small groups or one-on-one. The teacher also directs students to work together, with stronger students helping their struggling peers. The effect, therefore, is one of helping the teacher and students transition to a different curriculum; the computer is only the tool.

Figure 5.1

TAKS Passing Rates, Texas, 2006–2007
Mathematics
First Adminstration, Test Taken in English



Reasoning Mind is used as a core curriculum, usually by students in 4th, 5th and 6th grade. For most of the class period, every student sits at a computer and receives an individual lesson which includes problems as well as theory material. The teacher adjusts the assignments students are given but spends most of his or her time working with individual students. Because everything children do online is recorded and stored, the teacher can view students' records to identify which students need help and on what topics.

Immediately from this description we can see that students are now getting instruction directed toward their specific needs. On the one hand, the online lessons adjust based on a student's performance, changing the difficulty level and even diagnosing missing prerequisite knowledge and providing remedial materials; on the other hand, the teacher is now spending much more time addressing students' individual weaknesses. However, this individual approach—while no doubt exceedingly beneficial—would be in vain if it was not for the change of curriculum that comes with it. Indeed, studies have shown that "the use of technology" by itself, while fashionable, does not improve student performance (Dynarski et al., 2007).

The third component of Reasoning Mind's approach—besides a coherent curriculum and individual instruction—is that students must be engaged and interested in what they are learning. While that in itself is certainly no novel idea, the use of computers makes it much easier to achieve. Mathematics class can be turned into a game, with points given for problems correctly solved and hard work rewarded with access to online mathematics games. By motivating children in this way and creating a healthy sense of competition, we can substantially increase the chances that children will enjoy their studies and give them their full attention.

In summary, Reasoning Mind puts in a coherent curriculum, using individual instruction and an engaging format as methods to support this curriculum, and this transition is made possible by the tools of computers and the Internet.

While it is certainly impossible to describe in a short space all of the attributes of a coherent mathematics curriculum, it still makes sense to discuss some of the key components. The Reasoning Mind curriculum is essentially based on the Russian curriculum, developed over the course of several decades in the middle of the twentieth century; this curriculum has served as the basis for curricula in several countries that perform well in mathematics, including China and Singapore.

This curriculum emphasizes in-depth understanding of arithmetic. In particular, the goal is for children to understand the composition and structure of numbers. All of the operations on whole numbers, for example, are introduced and explained based on place value, rather than as unmotivated algorithms. Fractions are learned as an extension of whole numbers and only after children have developed a solid foundation in all four operations with whole numbers. Decimals follow as a special case of fractions. In 6th grade, a unit on ratio and proportion completes students' study of arithmetic. Both conceptual understanding and procedural fluency are developed and are seen as essential to each other.

A second important attribute of this curriculum is the early introduction of algebraic notions and the connections persistently made between these notions and arithmetic. After developing proficiency in working with numerical expressions, for example, children move without great difficulty to working with algebraic expressions, their natural generalization.

Other attributes of the curriculum include an emphasis on word problems, presentation of

general rules—accompanied by explanations and motivations—and integration of geometry and arithmetic.

One of the lessons Reasoning Mind learned early on was that curriculum reform—if it is to be effective—requires substantial training and support for teachers. Teachers must learn a completely different way of viewing mathematics, not to mention a large toolkit of approaches to explaining mathematical concepts to children. Thus, hundreds of hours of training and support are given to teachers implementing Reasoning Mind.

Training begins with a weeklong course usually taken by teachers in the summer before the school year. In this course, teachers learn how to navigate the Reasoning Mind system and begin to familiarize themselves with the curriculum.

Throughout the school year, teachers go through the Reasoning Mind system online as students. They take notes and discuss the materials they see with curriculum support staff. They also take exams over the material demonstrating proficiency in the new approach. This entire process takes between 100 and 200 hours throughout the school year.

This training, while time-consuming, is essential to the success of a project. It ensures that the instruction given to children is being changed and not simply the curriculum materials.

While not enough research has been done yet to come to any definitive conclusions regarding the effectiveness of Reasoning Mind's approach, initial findings are very promising. Several studies have been done comparing the performance of Reasoning Mind students to control group students on various tests; these studies are mostly randomized controlled trials, a very rigorous experimental design.

The earliest study done on Reasoning Mind was in 2003. This study showed that after one semester, the experimental group was doing better than the control group by 11 percentage points on the TAKS test: a 20% difference (see Fig. 5.2). This difference was found to be statistically significant and, in fact, quite large in terms of the standard deviation difference (Weber, 2003).

Most recently, a study was done on all three schools where Reasoning Mind was used as a 5th grade core curriculum in the 2006-2007 school year. The results on a test measuring students' preparedness for middle school—and in particular in-depth knowledge of arithmetic and readiness for algebra—showed students in Reasoning Mind doing better than the control group by margins of between 16% and 19% (see Fig. 5.3). An independent evaluation confirmed these differences to be statistically significant (Waxman and Houston, 2008).

Anonymous attitude surveys given to students and teachers have shown that both prefer using Reasoning Mind. Consistently around 75% of children report that they prefer Reasoning Mind to the traditional curriculum, with 15% showing no preference and only 10% preferring the traditional curriculum (Waxman and Houston, 2008).

Reasoning Mind is currently being used in fifteen schools by over 1,200 children; most of these schools are in the Houston area, but some are in Dallas and New Orleans. In the next few months, we plan on expanding the program to over 2,000 students.

Reasoning Mind's results have shown that by using the Internet, it is possible to successfully introduce a coherent mathematics curriculum into our schools. One of the things that makes this approach so attractive is that it is scalable to millions of students.

Figure 5.2

Average Scores on the TAAS-2002 and TAKS-2003 (% correct)

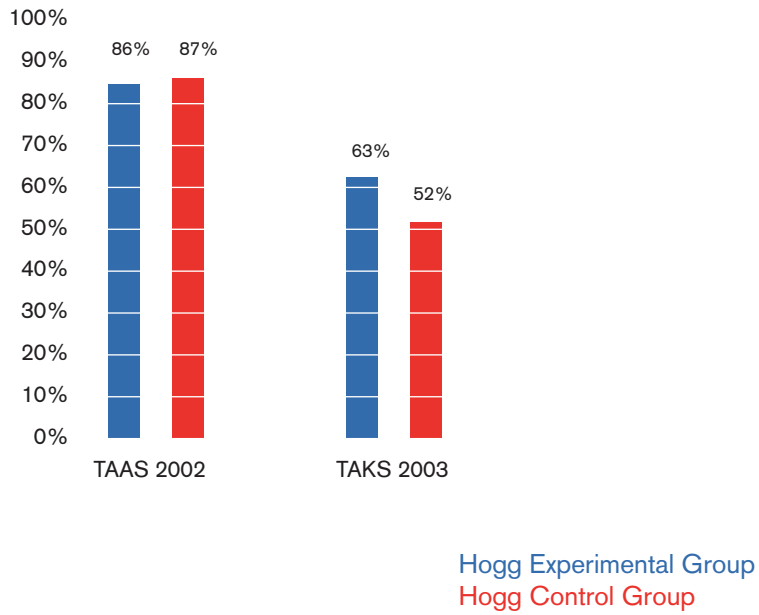
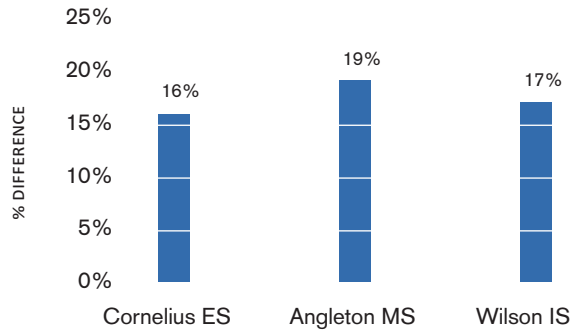


Figure 5.3

Differences in Performance on the RM Assessment between Students in the Experimental and Control Groups 2006–2007 School Year



Another important observation is that curriculum reform requires much more than simply changing the textbooks or moving from textbooks to a computer system: a successful curriculum reform must change teachers' instructional practices. For this reason, it is essential to provide substantial professional development and support to teachers.

I would like to conclude with three recommendations. First, we, as a nation, must place an emphasis on curriculum reform since a so-called coherent mathematics curriculum is a common attribute of every nation with high mathematics achievement. Second, we should continue seeking and developing ways to use the Internet as a tool for curriculum reform since the Reasoning Mind project has shown this to be a promising, scalable approach. And third, we should make sure that efforts to introduce a new curriculum are accompanied by substantial professional development and support for teachers, helping them successfully transition to the new approach.