Benchmarking Student Achievement: Lessons from International Comparisons

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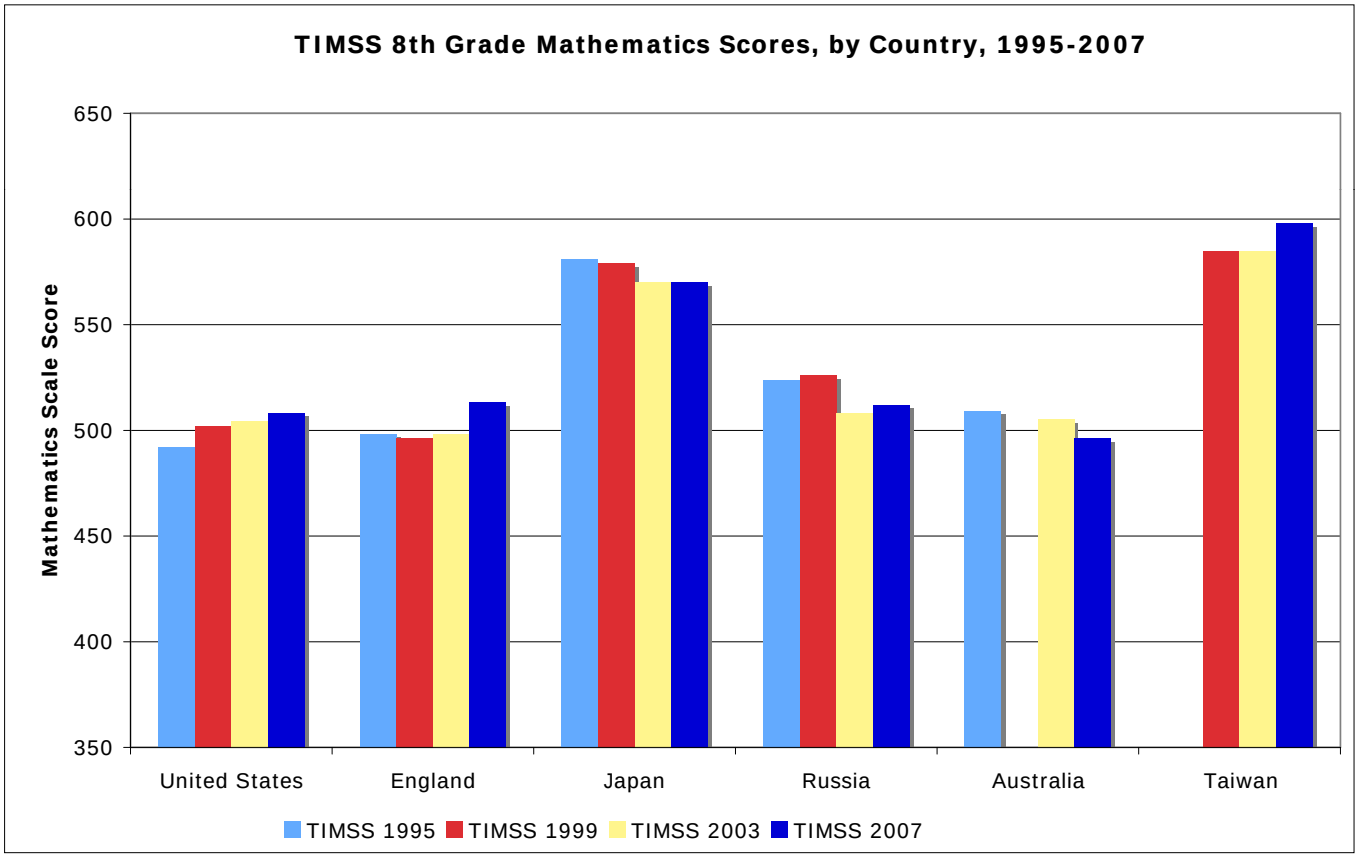
What do international tests tell us about US students' achievement?

- The US results in mathematics and science are significantly below those of our economic competitors in Asia, and also significantly below those of some European countries.
- Although many educators argue that tests tell us little about how much students are learning, there is also evidence that international math and science scores are significantly related to school factors that logically should increase learning.
- One of these factors is how much students are exposed, by eighth grade, to tested subjects such as algebra and geometry.
- Another is teacher experience.
- If we had the data, it is almost certain that teachers' math and science content and pedagogical content knowledge would be related to how well students in that country perform on international tests.

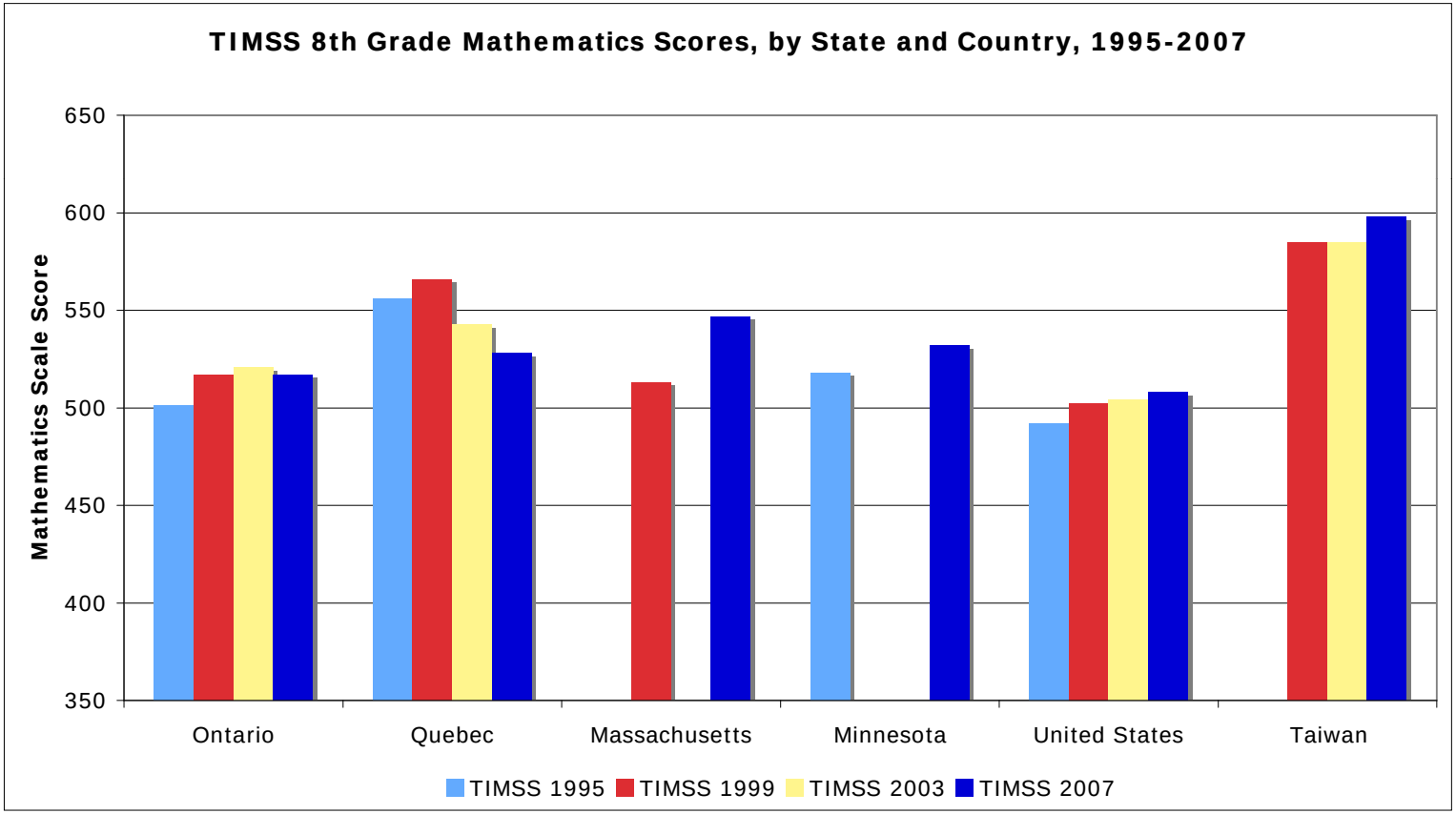
What do international tests tell us about US students' achievement?

- Thus, although tests certainly do not measure everything about student learning, they are one indicator of how much, on average, students do know about particular subjects, as well as an indicator of how that knowledge is distributed across social class and gender groups in each country.
- The two major international tests that attempt to measure students' math and science performance across countries are the Trends in Mathematics and Science Survey (TIMSS) and the Programme for International Student Assessment (PISA).
- The TIMSS is is keyed to a "standard" math & science international curriculum and applied at the 4th and 8th grade, in1995 (8th grade only), 1999, 2003, and 2007.
- The PISA is applied to 15 year-olds, and is more of an general quantitative reasoning test (what 15 year-olds should know to be effective in the labor force). It has been given in 2000, 2003, 2006, & 2009.

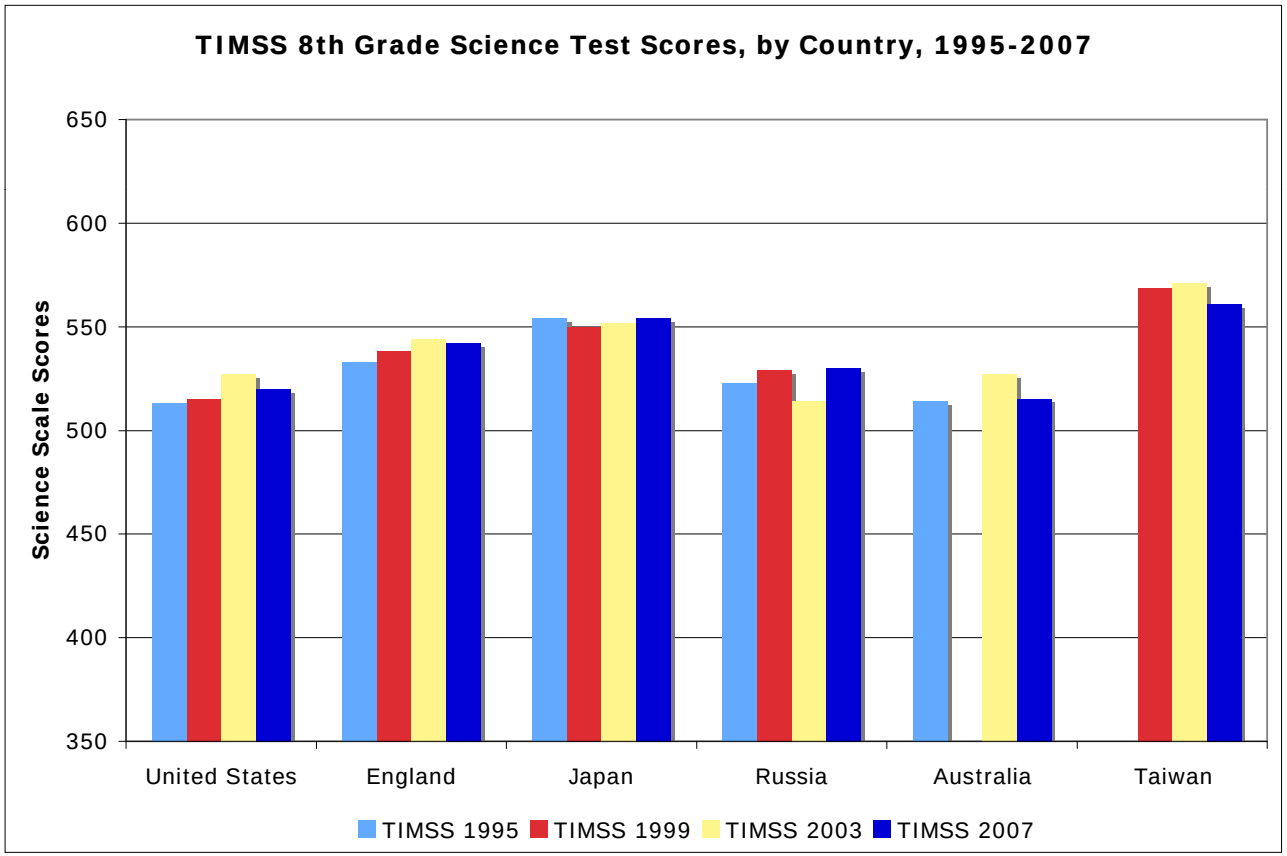
How well do US students perform on these tests?



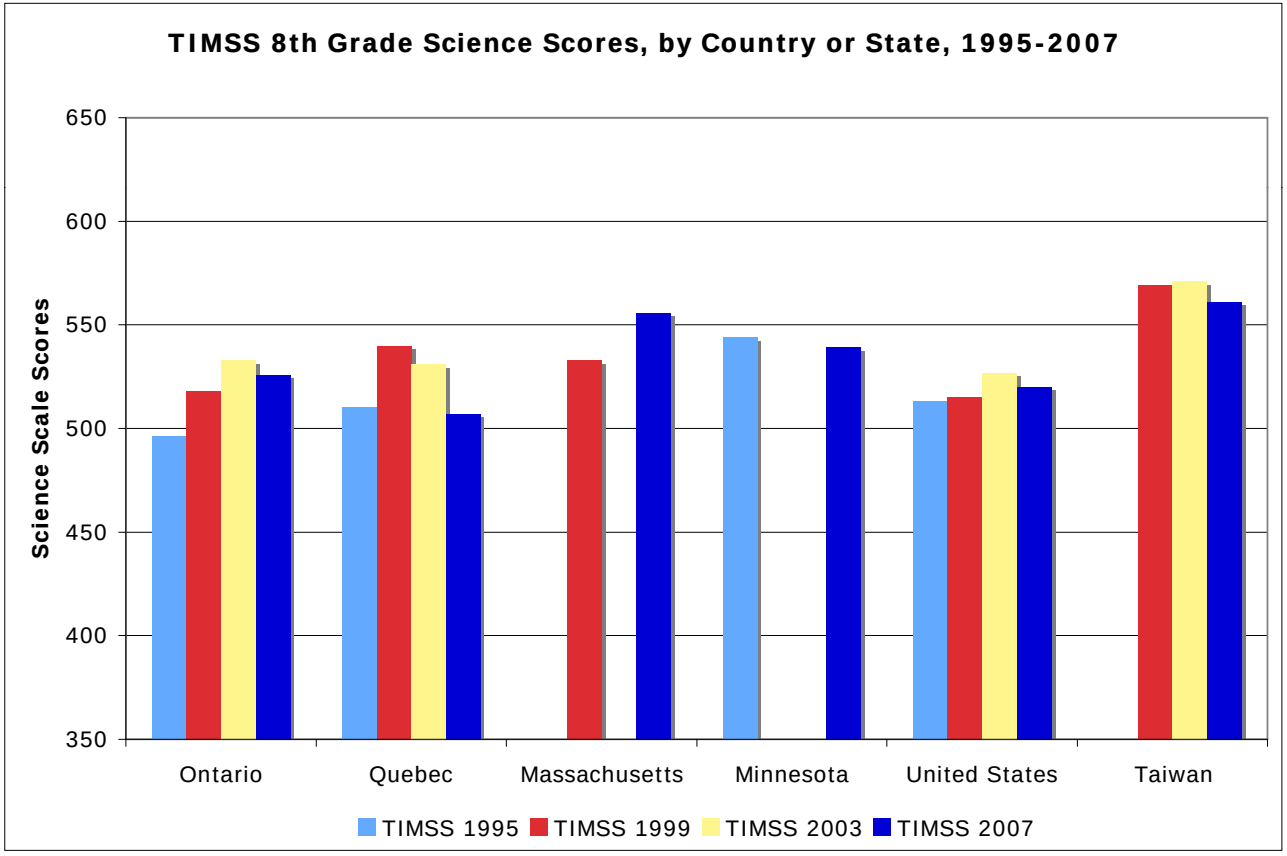
Results vary by US state



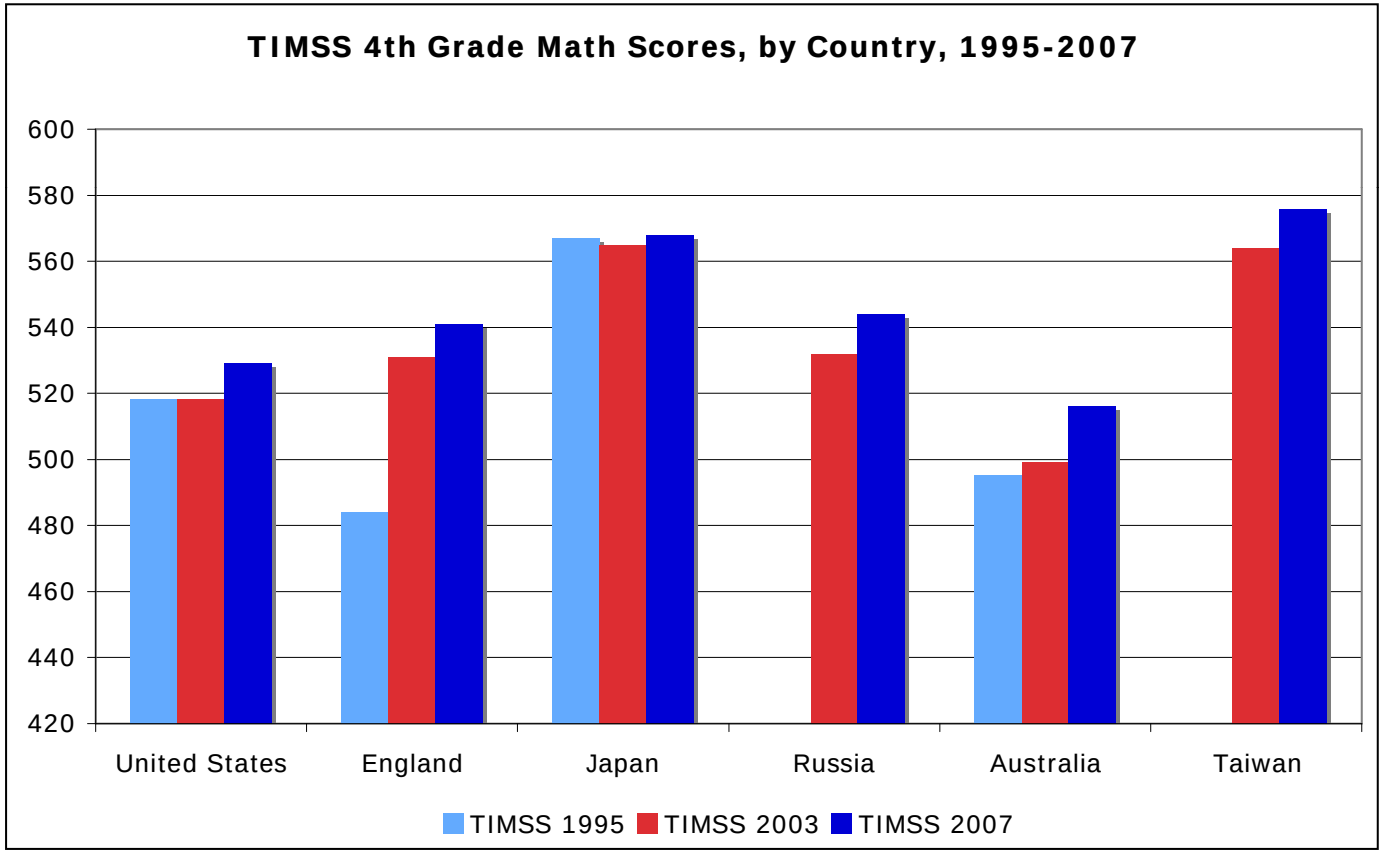
US students do relatively better in 8th grade science than in math



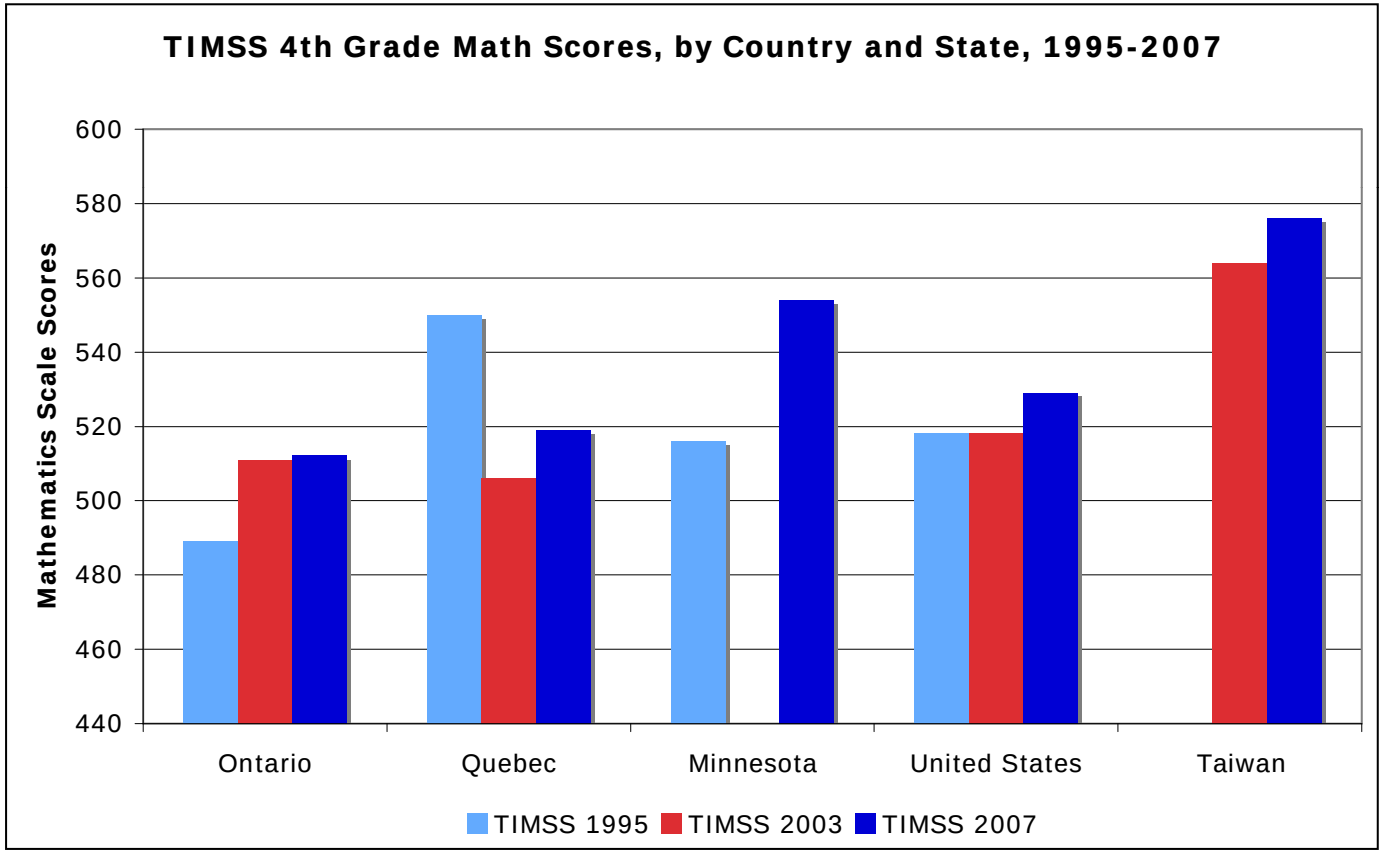
Students in higher scoring US states score relatively high in science



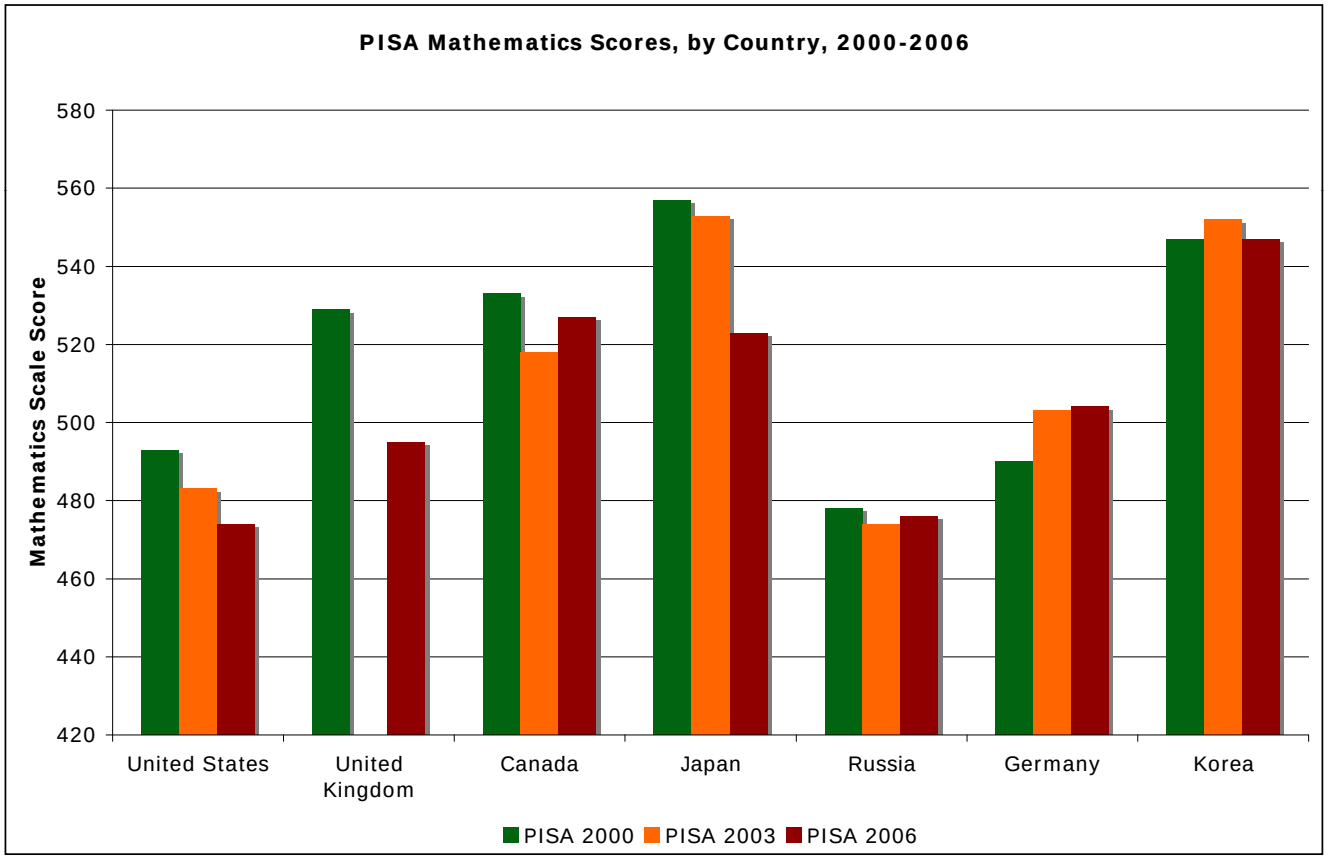
US students do relatively better in 4th grade mathematics tests



Students in high scoring US states do very well in 4th grade math even compared to students in Asia



US students do not do as well comparatively on PISA as on TIMSS



What can we learn from these test scores?

- These are not value added tests (multiple performance observations on the same students), so we cannot link a student's gain in performance to a particular teacher or the teacher's coverage of the curricular material.
- Nevertheless, we do know that the resources available to students in school do differ among countries. We can also note that although US students do not lead the pack in either math or science, they do better in science compared to students in the highest scoring countries and do better in elementary school mathematics than students in the highest scoring countries.
- We also observe that students in some states, such as Minnesota and Massachusetts, do much better than the US average. Minnesota is particularly interesting because of a math curriculum intervention beginning in the late 1990s.

What can we learn from these test scores?

- The issue of why US students do more poorly on the PISA than on the TIMSS relative to students in other countries, including our neighbor Canada, is a controversial one. Some argue that TIMSS is a “better” test; others argue that PISA is more oriented to general reasoning skills, not necessarily related to what the curriculum covers. Some argue that for this reason, PISA is a “better” test of real applied mathematics knowledge.
- To deepen the mystery, students in Eastern European countries and Russia, where the mathematics curriculum is supposed to be excellent, also score worse on the PISA than the TIMSS.
- In general, the high scoring Asian countries do very well on both tests. Indeed, the correlation of PISA and TIMSS scores across countries is 0.85 to 0.9, depending on the year.

Hypothesis I: math curriculum coverage is more limited by 8th grade in US schools

- There is considerable evidence that US students score lower on international math tests at the 8th grade (TIMSS) or 9th/10th grade (PISA) because only 25 percent of US students take algebra I in 8th grade or before and about the same percent takes geometry before the 10th grade. Both these subjects are well represented on the TIMSS and PISA tests. The highest scoring countries reach all students with algebra and geometry by 8th grade.
- Math teaching in high scoring countries (not in the US) is characterized by curricular coherence, curricular focus, and curricular rigor.
- In general, the US math curriculum compared with the standard European curriculum (used in Asia as well) covers too many topics and does not cover topics with sufficient depth of mathematical content. This lack of depth leaves most students unable to solve math problems because they lack understanding of the underlying mathematics.
- There is enormous variation of math course requirements among districts in the US, and enormous variation among districts in the proportion of students taking any algebra before high school.

Instructional Content Constructs

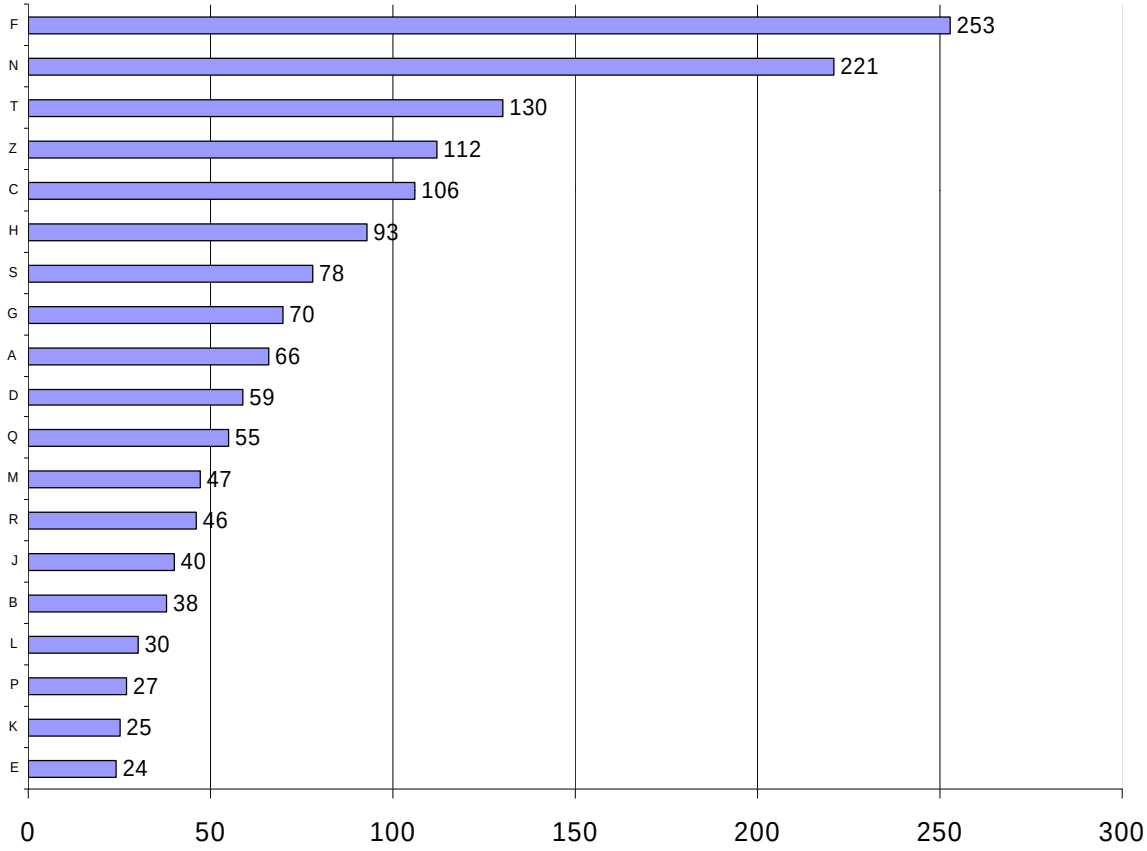
- Curricular Coherence
  - Curricular Structure
- Curricular Focus
  - Exposure Time (OTL)
- Curricular Rigor
  - Level of Cognitive Complexity

High scoring countries cover the key math topics by 8th grade

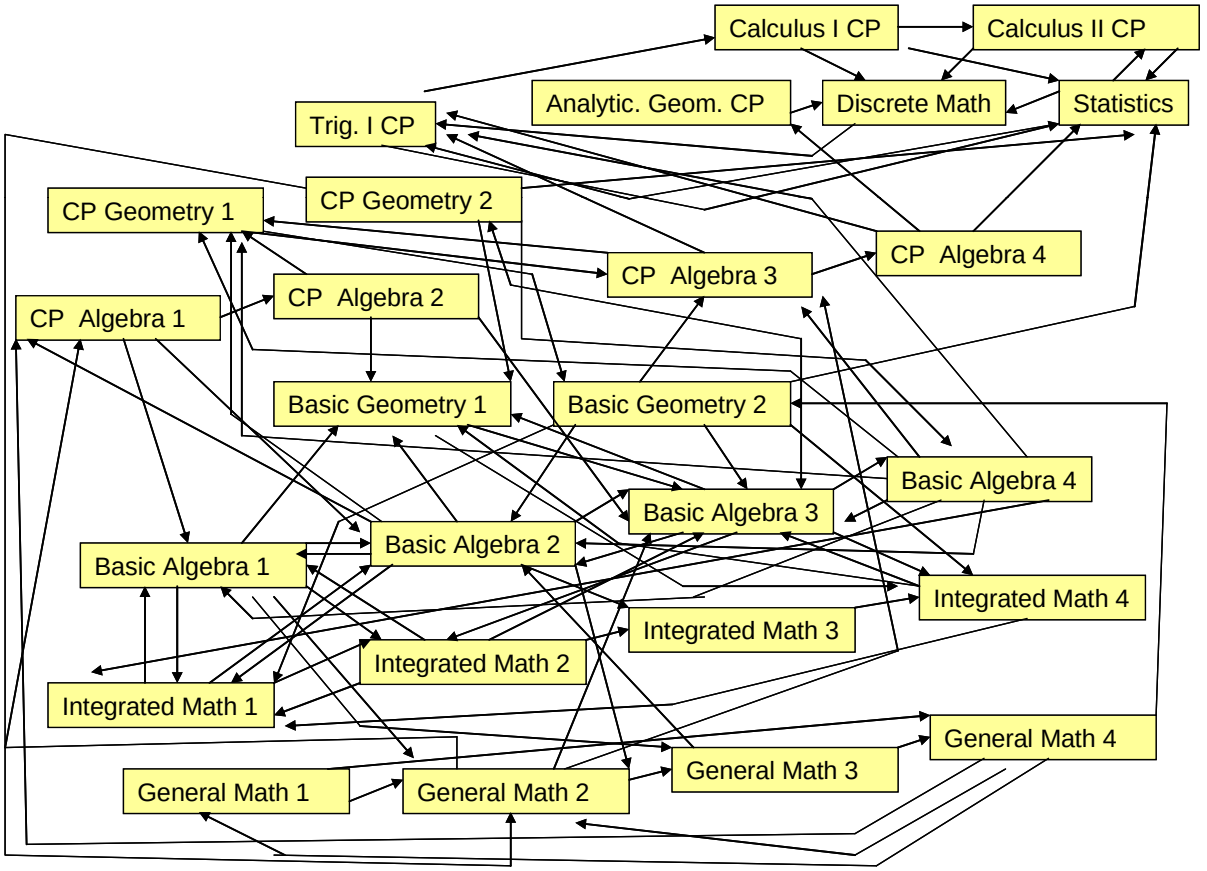
- ♦ **Intended by 4 out of the 6 top-achieving countries**
- ● **Intended by all but *one* of the top-achieving countries (5 out of 6).**
- ■ **Intended by *all* of the top-achieving countries**

Topic	Grade 1	2	3	4	5	6	7	8
Whole Number: Meaning	■	■	■	●	●			
Whole Number: Operations	■	■	■	■	●			
Measurement Units	♦	■	■	■	■	■	●	
Common Fractions			♦	■	■	●		
Equations & Formulas			♦	●	●	●	■	■
Data Representation & Analysis			♦	♦	●	●		♦
2-D Geometry: Basics			♦	●	●	●	■	■
2-D Geometry: Polygons & Circles				♦	●	●	■	■
Measurement: Perimeter, Area & Volume				●	●	●	●	♦
Rounding & Significant Figures				●	●			
Estimating Computations				●	●	●		
Whole Numbers: Properties of Operations				●	●			
Estimating Quantity & Size				♦	♦			
Decimal Fractions				●	■	●		
Relation of Common & Decimal Fractions				♦	■	●		
Properties of Common & Decimal Fractions					●	●		
Percentages					●	●		
Proportionality Concepts					●	●	●	♦
Proportionality Problems					●	●	■	■
2-D Geometry: Coordinate Geometry					♦	♦	●	●
Geometry: Transformations						●	●	●
Negative Numbers, Integers, & Their Properties						♦	●	
Number Theory							●	♦
Exponents, Roots & Radicals							●	●
Exponents & Orders of Magnitude							♦	♦
Measurement: Estimation & Errors							♦	
Constructions Using Straightedge & Compass							■	♦
3-D Geometry							●	■
Geometry: Congruence & Similarity								■
Rational Numbers & Their Properties								♦
Patterns, Relations & Functions								♦
Proportionality: Slope & Trigonometry								♦

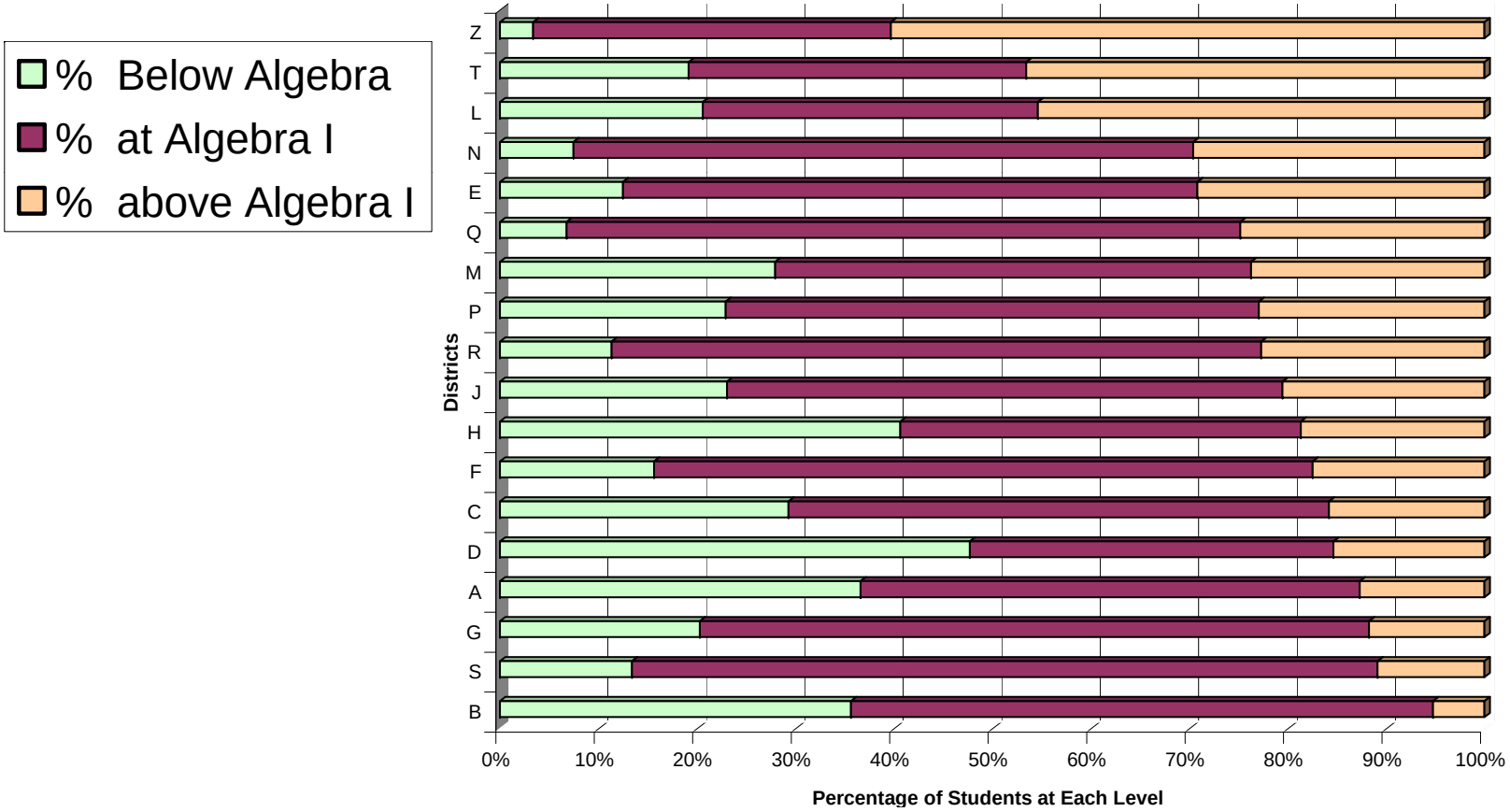
Variation in math course patterns for meeting HS requirements among districts



Math course-taking sequence in a typical US school district



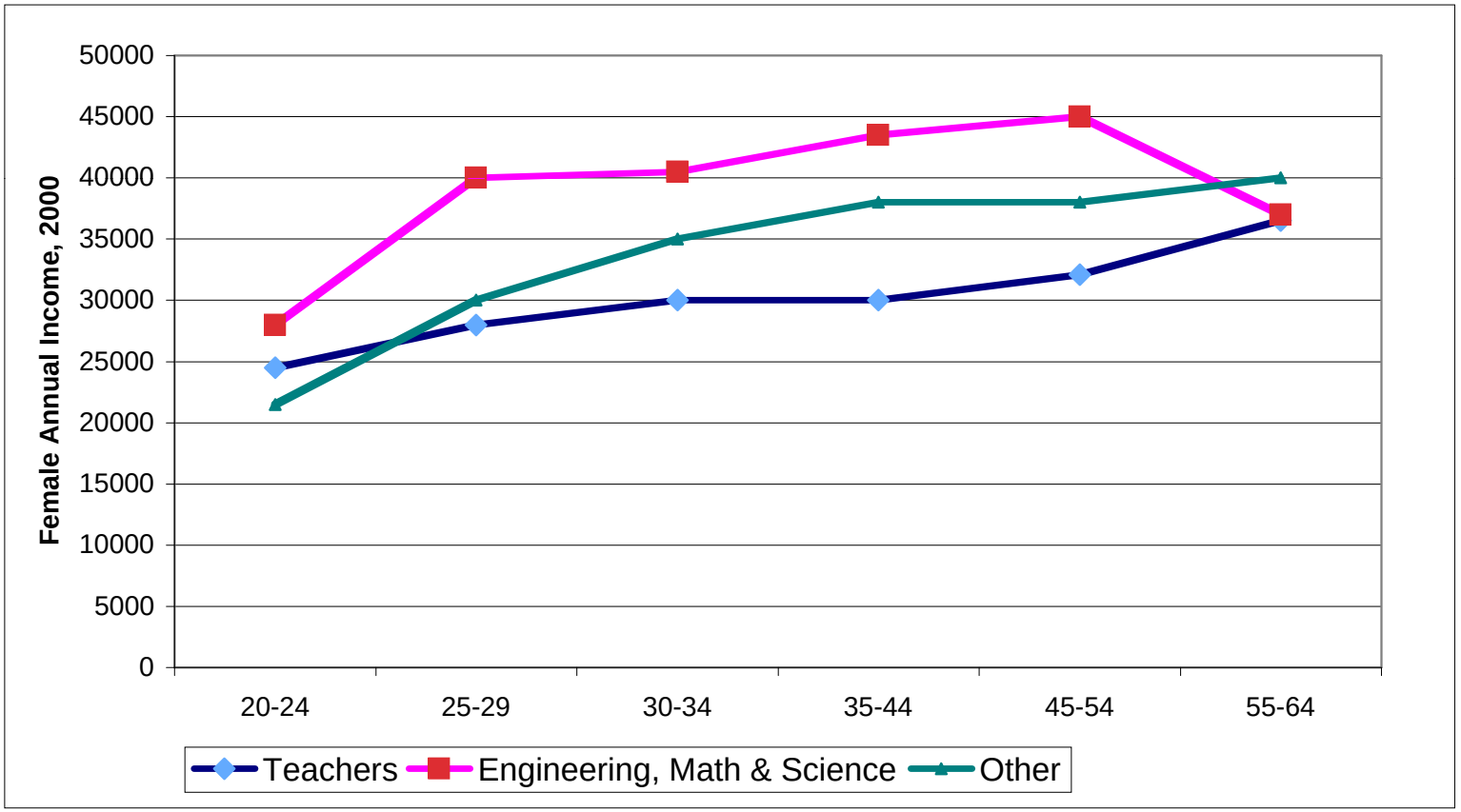
Level of first math course in high school



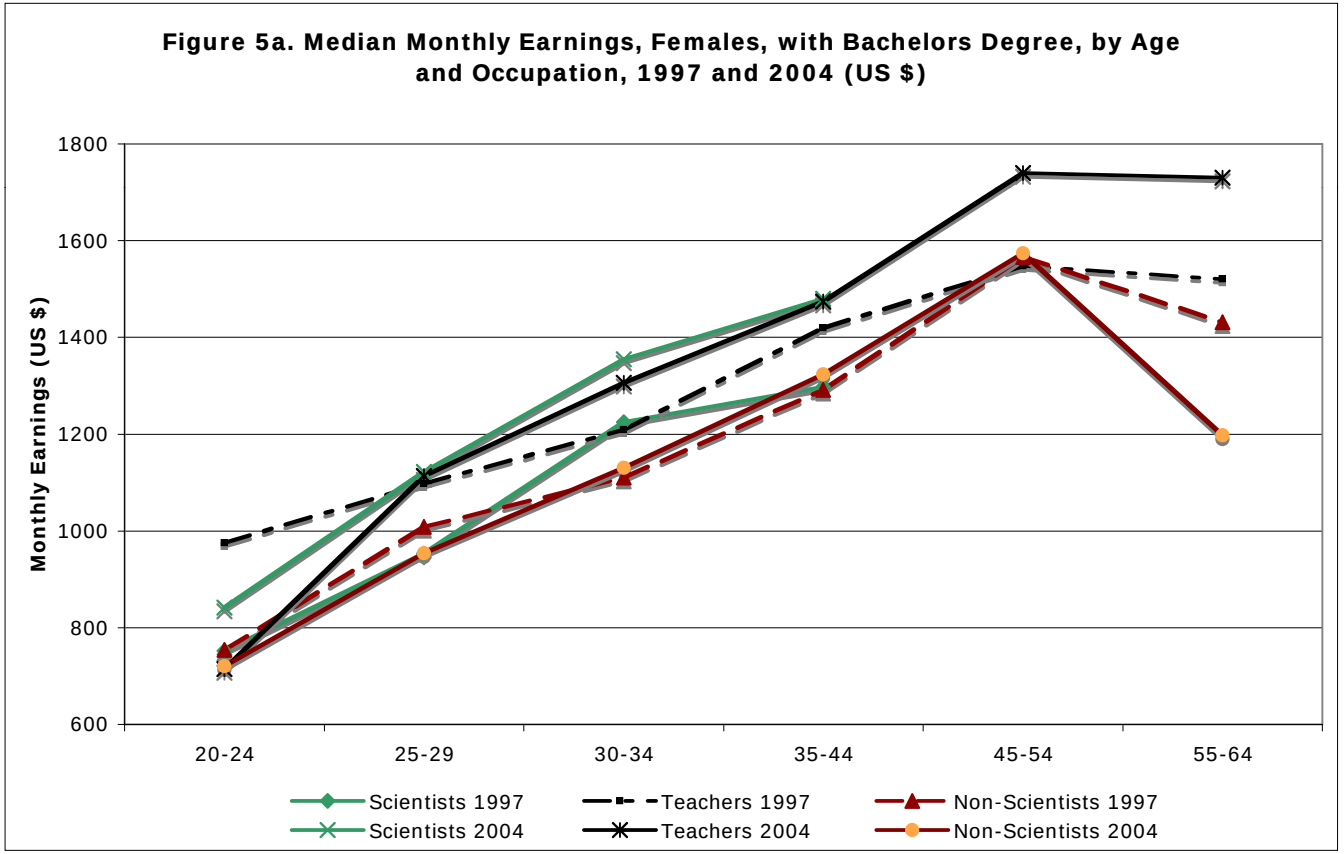
Hypothesis II: US middle school teachers are less than adequately trained to teach mathematics

- In addition, there is growing evidence that middle school teachers are poorly prepared to teach math at the level required to do well on these tests. Thus, increasing the quantity and quality of coverage is difficult even when the curriculum is improved. Contrarily, it is difficult to ask teachers to teach a demanding curricula when they are ill-prepared to teach them.
- Many, if not most, US middle school teachers are not trained as secondary school teachers, who generally need to major in mathematics in order to teach math in high schools.
- Despite these problems, 8th grade math test scores have risen substantially in the past 20 years, according to the National Assessment of Educational Progress (NAEP).

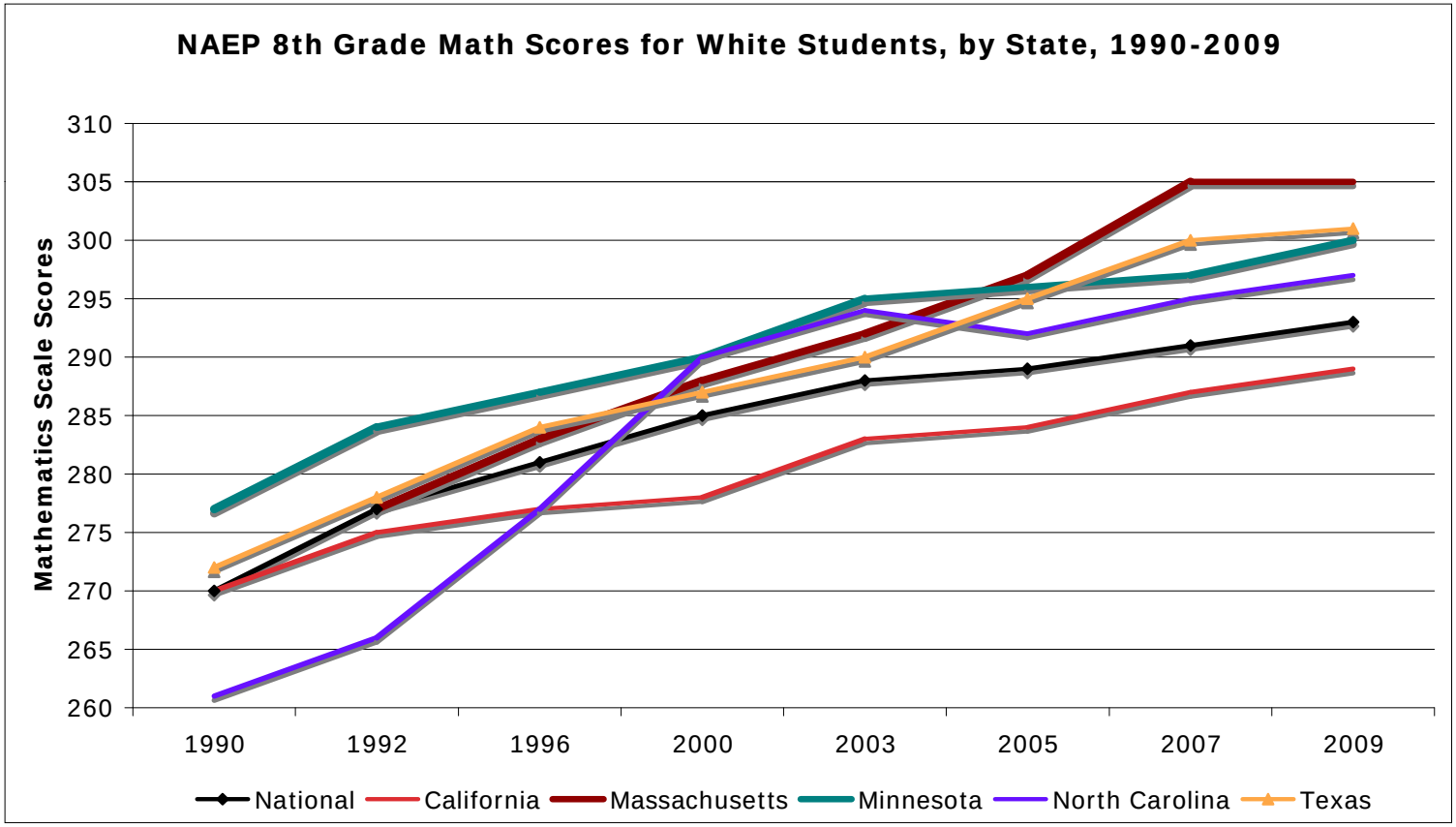
Are US teachers paid enough to attract more math and science skills into teaching?



Compare to female teachers in Taiwan (similar in Singapore and Korea)



NAEP math score increases, by state vary, even controlling for ethnicity



Hypothesis III: It is possible to increase math scores with increased accountability

- Both Texas and North Carolina have had strong accountability systems well before NCLB. Texas since the mid-1980s, and NC, since the early 1990s.The increase in their students' math scores has been unusually rapid. Massachusetts test score have also risen rapidly. California scores have increased at a much slower rate. Remember, the scores shown are for white students only.
- What implications do these differences in test score changes have for policy? Are highly organized accountability systems the answer? Interestingly, reading and science scores have hardly risen in the same period.

Is it worth trying to catch up to students in the highest scoring countries?

- Some economists claim that the payoffs to higher test scores on international tests (more able students) are high, resulting in higher productivity and higher growth rates.
- Even if such claims are true, an important question to ask is how much it would cost to raise US student mathematic scores to Asian levels.
- If the issue is only improving the curriculum or improving accountability, cost may be low, but if the improved curriculum can only be taught by better trained, better paid teachers (to attract more math majors into teaching), cost could be high.
- Cost may also be high if it means students spending more time outside school learning math (Asian-style extra courses).

Is it worth trying to catch up to students in the highest scoring countries?

- A major part of the issue may be the growing fraction of students in US schools who are disadvantaged minorities--much less likely to be taking algebra and geometry in middle school and early high school, or a full science curriculum in high school. More likely to have poorly trained math and science teachers in middle & high school (& primary school).
- In states such as California and Texas, the dimension of this problem and its implications for the future of the labor force are immense. Today, one-half the students in CA K-12 are Latinos; they are less than one-half as likely as Anglos to complete 4-year college. The situation is similar in Texas.
- Without an increase in the pool of highly qualified math and science teachers in K-12, it will be difficult to improve the capacity of the system to bring up the math and science learning of disadvantaged minority students. This will be expensive, and only one of several investments needed to improve student learning in our disadvantaged K-12 school population. Yet, it is fundamental to the future of our society.

Disadvantaged minority students take fewer math and science courses

- Algebra II / Biology/Chemistry/Physics
  - Less than 20 % of black students vs. 30% of all students
  - About 11 % of black general academic students vs. 15% of all general academic students
  - About 32 % of black college preparatory students vs. 40% of all preparatory students