

Student test scores in math computation in some mid-Atlantic states and the implications for chemistry instruction

Presented 4/10/2010 to the ACS Mid-Atlantic Regional Meeting
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In my view,

(Vote for ONE:)

In helping students succeed in **first-year** chem, the ***math background*** of entering students is:

- A. A major problem
- B. A minor problem
- C. Not a problem

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Good Afternoon. My slides today, with plenty of references, are posted on the web. I will cover just selected slides, but I will put up the web address at the end where you may view the slides with additional detail if you find any of them interesting.

Could I ask: How many of you frequently teach any form of first year college chemistry?

Anyone teach High School or AP chemistry?

My focus today is going to be on calculations in those courses.

I'd like to start by asking you to please **read** the question on this slide -- then be ready to vote for A, B, or C.

Ready? How many of you would vote raise your hand. for A, _____ B?
_____ C? _____

(Voting audience was 100% major)

Vote for ONE:

To solve *calculations* in first-year Chem,
it is *most* important for students to have
background knowledge in

- A. Use of a calculator
- B. The theory of mathematics
- C. Fundamentals of math computation

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Please read and be ready to vote.

We ask students To be able to solve like THIS

$$\begin{aligned}
\mathcal{E} &= \mathcal{E}_{\text{cell}}^{\circ} - \frac{0.0591}{n} \log(Q) \\
&= 1.76 - \frac{0.0591}{2} \log \left(\frac{[\text{Zn}^{2+}][\text{VO}^{2+}]^2}{[\text{VO}_2^+]^2[\text{H}^+]^4} \right) \\
&= 1.76 - \frac{0.0591}{2} \log \left(\frac{(1.0 \times 10^{-1})(1.0 \times 10^{-2})^2}{(2.0)^2(0.50)^4} \right) \\
&= 1.76 - \frac{0.0591}{2} \log (4 \times 10^{-5}) = 1.76 + 0.13 = 1.89 \text{ V}
\end{aligned}$$

-- Zumdahl, 5th edition

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Or THIS

$$\begin{aligned}\mathcal{M} &= \frac{\overline{dRT}}{P} \\ &= \frac{(3.09 \text{ g/L})(0.0821 \text{ L-atm/mol-K})(304 \text{ K})}{(735/760) \text{ atm}} \\ &= 79.7 \text{ g/mol}\end{aligned}$$

-- Brown, Lemay, 8th Ed. p. 368

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Or this

thus

$$u_{\text{rms}} = \sqrt{\frac{3 \left(8.3145 \frac{\text{J}}{\text{K} \cdot \text{mol}} \right) (298 \text{ K})}{4.00 \times 10^{-3} \frac{\text{kg}}{\text{mol}}}} = \sqrt{1.86 \times 10^6 \frac{\text{J}}{\text{kg}}}$$

Since the units of J are $\text{kg} \cdot \text{m}^2/\text{s}^2$, this expression becomes

$$\sqrt{1.86 \times 10^6 \frac{\text{kg} \cdot \text{m}^2}{\text{kg} \cdot \text{s}^2}} = 1.36 \times 10^3 \text{ m/s}$$

-- Zumdahl, 5th Ed. p. 218

Vote for ONE:

To solve *calculations* in General Chem,
it is *most* important for students to have
background knowledge in

- A. Use of a calculator
- B. The theory of mathematics
- C. Fundamentals of math computation

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All of these are important.

But if you had to pick ONE, Which is most important?

How many vote for A: _____ B: _____ C: _____

(Voting audience was 100% calculations)

NCTM standards = ?

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Question 3

If you are familiar with the NCTM standards,
please raise your hand?

Virginia Math Results:

- Stanford 9 standardized test given statewide
- National percentile average = 50 on 1995 norms

VA all students	Grade 9				
	1998	1999	2000	2001	2002
Total Math	54	55	55	55	55

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My goal today is to look at the evidence. Is math preparation is a problem? If so, WHY? And how can we fix the problem?

About 8 years ago, I was asked to represent my Virginia faculty organization

On a task force looking at the issue

Of why so many students entering college were needing remediation.

Being a chem instructor, I thought the problem was the K-12 math programs

But when I looked at the standardized tests, in "Total Math"

Virginia scores were above average – average being the 50th percentile -- and steady. (point)

But when I looked in the report detail, I found that on the test VA was using

Two **subtests** were reported described as

- “**Math Problem Solving**, which focuses on **reasoning** skills, and
- **Math Procedures**, which measures the student’s facility with **computation**.”

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Talk them

Virginia Math Test Scores

VA Stanford 9	Grade 9				
	1998	1999	2000	2001	2002
Total Math	54	55	55	55	55
Problem Solving	58	61	63	64	65
Procedures	46	44	42	41	39

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The scores went UP in math theory,
but they were low -- and going lower --in computation.

When The 39th percentile is your state average in math computation,
Not many kids are going to be prepared for the rigor and pace of
college chemistry.

Next three slides from:

Tom Loveless
Brown Center on Education Policy
of the Brookings Institution
Presentation on Math Reform
at AEI March 4, 2002

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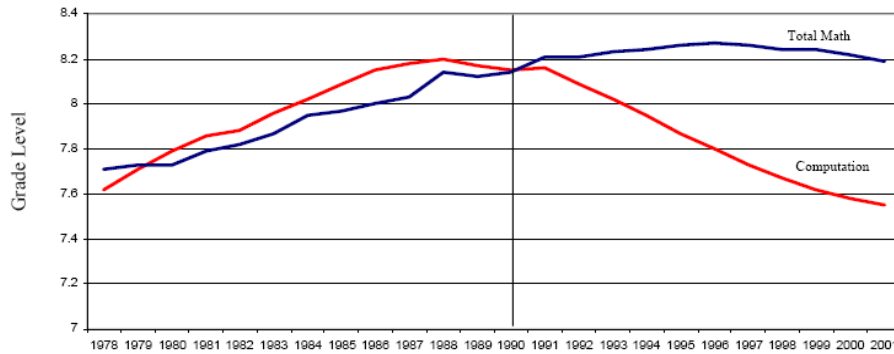
I went looking for additional data.

And I found a report from

Tom Loveless at the Brookings Institution

Tom said the best data was for the state of

ITBS 8th Grade State of Iowa, 1978-1999



Data taken from Iowa Basic Skills Testing Program--IA Annual Comparisons
 Computation assesses operations with whole numbers, fractions, and decimals.
 Total Math assesses non-computation math skills.

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Iowa.

In Iowa, like Virginia, each K-12 district does its own textbook adoption
 So you get a random sample of curricula nationally.
 And Iowa gave the same test for over 20 years.

Compare the BLUE line and the RED

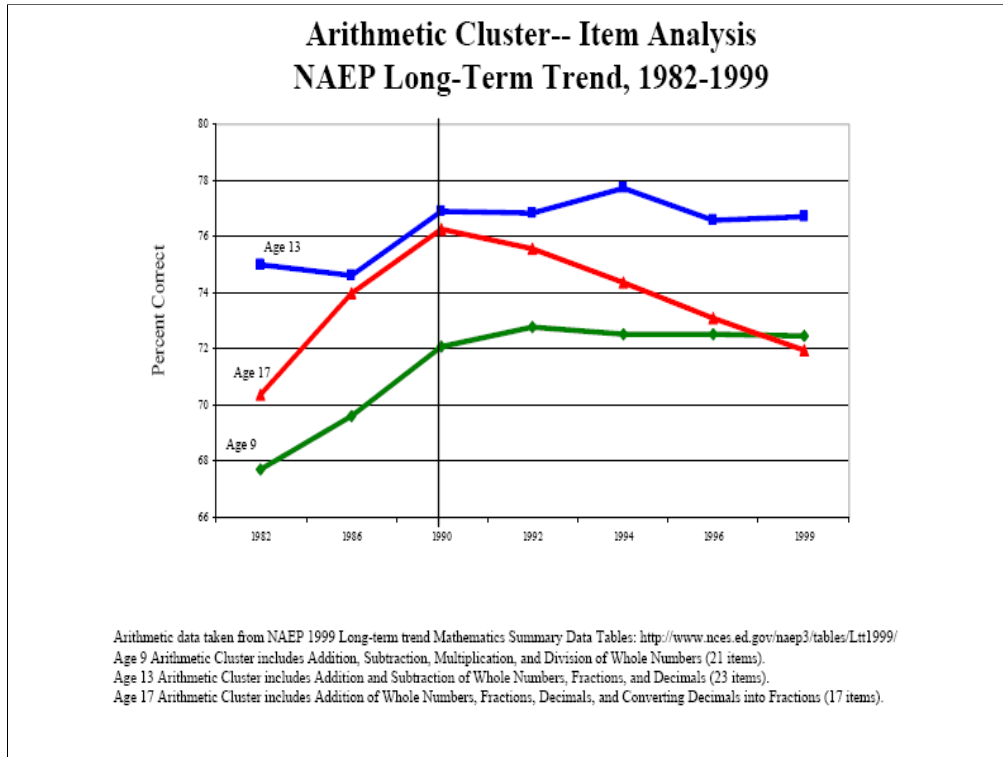
Both went up together between 1978 and 1990

But starting in 1990, total math flattens out and computation goes down

Just like Virginia.

And (important point) total math hides computation.

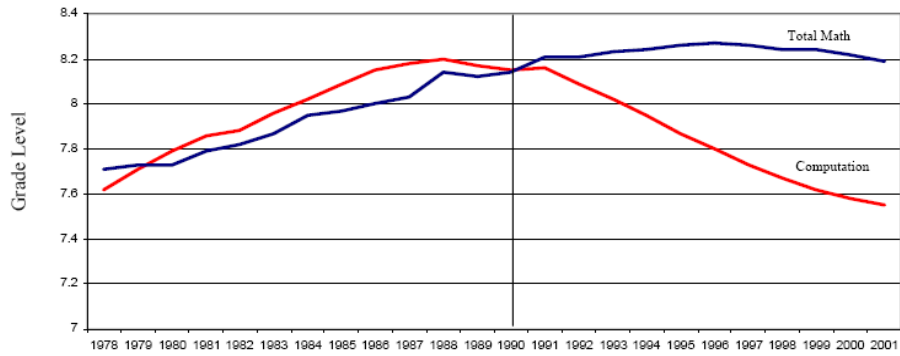
Dr. Loveless also looked at a nation-wide measure:



The national assessment of educational progress (the “nape”)
 Given every two years in each state.

For the 17 year olds in red
 Tom looked at questions that involved the arithmetic that we do a lot of in chemistry
 And found that scores went up from 1982 to 1990
 But after 1990, went down.

ITBS 8th Grade State of Iowa, 1978-1999



Data taken from Iowa Basic Skills Testing Program--IA Annual Comparisons
Computation assesses operations with whole numbers, fractions, and decimals.
Total Math assesses non-computation math skills.

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Just like for math COMPUTATION in Iowa

thus

$$u_{\text{rms}} = \sqrt{\frac{3 \left(8.3145 \frac{\text{J}}{\text{K} \cdot \text{mol}} \right) (298 \text{ K})}{4.00 \times 10^{-3} \frac{\text{kg}}{\text{mol}}}} = \sqrt{1.86 \times 10^6 \frac{\text{J}}{\text{kg}}}$$

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-- Zumdahl, 5th Ed. p. 218

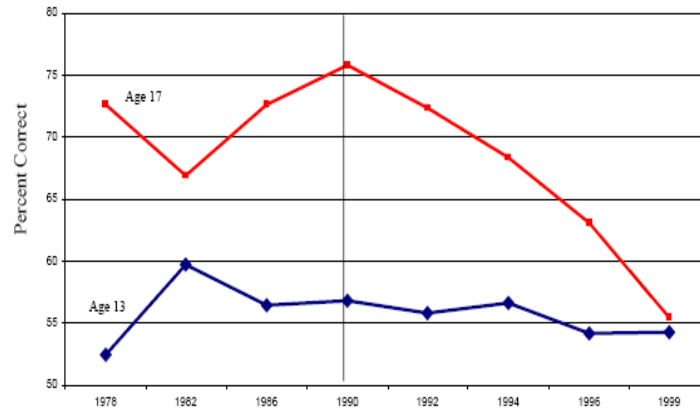
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- 7:20 -

In chemistry, we need to solve some fractions.

And Dr. Loveless looked at fractions on the NAEP:

Fractions-- Item Analysis NAEP Long-Term Trend, 1978-1999



Fraction data taken from NAEP 1999 Long-term trend Mathematics Summary Data Tables

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And found , for the 17 year olds in red, fluctuation,
Then a dramatic decline -- after 1990
There is a lot more data, but the evidence is consistent.
Computation goes down ~1990.
What went wrong in about 1990?

“The **1989** NCTM standards played the role of national standards....

Nearly all state standards after 1990 were modeled on the *1989 NCTM Standards*.”

-- from **Computation Skills, Calculators, and Achievement Gaps: An Analysis of NAEP Items**
Tom Loveless, The Brookings Institution, April 2004

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Dr Loveless did a paper, which is on the internet, and he says this:

The Math Wars

Short history:

A quarter century of US 'math wars' and political partisanship

David Klein

California State University, Northridge

<http://www.csun.edu/~vcmth00m/bshh.html>

longer version:

<http://www.csun.edu/~vcmth00m/AHistory.html>

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What's this about?

You can find more information in these references

in my posted slides. But briefly:

The NCTM is the National Council of Teachers of Mathematics

A curriculum group that publishes policy statements on K-12 math education.

NCTM's *An Agenda for Action* (1980):

- “All students should have access to **calculators** and increasingly to computers **throughout** their school mathematics program.”

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And these have become influential.

This NCTM recommendation said

Students should have access to calculators at ALL times.

And in

New Jersey -- Current Math Standards

STANDARD 5 — TOOLS AND TECHNOLOGY

K-12 Overview

All students will regularly and routinely use calculators, computers, manipulatives, and other mathematical tools to enhance mathematical thinking, understanding, and power.

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New Jersey, the state tells teachers to have students use calculators
At ALL grade levels.

NJ: Use Calculators in 1st Grade

- **Q and A**
Core Standards in Mathematics
NJ State Board of Education – 2002 to current
- **Q: The standard says that students will "use calculators as problem-solving tools...." For what grade levels is this a reasonable expectation?**
- **A: Calculators** can and should be used at **all grade levels** The majority of questions on New Jersey's new **third-** and fourth-grade **assessments** in mathematics will assume student access to at least a four-function calculator.

-- <http://www.state.nj.us/education/frameworks/math/math3.pdf>

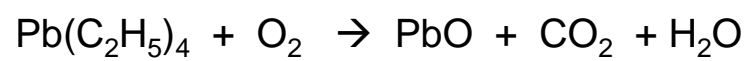
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This is not optional for teachers

Take a look at that last paragraph.

In K-12 in the era of accountability, what gets tested had better get taught.

To Balance:



Use a calculator?

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My question for you is:

If students are taught to use a calculator to balance an equation,

How far are they going to get in chemistry?

1989 NCTM Standards

Recommended for “**decreased** attention” were

- “Long division”
- “Relying on **outside authority** (teacher or answer key)”
- “Rote **practice**”
- “Paper and pencil **fraction** computation”,
- “Manipulating symbols”
- “Memorizing rules and algorithms”, and
- “Finding exact forms of answers”

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In about 1990, NCTM published their standards

Let's talk about this. Decrease attention to

Exact answers: is it OK in math to teach $2x2=6$?

Manipulating symbols. You wonder why they can't handle $y=mx+b$? It was de-emphasized.

Fractions? IF (pointer)

one of those outside authorities -- when you were in 5th grade --

had not had you practice

with fractions,

$$\begin{aligned}\mathcal{M} &= \frac{dRT}{P} \\ &= \frac{(3.09 \text{ g/L})(0.0821 \text{ L-atm/mol-K})(304 \text{ K})}{(735/760) \text{ atm}} \\ &= 79.7 \text{ g/mol}\end{aligned}$$

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-- Zumdahl, 5th Ed. p. 218

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would you be in this room today?

Impact

“By 2000, all but two states ... modeled their own curriculum **standards** on the NCTM's, and publishers revised math **textbooks** to conform with NCTM's prescriptions.”

-- from

**Computation Skills, Calculators, and
Achievement Gaps:**

An Analysis of NAEP Items

Tom Loveless, The Brookings Institution, April 2004

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Since nearly 48 of the 50 states adopted these standards

Is it surprising that students have trouble with calculations in the sciences?

2003: Data Stops Due to

No Child Left Behind (K-12)

Required States to

- Set State Standards and
- Test on State Standards

With high test costs, most states stopped nationally normed tests

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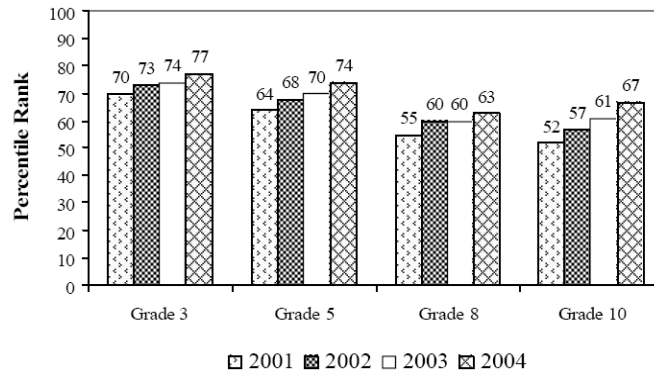
Another factor affecting student preparation to solve calculations was NCLB. Talk the slide.

Delaware Student Testing Program (DSTA)
Includes Abbreviated Version of Stanford 9 (Nat. Normed)

DSTP MATHEMATICS — continued

Chart 7

Stanford 9 Percentile Ranks, DSTP Mathematics



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Delaware does something good.

Delaware includes in their state test

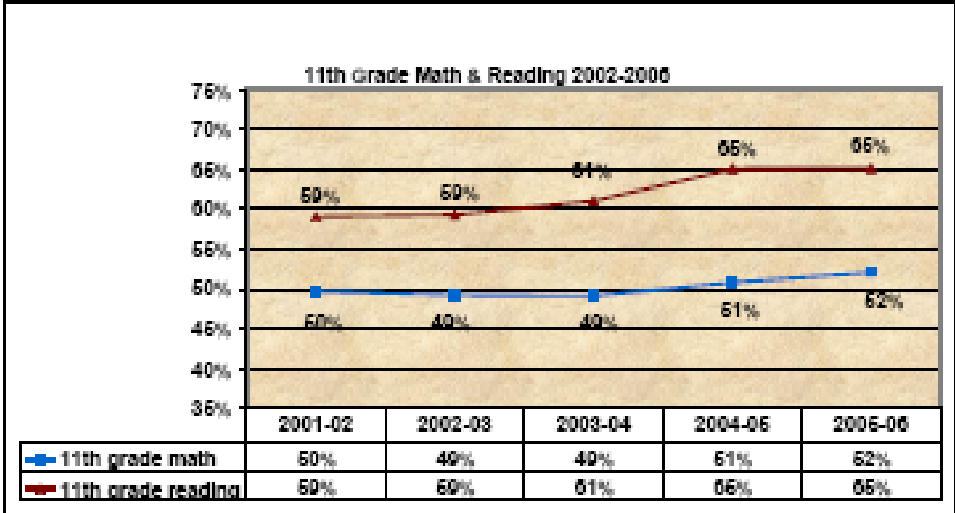
A short portion of the Stanford test that has national norms.

And you can see progress vs. national norms

But they don't disaggregate for computation

And very few states report any national norms.

Pennsylvania:



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This state test says 50-52% of students are “proficient in math in PA,”
But what does that mean -- versus students in California, or China, or India?
That’s what’s important, and that’s not being measured.

New York

Regents Exams

All Students

Percentage of students

Total Tested scoring at or above:

55 65 85

	2007-08	2006-07	2005-06	90%	73%	15%
Physical Setting/ Chemistry	2007-08 109,414	2006-07 108,034	2005-06 104,541	90%	73%	15%
				90%	71%	13%
				90%	74%	21%

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New York

Reports the Regents results. That's useful.

In Maryland: Math Remediation

Among MD HS students who took the SAT or ACT in 2008 and who enrolled in MD public colleges or universities:

- **Core** students = 3 years of HS Math and 2 years of HS science; **Non-core** students = not.

A *remedial math* course in college was needed by

- 32% of core students and 49% of non-core students.

Including, at University of Maryland system campuses

- 14% of core students and 27% of non-core students.

And at MD community colleges

- 56% of core students and 69% of non-core students.

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In Maryland: that's a good study to do,

But NO ONE is reporting computation scores

And few states are measuring versus the meaningful standards: what students elsewhere can do.

In 2006, the % of
U.S. Electrical Engineering Ph.D's
awarded to students
who were U.S. citizens was about

25% 50% 75% 90%

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Where does this leave us? Try this question

Double E PhDs - the number that go to
children of our own citizens IS - who knows?

The answer is:

- In 2006, the percentage of US Electrical Engineering Ph.D's awarded to US citizens was ...

23%

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Its great that America gets first shot at the world's best and brightest
Many stay here and become leaders in our economy
But 23% means that very few of our own children
Are competitive in the world economy
Why? States ordered teachers to decrease attention to computation.
At 23% , our economy, our funds available for education,
And the ideals that America has always stood for,
I would submit are at real risk.

Good News

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There is good news to report.

NIH Learning Research:

1995: NIH starts research on learning difficulties.

1998: NIH reports on comprehension/cognition.

2000: NIH NRP Report recommends

- Systematic, explicit instruction
- Drill and practice = fluency in fundamentals.

2004: NIH “Reading First” starts in Title I

2008: = Title I K-3 students tested, scores UP

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In 1995, Congress and the President asked the NIH to investigate falling nationwide test scores in reading and math. The NIH did their usual gold-standard research on how students learn And made recommendations on how to improve instruction. And the NIH science worked.

Sacramento, CA

- Urban District – Low Scores
- 1998: New Superintendent adopts “Saxon Math” Series
- Saxon has computation and cognitive science emphasis
- Scores skyrocket.

Student Test Scores – Sacramento, CA			
Stanford Test – National Percentiles – Math Procedures			
YEAR	Grade 2	Grade 4	Grade 6
1998	30	32	43
1999	46	39	53
2000	55	50	61
2001	57	57	64
Change	Up 27	Up 25	Up 21

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Sacramento, a high poverty urban district.
tried science-based math programs and

look at those amazing gains – just from adopting
Science-based textbooks.

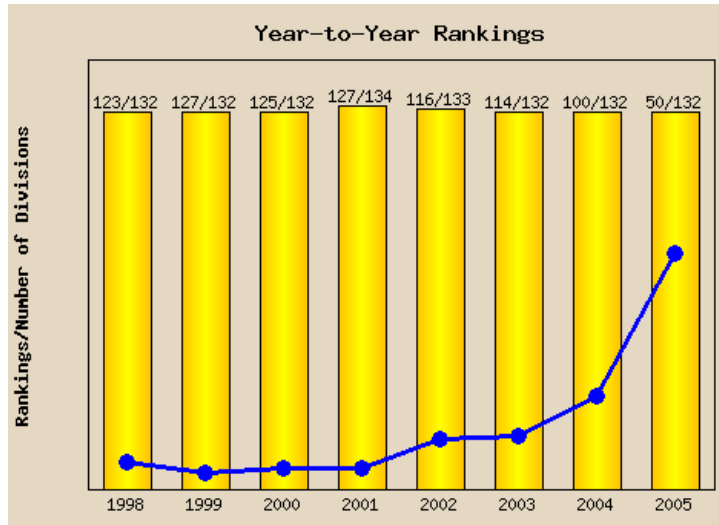
Richmond, VA

- 25,000 students
- Urban, High-poverty
- 70% Reduced and Free Lunch
- 90% African-American

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Richmond VA is another urban, high poverty district.

Between 2001 and 2005, in 3rd Grade Reading, for *all* students, Richmond VA rose from ranking in the bottom 5% to the top 40% of the state, an unprecedented accomplishment for a high-poverty district.



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In 2001, Richmond started using a new curriculum program
That was designed based on NIH cognitive research
And Richmond went from ranking 123 out of the 132 districts in the state
to 50th out of 132: From bottom 5% to the top half of the state in 4 years.

Two Philosophies vs. Science

The Traditionalists believed in

- Drill and Practice, Memorization of Facts
- Learning is Hard Work

The Progressives believed

- Children Learn Naturally, By Discovery
- Don't "Drill and Kill"

NIH/Cognitive Science research:

- Play Motivates, But LT Learning = Drill

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The NIH research addressed the great debate over drill and practice versus discovery
And said, there is a time and place for both.

NCTM: Based on Extrapolation

- Science: Children learn speech w/o instruction.

Therefore

- Children are born to learn naturally
- Students learn best w/o explicit instruction
- The best learning is natural, by play

An appealing, romanticist view of childhood and learning.

NIH/Cognitive Science findings:

- Discovery & Inquiry Motivate Students
- Teaching Concepts is Crucial
- Speech is learned naturally (to age ~12)

However:

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The NIH research says
is that the NCTM got some things right

NIH/Cognitive Science findings:

- **Other** learning is not natural; is hard work. Solving problems like an expert requires
 - Extensive Knowledge In LT **Memory** +
 - Fluency: Automaticity in the fundamentals
- Learned by
- Spaced Drill and **Practice** + Overlearning

-- *NRP Report*, NIH (2000), Willingham, *Cognition* (2004)

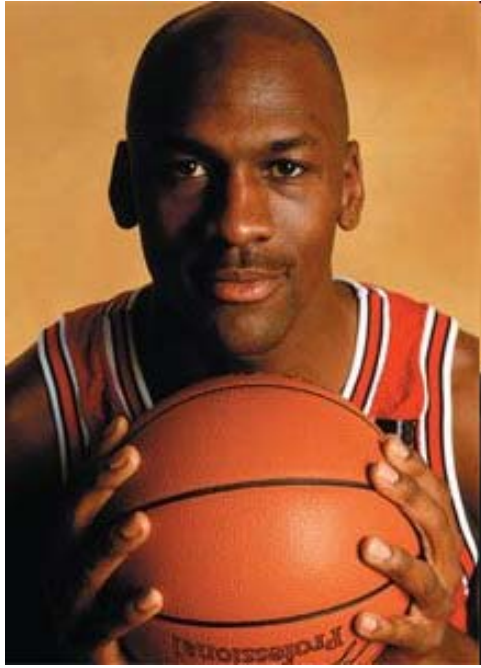
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But that, except for learning speech,
Which evolution has designed children (until age ~12) to do
learning takes practice.
NIH says the role models for our students
Should be people famous for their work ethic.



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Lindsay Vonn



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MJ



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Joshua Bell

Memorization?

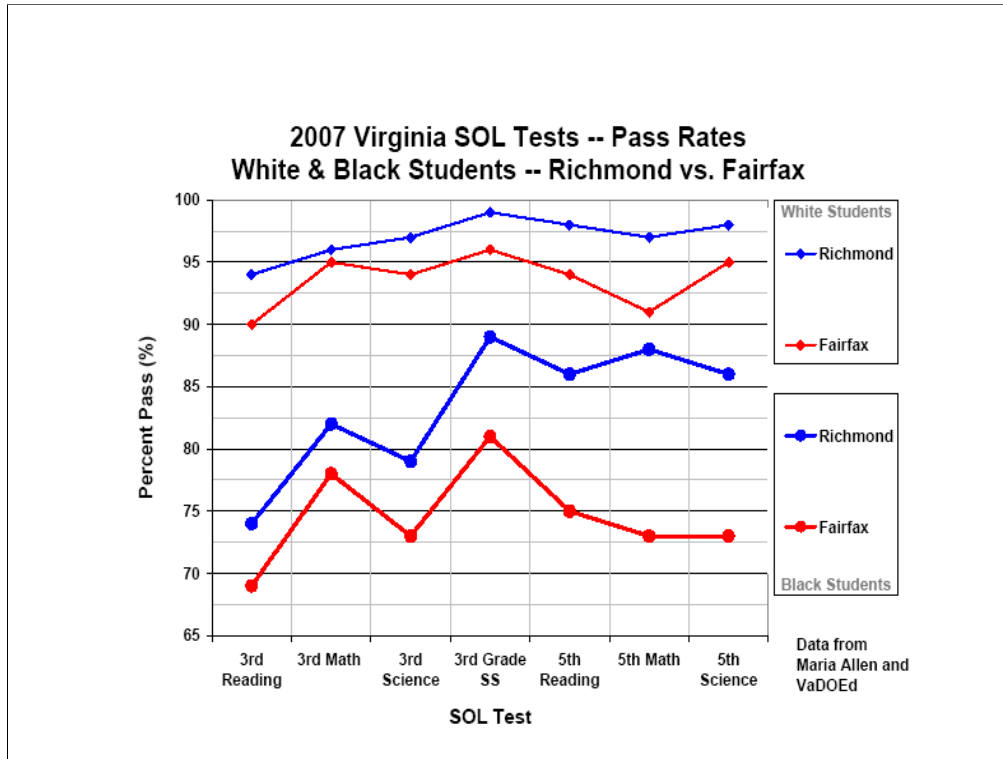
- “Data from the last 30 years lead to a conclusion that is not scientifically challengeable: thinking well requires knowing facts.... The very processes that teachers care about most-critical thinking processes like reasoning and problem solving-are intimately intertwined with factual knowledge that is in long-term memory (not just in the environment).
*There is one important exception-how experts think. Building expertise actually changes the thought process, but such change takes many years of advanced study.“

-- Daniel Willingham

http://archive.aft.org/pubs-reports/american_educator/issues/spring2009/index.htm

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Cognitive scientists now universally agree that learning takes memorization: Drill that moves facts into long-term memory.



Does this work? The NIH science works so well that in Virginia

In 5th grade math, Richmond black students are scoring nearly the same as white students in Fairfax Co. VA

One of the nation's wealthiest suburban school district.

Despite all of the real disadvantages of poverty.

This shows how scientific research can help with issues that have divided our nation for over 400 years.

Fairfax uses NCTM-type curricula, Richmond uses NIH-research-based curricula.

The graph below shows Year-to-Year Rankings for **Fairfax**.
The yellow bars represent the total number of Divisions in **Virginia**.
The blue dots represent the ranking of **Fairfax**.
The higher the blue dots are the higher the rankings.
Chemistry Pass



Wealthy Fairfax County has been below the state average on the state Tests in Chemistry for 9 of the past 11 years.
NCTM-based curricula are one key reason why.

For First-Year Engineers

- Don Dahm at Rowan Univ. taught 2 semesters of General Chemistry on the schedule of a ONE semester course,
- Then gave the *ACS General Chemistry 2 Semester Exam*
- Don's students scored at the average...

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In chemistry: I've been involved in a project with

Don Dahm - Don is here -- wave Don, To apply the NIH research to chemistry

One goal is to fill in gaps in computation skills as homework before lecture

so that you have more time in lecture to work on concepts.

Don did this teaching "2 semesters in one semester" experiment, and Don's students scored at the

63rd ACS Percentile

- In part by assigning math computation lessons as homework prep for lecture.
- Details on his model (plus all assignments -- Free): Search “ACS ChED CCCE Newsletter” Or
- http://ched-ccce.org/newsletter/Pages_NewsF09/F2009_News.html

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We think Don's approach will work with any group of first year students
If you might like to try an experiment like this,
Ply Don with coffee in a few minutes..., or send him an email at Rowan.
All of the lessons Don used are FREE online at the reference shown here.

At Frostburg

Read about Mary Mumper's success using a Prep Chem design focused on computation, also at:

“ACS ChED CCCE Newsletter” or

http://ched-ccce.org/newsletter/Pages_NewsF09/F2009_News.html

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15:10

Mary M at FB has also used the same lessons in preparatory chem. and has gotten very good results, which you can also read about here.

The Opportunity for Change

March, 2010:

National Governor's Assn.
proposes

- K-12 "Common Core Standards"
- Non-federal, state voluntary
draft "National Standards"

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In the past month, a new set of national math standards has been proposed.

For a review of the Common Core Math Standards:

- http://edexcellence.net/doc/20100323_CommonCoreReview_Math.pdf

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The standards are here.

Common Core Standards:

Good on Computation:

- “Fluently add and subtract within 20. By end of Grade 2, know from memory sums of one-digit numbers.” (Grade 2)
- “Fluently ... multiply whole numbers using the standard algorithm....” (Grade 5)
- Fluent means: fast from memory.

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They are pretty good on computation

And they are about to be debated in just about every state.

And that's an opportunity for you and your colleagues to be heard.

A Suggestion:

1. Gather the available computation DATA for your state.
2. Share it with Physics, Engineering, *and* Math colleagues.

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I have put up on these web slides some suggestions on how to get involved.

3. Decide Goals. Consider:

- a. Include chemists, physicists, and engineers on committees deciding *computation* standards.
- b. No calculator use before 7th grade?
- c. State testing that includes mental arithmetic
- d. Tests that measure versus international norms
- e. Test on “ready-for-college” standards
- f. Report computation scores
- g. High test security and reliability

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Including some possible goals

The Key to Success

4. Take DATA to technology **business** leaders. Ask support for goals. You'll get it.
5. Take **business** leaders to ask **political** leaders for support.

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And how to win.

Results

- 6. You will achieve your goals.**
7. In 5 years, you will start to see better prepared students.

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But it will take time to get students with a good foundation to you.
Good math instruction needs to start in Grade 3,
But those students then take 10 years to get to Grade 13.
That's all the more reason to start now.
And the opportunity to be heard will pass quickly.

Meanwhile

Consider temporary fixes
that teach computation outside of class
such as Don and Mary's.

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In the meantime, consider this.

Summary:

- Student STEM calculation skills have fallen substantially.
- We see it. Data proves it. They are unprepared for STEM courses.

Because:

- State standards = NCTM = deemphasized teaching of math computation.
- State tests do not report computation.

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In conclusion,

We know that student skills needed for STEM fields have fallen.

We know the reasons.

We know what to do about it.

Bottom Line

- STEM Workforce Skills are in Decline
and our Economy is in Trouble

BUT Good News:

- Scientific Research on Learning
= Improved Curriculum = Student Gains
- We know how to fix the problem
- 2010: “Common Core Standards”
= Opportunity To Win Change

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But we act together, we can win change.

Our responsibility

- If we see a serious problem in student preparation for STEM, we need to let the public and decision-makers know.
- Point out how science-based instruction can fix the problem.
- Insist that they address the problem.

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A primary goal in first year chemistry is to encourage students to enter STEM majors.

But if your supply chain does not do its job, You cannot do yours.

No one is reporting data on math computation.

So, unless STEM instructors speak up, No one will know that there is a problem.

I hope that for the sake of our children and the nation

You will insist that your state leaders decide

That we need to teach students how to do math computation

Before they get to chemistry.

These slides are posted at
www.ChemReview.Net
at the MARM tab on the left.
(The lessons used by Don and
Mary are also posted there)
Done! Questions?

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That's it.

Thank you for your patience.

The slides are posted here.

Please feel free to use them.

Did I leave time for Questions?

*16:50