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MATH — Home

Classroom Dynamics
- International Comparisons
- The Train Problem

Learning the Language
- The MPG Illusion

Tech Support
- Electronic Notebooks
- Interactive Textbooks

Resources

Text-only | Flash Special Report

MATH: What's the Problem?

Most agree that math smarts are essential to the country's future.

Yet, U.S. students' math scores rank below those of many other countries. Why do so many people struggle with math? Why is math so important, anyway?

Credits & Acknowledgements

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Image Credits:
Animated collage - John Prusinski, S2N Media, Inc.
Opening images - Photos.com

We wish to acknowledge the following people and organizations for their contributions to this project:

Kara Suzuka, Assistant Research Scientist, University of Michigan School of Education

Stephen Hegedus, Ph.D, director of the Kaput Center, University of Massachusetts Dartmouth

Mathematics students (and their parents) from schools in the South Coast region of Massachusetts

The Math Teachers' Circle Network

The Mathematical Association of America

Middle School of Mathematics and Science (MS)2, Washington, D.C.

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- Interactive Textbooks

Resources

Classroom Dynamics

'Rithmetic may be the last of the three Rs, but mathematics is a subject that touches every family. Improving math education has been a topic of national focus on-and-off for as long as there has been formal schooling. As international assessment tests found U.S. students being outperformed by those in many other countries, a 2007 report, "Rising Above the Gathering Storm," made improving math education key to improving the science and technology enterprise. Meanwhile, the National Mathematics Advisory Panel (NMP) diagnosed the delivery system for math education as being "broken and in need of repair." A long list of recommendations highlighted the importance of research to guide effective teaching from the earliest grades, and algebra as a gateway subject to higher-order math learning. Among the voices in this discussion are two members of the NMP: Joan Ferrini-Mundy, the National Science Foundation's (NSF) division director for the Division of Research on Learning in Formal and Informal Settings; and Deborah Loewenberg Ball, dean of the School of Education at the University of Michigan. They are joined by William Schmidt, university distinguished professor of education and statistics at Michigan State University.

VIDEO TRANSCRIPT
WILLIAM SCHMIDT: I think the problem is that just we simply have not done an adequate job of teaching our children and so we've done that for generations and so, therefore, adults say "I'm no good at math," and that's sort of okay. They think of it that way. It's sort of funny and they communicate that to their kids and people think it's only if you really have a math gene, but that's just so wrong. Other countries respect mathematics and they expect all kids to learn it to some basic level. They're all not going to be math people, but they all can learn it to a basic level.

STUDENT: 9, 10, 11, 12, 13, 14, 15, 16 –

DEBORAH LOEWENBERG BALL: That's very good. You're like –

DEBORAH LOEWENBERG BALL: I was a French major in college. In high school, I was fascinated with languages and humanities and social sciences and found my way toward elementary school teaching where, in fact, a course of math was one of the subjects I had to teach. Within a few years, I found that my ability to teach my own students math was less good than my ability to teach other subjects.

DEBORAH LOEWENBERG BALL: You're doing fine. You can't think of other ones?

STUDENT: What? Oh my gosh.

DEBORAH LOEWENBERG BALL: So, I began studying math at that point, once I was an elementary school teacher, and that essentially grew and launched an interest that I've had ever since, and the question about what is it about teaching young children mathematics that – what is the demands of the teacher?

DEBORAH LOEWENBERG BALL: I want to give you some directions for how to work on this. You're going to work in teams today and on your team –

DEBORAH LOEWENBERG BALL: Well, elementary math lab is first and foremost a program for schoolchildren in the area, and we deliberately designed this program to enroll students who are struggling in mathematics and we chose the age level of entering fifth graders who are about 10, because this is a key age at which children who begin to find math difficult or struggle with it really fall behind.

DEBORAH LOEWENBERG BALL: It's first and foremost a laboratory in learning and in teaching.

DEBORAH LOEWENBERG BALL: I want you to write down the way you'd record it with multiplication and I also want you to write down or sketch the rectangle.

DEBORAH LOEWENBERG BALL: Another feature is that we gather really good records of the work across the time of the laboratory class. It runs for two weeks, every day for two and a half hours and during that period, we videotape with more than one camera everything that's going on in the classroom. So, as a product of the laboratory, we have very high quality digital records that could be used for research purposes, for viewing by groups who aren't there live to create materials that could be used in teacher education elsewhere or in professional development.

JOAN FERRINI-MUNDY: One wonderful thing about the National Science Foundation is that we've been funding work in mathematics education aimed at improving mathematics teaching and learning for more than 50 years, going back all the way to the post-Sputnik new math curriculum and studies that were done in those years. So, we really do have a wonderful cadre of experts who have been studying mathematics teaching and learning. We've been studying international questions about mathematics education, and been developing and testing curricula and who have been working with teachers to improve the preparation and continuing growth of teachers.

JOAN FERRINI-MUNDY: I'd like to make a pitch for the importance of research about mathematics teaching and learning because everybody took math. It's possible to think that everybody – everybody does, in fact, have strong opinions about how math ought to be taught and how math ought to be best learned and so forth, and that needs to be supplemented and examined more fully, I think, through systematic research that can look at questions of teaching and learning, that can look at the ways in which certain materials might impact certain learners and so on. So, I'm very much supportive of the idea that interdisciplinary research that brings together mathematicians, scientists, mathematics educators, psychologists, cognitive scientists, statisticians, teachers, that's going to be part of the key to being able to solve some of our mathematics learning problems. Current reports and documentation would suggest that we are at risk relative to competitiveness and innovation, that we want to be sure we have a well prepared scientific and technological workforce and mathematics, of course, is at the center of that, but I would also add to this that it's important to have a mathematically literate populous and citizenry, people who can make sound decisions in their daily personal lives who can read and understand issues about health that depend upon statistics and mathematical ideas. So, again, both in terms of our technological and scientific competitiveness as well as our everyday life, I think math is important.

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Tech Support
- Electronic Notebooks
- Interactive Textbooks

Resources

International Comparisons

VIDEO TRANSCRIPT
WILLIAM SCHMIDT: I guess the simple summary of this, in many ways, is that at 4th grade and third grade, we tend to do sort of okay around the average internationally. By the 8th grade, we're below the international average and by the 12th grade, we're essentially at the bottom of the international distribution. But I think what we've learned pretty clearly is one of the major differences among countries has to do with the nature of their curriculum. These countries that achieve well have high expectations, especially during the middle grades. They're more rigorous and demanding. In 8th grade in these top-achieving countries, the middle school curriculum is about algebra and geometry and in the U.S., for most kids, it's still arithmetic; fractions, decimals, and percents. The fact that I cited that at the middle grades in this country, we track children and it's only that small elite group that gets to take "the algebra class." So, I think we're hurting our situation by not giving all children this kind of basic education. I think it's time, after five, six years of arithmetic, it's time to move on. People in other countries often ask me, "Well, goodness, you keep reforming education but you never get any better. Why do you keep doing this?" And, I think the answer is because we've never really attacked the two central issues. We attack a lot of peripheral ones, and the two central are the curriculum, which I've spoken a little bit about, and the teachers. Now, I think the curriculum is the heart and the core of the matter. These kids, as they're growing up, they're not competing with the kid sitting next to them in school, even in the next school over, not even in New York or in the West Coast, but kids all over the world. So, from their point of view, this is serious because their future is really dependent on their adequate preparation in math and science.

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Classroom Dynamics
- International Comparisons
- The Train Problem

Learning the Language
- The MPG Illusion

Tech Support
- Electronic Notebooks
- Interactive Textbooks

Resources

Can You Solve the Train Problem?

Over several days, fifth-graders at the summer Elementary Mathematics Laboratory at the University of Michigan worked on a mathematics problem that called for creative thinking and persistent effort. The problem asked them to try to build a train that would meet a set of specific conditions in the arrangement of its cars and numbers of passengers that each could carry. Here's the problem:

The Train Problem
The EML Train Company makes five different-sized train cars: a 1-person car, a 2-person car, a 3-person car, a 4-person car, and a 5-person car. These cars can be connected to form trains that hold different numbers of people.

[graphic of white box] -- 1-passenger car
[graphic of red box] -- 2-passenger car
[graphic of green box] -- 3-passenger car
[graphic of purple box] -- 4-passenger car
[graphic of yellow box] -- 5-passenger car

A customer named Mr. Howe wants to order a special 5-car train that uses exactly one of each of the different-sized cars. He wants to be able to break apart his 5-car train to form smaller trains, one to hold exactly each number of people from 1 to 15. In addition, he wants to be able to form these smaller trains using cars that are next to each other in the larger train.

For example, if he purchased this train:

[graphic of white box, red box, green box, purple box, yellow box lined up horizontally]

He would be able to make a white-red-green train, or a red-green-purple-yellow train, but not a red-yellow train.

Can the EML Train Company fill Mr. Howe's order? Explain how you know.

In the end, the students had answered the question.

So how about you? Try the problem yourself and see in more detail the challenge that these fifth graders were facing.

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Special Report
Text-only

MATH — Home

Classroom Dynamics
- International Comparisons
- The Train Problem

Learning the Language
- The MPG Illusion

Tech Support
- Electronic Notebooks
- Interactive Textbooks

Resources

MATH: What's the Problem? — Text-only | Flash Special Report

Learning the Language of Math

Did you squeak through high school taking an absolute minimum of math? The signs of a culture lacking in basic math literacy are everywhere. The mathematically-challenged struggle with understanding the impact of compounded interest and variable-rate mortgages. They're ill-equipped to process the modeling and predictions related to climate change, polling statistics in news reports, or the probability of winning the lottery. But most Americans don't see math as very important–even to their children's education. A series of surveys by Public Agenda shows that there's a real gap between leaders and the public on this issue. Here, discussing the value of math proficiency are Cora Marrett, NSF's assistant director for the Education and Human Resources Directorate; Tony Chan, Assistant Director for Mathematical and Physical Sciences (MPS) Directorate at NSF; and David Bressoud, president-elect of the Mathematical Association of America.

VIDEO TRANSCRIPT

TONY CHAN: You look at all the big problem that society faces from energy to climate change to even now a lot of the social sciences, if you look at how, you know, human beings interact and so on, all of them have a mathematical component to it. Math, it's just a language of understanding the natural world. So, the more you understand, the more you want to predict, the more you want to understand the structure behind different components of that natural system.

DAVID BRESSOUD: Mathematics, at its heart, is really looking at the patterns in the world around us, numerical patterns, spatial patterns, especially, and understanding those patterns and we're naturally pattern observers. That's part of the human nature. I mean, that's built into our DNA, that we look around the world around us and we try to understand what's likely to happen. One example that I think of are mathematical models of things like the fishing industry. So, why is it that the fisherman go out and for years and years they catch the fish and there are plenty of fish there and then suddenly it collapses? Well, part of what mathematics can do and has done is to build the models that enable us to understand what's going on with fish populations and the effect of this draw and we can see that there really is a tipping point. There really is a point mathematically. The model reveals to us that we need to be aware of a tipping point where suddenly the fish population is going to collapse.

CORA MARRETT: Almost any field one can think about will require levels of mathematics. This is not something anymore that is exclusively if one is going into, let's say, mathematics teaching. If we're going to have more people than having broad options, we're going to have to do a lot to enhance, to strengthen what happens in math education. So, in terms of what the implications are, and the implications are profound for any field of science or engineering we're talking about, but it's also profound for anyone being able to lead a life of an informed citizen.

DAVID BRESSOUD: We're not getting enough students coming out of high school who are prepared for the kind of jobs that are in the workplace, even if they're not highly technical jobs. The fact is that they're jobs that require decision-making and decision-making often based on numbers because we're living in a world today, thanks to computers, that's just inundated with data.

TONY CHAN: But I think the other reason is probably that people do not, somehow, learn or know that mathematics is actually part of the natural world. It's useful. It's enlightening to understand mathematics, not the technical sense, but to use that to understand the world around us. I think once people appreciate that, then I think they will be more motivated to learn about mathematics.

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MATH — Home

Classroom Dynamics
- International Comparisons
- The Train Problem

Learning the Language
- The MPG Illusion

Tech Support
- Electronic Notebooks
- Interactive Textbooks

Resources

The MPG Illusion *

*** based on an article in *Science* magazine, June 20, 2008**

Which saves more gas: replacing a car that gets 25 miles per gallon (mpg) with one that gets 35 mpg? Or replacing a car that gets 16 mpg with one that gets 20 mpg?

Before you answer, consider this. Here in the U.S., we measure fuel efficiency by looking at how many miles a car can travel on a gallon of gas, rather than how many gallons of gas it takes to travel a given distance.

Many other countries calculate fuel efficiency in terms of liters of gas consumed per kilometer. This is a better gauge of the impact your car has on your wallet (with the cost at the pump) and on the environment (with the amount of fuel burned) for the amount of driving you do.

Now for the answer: Replace the car that gets 16 mpg with one that gets 20 mpg. On a 400-mile trip, a car that gets 16 mpg uses 25 gallons of gas, while one with 20 mpg uses 20 gallons. Thus, there's a savings of five gallons with the more fuel-efficient car.

The savings are smaller when going from a car that gets 25 mpg to one that gets 35 mpg. The car with 25 mpg uses 16 gallons of gas on that 400-mile trip. The one with 35 mpg uses 11.4 gallons, a savings of 4.6 gallons.

These kinds of savings are reflected in the chart. When you look at gallons of gas used per 10,000 miles driven, big decreases in gas consumption start to level off with cars that get more than 35 mpg.

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MATH — Home

Classroom Dynamics
- International Comparisons
- The Train Problem

Learning the Language
- The MPG Illusion

Tech Support
- Electronic Notebooks
- Interactive Textbooks

Resources

Tech Support

Forget the overheads and film strips shown to passive students in yesteryear. Today's technology can engage students directly in doing mathematics, support the learning of concepts, offer customized instruction and tutoring, and leave a trail of data to gauge impact. Here, we highlight two technologies whose initial development was funded by NSF in the 1990s. Both SimCalc and Cognitive Tutors have since been commercialized and their use in school districts has been studied in terms of student progress and results. To give some perspective on technology and how it can, under specific conditions, help students succeed at math are Ken Koedinger, professor of human-computer interaction and psychology at Carnegie Mellon University and Jeremy Roschelle, director of the Center for Technology in Learning at SRI International.

VIDEO TRANSCRIPT

JEREMY ROSCHELLE: I think when people are saying, "I don't need anymore math and arithmetic," they're looking at one kind of math, which is sort of shopkeeper math and maybe they've had enough to be a shopkeeper. When you're looking at people who are innovators and driving the future of the economy, they're look at math as a tool kit that allows you to do new science, engineering, and innovation, and that's not about adding numbers.

JEREMY ROSCHELLE: You know, many parents and people have some images of what technology could bring and they think it's fun or it's engaging or it's games, and all those things are nice, but, really, what the research has shown is some deeper reasons that we should use technology, and one is the ability to bring concepts to life. When you can put the concepts in a digital interactive, often dynamic, or animated form, students are much more able to really understand mathematical concepts and when they understand the concepts, they perform much better.

JEREMY ROSCHELLE: Part of math literacy is really graphing literacy because one of the representations that you see in newspapers is graphs. Part of it is being able to read tables and not just see them as piles of numbers, but see mathematical relationships in the tables. Part of it is being able to look at formulas in algebra and make some sense of that and then to relate that to the events you're trying to explain or predict, and that's the storytelling. So, what SimCalc really aims to do is connect these things in the experience of the students and the teacher.

STUDENT: The space between the dots gets bigger.

TEACHER: The space between the dots gets bigger. What do you mean?

STUDENT: It, like, skips – the line is –

TEACHER: Hold on. One at a time. Carson, finish your thought. Go ahead.

STUDENT: The, like, dots are closer and then once it gets [inaudible].

KEN KOEDINGER: Math is a book about being able to express yourself, to communicate ideas, but it's also about, you know, part of communicating, you know, ideas. So, if you're going to understand issues like interest rate. You need to be able to read mathematics, right? You need to be able to understand it as a language.

KEN KOEDINGER: Well, Cognitive Tutors grew out of past research in cognitive science and that research was on how people learn, sort of understanding how the brain works, but also on how we can get technologies to essentially simulate student learning. While it is an advanced technology and it's tutoring students in a one-on-one way like a human tutor does, it's not replacing the teacher. So, it has this function of being able to zero in on those needs that a student has, where they struggle and what do they not know and gives instruction just on that. That's the technology component, but it's also embedded in a full classroom so two days a week students are using this technology, typically. Those other three days a week they're in a regular classroom. The materials are designed to help

students appreciate why algebra is important by connecting them to real world problem solving, but what's nice is, in the computer lab, those kids that are somewhat falling behind, they're not left behind. They get help where they need it. Those kids that are racing ahead, they're being challenged. They're doing things that are interesting. So, we found that it's not just about mathematical achievement and getting the concepts, it's also more engaging for students because they feel like they're really making progress. They're having success experiences and the harder they work, the better they do.

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Classroom Dynamics
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Learning the Language
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Tech Support
- Electronic Notebooks
- Interactive Textbooks

Resources

Coming Attractions: Electronic Notebooks

VIDEO TRANSCRIPT

JEREMY ROSCHELLE: I think we're going to see a lot of interactions with devices in math that use a stylus, not a keyboard. If you've ever tried to type mathematics, it's horrible. X-up carat-2 is a horrible way to say, X-squared, which is very easy to write if you have a pen, and pens are great because kids can sketch things. Like, sketch what you think the graph of this might look like. So, we're going to want some combination that has something to focus everyone's attention and a very natural way to write mathematics, which may be a handheld or a slate or a tablet, and you're going to want those to be connected so that a teacher can present something, ask students to do something at their desk, and then move the mathematics that students made back to the display at the front of the classroom. So, I think those are some of the basic features, and I think, you know, feel very natural. This smart board will feel just like a blackboard and it won't stand out as technology and that the stylus that you're using will feel like a pen and it won't stand out as technology. So, I think we'll just – technology will become very natural and it'll just add to the capabilities of what teachers and students can do.

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Special Report
Text-only

MATH — Home

Classroom Dynamics
- International Comparisons
- The Train Problem

Learning the Language
- The MPG Illusion

Tech Support
- Electronic Notebooks
- Interactive Textbooks

Resources

Coming Attractions: Interactive Textbooks

VIDEO TRANSCRIPT

KEN KOEDINGER: These kind of technologies, I think are the textbooks of the future. We will not just sit there and read passively, but be able to test our ideas and get feedback about whether those ideas are right and wrong, and that kind of interactivity is what makes learning really powerful and it makes it more fun and more interesting. We can track all of that, too, in a way that, you know, one of the visions I have is that we won't need to have these two-hour high stakes tests because our understanding of what students know and don't know will be much richer from their years' worth of interaction with these technologies, right, and we'll be better able to say to the students and their parents and their teachers and so forth what it is they know and don't know, where are their strengths and where are their weaknesses, and that kind of online assessment, it's really powerful, and it will advance the science and technology base as well.

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