UNITED STATES DEPARTMENT OF EDUCATION

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NATIONAL MATH PANEL MEETING

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Monday
November 6, 2006
8:15 a.m.

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East Vidalakis Hall
Schwab Residential Center
680 Serra Street
Stanford, CA

PANEL MEMBERS:

DR. LARRY FAULKNER, CHAIR
DR. CAMILLA PERSSON BENBOW, VICE CHAIR
DR. DEBORAH LOEWENBERG BALL
DR. DANIEL BERCH (PRESENT VIA CONFERENCE PHONE)
DR. A. WADE BOYKIN (NOT PRESENT)
DR. FRANCIS (SKIP) FENNELL
DR. DAVID C. GEARY
DR. RUSSELL M. GERSTEN
MS. NANCY ICHINAGA
DR. DIANE JONES (PRESENT VIA CONFERENCE PHONE)
DR. TOM LOVELESS
DR. LIPING MA
DR. VALERIE F. REYNA
DR. WILFRIED SCHMID (NOT PRESENT)
DR. ROBERT S. SIEGLER
DR. JAMES SIMONS (NOT PRESENT)
DR. SANDRA STOTSKY
MR. VERN WILLIAMS
DR. HUNG-HSI WU

EX OFFICIO MEMBERS PRESENT:

DR. KATHIE OLSEN (NOT PRESENT)
MR. RAY SIMON
DR. GROVER J. (RUSS) WHITEHURST

STAFF:

MS. TYRRELL FLAWN, EXECUTIVE DIRECTOR
DR. MICHAEL KESTNER
MS. IDA EBLINGER KELLEY
MS. JENNIFER GRABEN
MR. KENNETH THOMSON
MS. HOLLY CLARK

C-O-N-T-E-N-T-S

National Assessment of Educational Progress (NAEP)

C-O-N-T-E-N-T-S (CONTINUED)

Public Comment

C-O-N-T-E-N-T-S (CONTINUED)

Instructional Technology and Calculators (cont.)

Research and Instructional Practices

P-R-O-C-E-E-D-I-N-G-S

8:15 a.m.

DR. FAULKNER: (presiding) Okay, let me ask everyone to please take their places.

The video people wanted a minute's notice. So I am giving them a minute's notice.

(Pause.)

Let me welcome everyone to the morning session of the National Mathematics Advisory Panel. We are glad to have the public here with us. I want to welcome members of the public and members of the panel to this session.

Let me also ask about signing services. We have signing services available. It is operating right now, right? Behind the camera, I think.

If there's need for these services, we are glad to continue them. If no one is using them, we will not continue them. I would like to ask if there is a continuing need.

(No response.)

If not, then we will discontinue, and if someone arrives who needs these services, we can reinstitute them. Thank you.

Let me thank Stanford University for hosting the National Math Panel on this occasion. We have tried commonly to hold the panel meetings in places around the country that represent high achievement in education, and this is certainly one of those places. It is a privilege and a pleasure to be here in Stanford.

We would also like to acknowledge Dean Debra Stipek, Dean of the School of Education, and we want to thank her for her assistance in planning the meeting. I don't believe Dean Stipek is with us, but if she is, I would like to ask that she stand and be recognized.

Now it is my pleasure to introduce the President of Stanford University, John Hennessy, who is with us to make a few comments to the panel and to the audience. President Hennessy joined the Stanford faculty in 1977 as an Assistant Professor. He has had a meteoric career at Stanford, was named Dean of the School of Engineering in 1996, Provost in 1999, and in 2000 he was President.

He is a pioneer in computer architecture. He is the embodiment of the Stanford legend in that he also engaged in the development of a commercial enterprise derived from his own research. He founded MIPS Technologies, which designs microprocessors. He is a member of the National Academy of Engineering and the National Academy of Sciences and has lectured and published widely, and has been co-author of two internationally used undergraduate textbooks on computer architecture.

President John Hennessy.

DR. HENNESSY: Thank you, Larry. Welcome to Stanford. I think I should also say welcome to Silicon Valley. I think both on behalf of the University and on behalf of my many friends and colleagues in the Valley, we believe that the work of this panel is critically important.

Here at Stanford half our students major in science or engineering topics. With the ongoing changes we see in the social sciences, for example, where by far the most popular major is economics, a major that now requires second-level calculus and analysis in order to pursue that major, we see a growing need for mathematics across a variety of disciplines. Hence, the work of this panel is critically important.

If you were to take a trip down to the Valley and walk through the halls of Intel or Google or Cisco or Yahoo, what you would see is that this Valley has been built on, and relies on, the importation of talent from around the world. That I think is a fundamental threat to our ability to continue to lead in science and technology and to innovate. If we are going to continue to be world leaders at a time of increasing competition, we are going to have to do a better job of educating people in our own country and preparing them for careers in science and engineering.

I think, as we all know, that problem is one where each part of the pipeline has to make a contribution. We in the universities have to do a better job of educating young people and attracting them into science and engineering. High schools have to do a better job. But it all begins with the K-8 experience.

Increasingly we see, in the sciences and, as has always been the case, in engineering, a critical need for mathematics as the fundamental tool. In other cases mathematic has been the fundamental stumbling block that prevents a young person from thinking about a career in science or engineering. So the panel's work is absolutely crucial to this.

When I went to school you could be an engineering major and you could survive if you had not had calculus in high school. You would struggle a bit in the beginning, but you could get through. That is not true today. Students who come into a good engineering schools majoring in engineering or physics or chemistry without calculus will find it incredibly difficult to succeed and graduate in four years.

What happens? They opt out. They choose another career.

So I think it is important to remember that the demands we are putting on our young people and on the talented people that have the aptitude to succeed in these disciplines are higher than they have been before.

It is also critical that we worry about the problem of inclusion. Obviously, we need more young people going into science and mathematics careers. That requires that we include a larger group of Americans pursuing those disciplines. We can't educate only those of us that are techies and nerds and leave behind the rest. We need to do a better job of inclusion, and that, of course, comes down to many factors, but certainly pedagogy is one of those.

Thinking about how we prevent the situation that so many young people are turned off by their experience, and particularly their encounter, with mathematics is an absolutely crucial issue.

One of the things that never fails to amaze me is how even a significant number of undergraduates at an institution like Stanford, where even our students majoring in English and history have a fairly strong background in mathematics in order to get in, decide that that is not for them.

I wonder where that seed was mislaid along the way and they made the decision that this was not the right thing for them. It is a question we should all ask ourselves.

I think we also need to think about the changes that are ongoing in our world and what we are trying to achieve when we teach mathematics to young people. Like many, I learned how to do long division, long multiplication by rote, but I guess I never quite, until much later in life, learned about place value and got the really understanding about place value.

My kids went through the same thing 20, 25 years after I did, and I had to explain to them why that rule about borrowing really works and why you shift when you do long multiplication. But the real value is in teaching about place value, a concept that they will use time and time again if they learn it at the very beginning.

I also want to say a word about teachers. They are obviously absolutely crucial to this. I have always viewed teachers as key public servants. We just announced that we have put in place a loan forgiveness program for graduates from the Stanford Teacher Education Program (STEP) so that we can help them if they really decide they want to pursue teaching as a profession.

That is a crucial issue for all of us, and it is crucial that we think about how we prepare and educate teachers to be teachers, good teachers of mathematics, and how we continue to attract them to the discipline.

So, in sum, I think the work of this panel couldn't be more crucial. We applaud the efforts. We thank you for what you are doing, and we give you our best wishes on an absolutely crucial topic for the nation and for our young people.

Thank you and welcome to Stanford. Enjoy your meeting. Thanks.

(Applause.)

DR. FAULKNER: Thank you very much, John. We really appreciate the support we have been given by Stanford and appreciate your joining us here today.

Okay, we are now beginning the session on Trends in International Mathematics and Science Study or TIMSS. This material related to this is at Tab 8 in the notebook.

I would like to acknowledge Tom Loveless, Skip Fennell and Bob Siegler for their assistance in planning the session.

We have, I think, three folks here to testify. Somehow I have mislaid my glasses, and I am in very bad shape here with respect to reading their names. So let me do my best here.

We have Michael Martin, Co-Director of TIMSS and PIRLS International Study Center at Boston College. We have James Stigler, Professor of Psychology at the University of California at Los Angeles, and we have Gerald LeTendre, Professor of Education Policy Studies at Pennsylvania State University.

We will begin by having presentations from each of these three individuals, 10 minutes each, and then we have 35 minutes of questions and answers.

So if anyone finds a pair of glasses, let me know.

(Laughter.)

Let us begin with Michael Martin.

DR. MARTIN: Good morning, Mr. Chairman, everybody. Thank you very much for inviting me to this panel. We are privileged to be here.

I bring apologies from my Co-Director, Ina Mullis, a long-time student of student achievement in mathematics in the United States and internationally. She is very sorry not to be here.

As the Chairman said, I am Co-Director of the Trends in International Mathematics and Science Study (TIMSS) project. TIMSS has been studying student achievement in mathematics and science internationally since 1995. We conduct TIMSS on a four-year schedule every four years, starting in 1995 and again in 1999, 2003, and we are currently working on the 2007 assessment.

The message from TIMSS 1995 is quite stark. The performance of U.S. students in an international perspective is really quite mediocre in mathematics. It is just about average on the TIMSS on the mathematic scale.

This TIMSS mathematics scale was developed in our first TIMSS in 1995 to have an average of 500 -- it is quite an arbitrary scale -- and a standard deviation of 100. So the U.S. mathematics performance in relation to the scale average was just about average overall, but even more disturbingly it seemed to become worse and worse as you progress up the grades. It is not too bad at fourth grade, about average in eighth grade, but worse in twelfth grade.

More specifically, at the fourth grade the average achievement of U.S. fourth-graders was just above average. The score was 518 compared to the average of 500. This, for example, was well below the highest-achieving country, Singapore, which had a score of 590.

At the eighth grade, the performance was not quite so good. It was almost average, 492, but now somewhat farther behind Singapore, for example, which had a score of 609.

Then at the twelfth grade, we had two different tests. We had an assessment of mathematics literacy, which is essentially eighth or ninth grade mathematics for all students. The score here for U.S. twelfth-graders was below average, which was 461. We also had an advanced mathematics test for students who had taken advanced preparation mathematics. This is about 14 percent of the cohort, and the performance here was also well below average at 442.

So there was the hypothesis from the TIMSS 1995 results that, because there had been so many reform efforts in the 1980s and early 1990s concentrated at the earlier grades, that perhaps if TIMSS is repeated when the fourth-graders were in eighth grade, perhaps we would see a dramatic improvement.

So we repeated TIMSS 1995 in 1999 at just the eighth grade, but the results were disappointing in the sense that the eighth-graders, who had been fourth grade in 1995, were still about average with a score of 502, slightly better, but no great improvement. In fact, compared to when they were in the fourth grade, these 1999 eighth-graders, relatively speaking, had slipped from above average to about average.

Moving forward then to TIMSS 2003, the message stays much the same. At the eighth grade, students are still just about average at 504, although this does represent gradual improvement from 1995 to 2003, from 492 in 1995 to 504 in 2003.

At the fourth grade, the students were holding steady. Their score in 1995 was 518, and it is 518 in 2003 also.

I could point out that consistently the high performers in mathematics in TIMSS have been the Asian countries. Singapore, for example, had a score of 605 at the eighth grade and 594 at the fourth grade.

Now TIMSS doesn't just give a score to each of these students. It also makes on the scale to treat as international benchmarks. For these benchmarks, then, we describe in some detail what the actual mathematics the students scoring at these benchmarks know and can do.

So the TIMSS Advanced International Benchmark, which is the highest one we use, is set at a score point of 625. Now the students reaching this benchmark can do quite a bit of mathematics by eighth grade standards. They can, for example, apply algebraic concepts and relationships to solve problems. They can solve simultaneous inter- equations, two equations I should say. They can model simple situations algebraically, and they can apply measurement and geometry in complex problem situations, complex by eighth grade standards, of course.

So one of the things we do is we report the percentage of students in each country who reach these benchmarks, and this is instructive, I think. If we look at the performance from eighth grade in 2003, we see that the highest-achieving country of Singapore had 44 percent of its students reaching this advanced benchmark. Chinese Taipei, that's Taiwan to you and I, was 38 percent. In Korea, it's South Korea, of course, 35 percent. In Hong Kong, which when we started was a country, 35 percent; Japan, 24 percent; within the United States, the figure is just 7 percent.

So what could be the reasons for the United States' performance being so far behind these Asian countries? Let me just consider a few other obvious candidates and see if we can't tease something out here.

Is it a question simply of more resources? Apparently not. Japan and the United States are really quite similar in terms of Gross National Income (GNI) Per Capita. They are the highest in the TIMSS 2003 participants with an average of about 35,000 U.S. dollars per capita.

Next comes Singapore and Hong Kong, which are about mid-range, between 20,000 and 25,000 U.S. dollars. Then both Korea and Chinese Taipei, which were both high achievers, a comparatively modest per capita GNI, about 10,000 U.S. dollars.

So, actually, if resources were just the keynote, the United States would be quite an underachiever.

We sometimes hear countries say that part of the reason these countries do well is because they have a national curriculum that is highly focused and they have examinations at the end of secondary school, which have very serious consequences for these students' futures. This is a possible explanation or partial explanation of the differences.

It is true that each of these countries has a national curriculum, and each has highly important high-stakes examinations, and this is not true in the United States. I can testify from personal experience that having gone through a country, lived in a country like Ireland where we have the same idea, you work really, really hard in the secondary school. I notice my daughters who went to twelfth grade in Massachusetts really enjoyed their senior slump year while their cousins in Ireland were working really hard at mathematics, science, and all the other subjects. So there may be something of this.

Is it just a question of being in the curriculum? Our colleague, Ms. Schmeiser, has traded this around quite a bit. It doesn't seem to be just that because Singapore, for example, has all of the TIMSS mathematics topics in their curriculum. This is also true of Japan, and the United States has about 83 percent, I would say.

But, for example, Chinese Taipei has only two-thirds of the topics, and Korea and Hong Kong only about a half. So it is not just a matter of being in the curriculum.

Is it a matter of being in the curriculum and being taught? Again, this doesn't seem to be the easy answer because about 80 percent, more than 80 percent of the topics were taught to almost all of the students in Singapore, Chinese Taipei, and Korea, not so much in Hong Kong, and then the United States at 80 percent. So it is all pretty similar there.

Is it a question of teacher preparation? Can it be that teachers who do not know mathematics can teach mathematics? Probably not. In Singapore and Chinese Taipei, more than 80 percent of the students were taught by teachers who have mathematics as their major, have a major of mathematics in their degree. In Hong Kong, this figure was just 63 percent. In Japan, it is 80 percent. In Korea, it is just 37 percent, but Korea, as we saw, is not the richest country in the world. In the United States, it is just about half. Just about half the students in eighth grade were taught by teachers who had good qualification in mathematics.

Whatever kind of preparation they had, how ready are they, prepared to teach these things? Do the teachers feel confident and secure and ready to teach? This is true in almost all countries. Practically all of the students are taught by teachers who say, "Yes, we feel ready to teach the content of the TIMSS assessed," regardless of their level of preparation.

One of the big findings we see in TIMSS is that students who attend orderly schools where things are well organized, where there are no disruptions, where they don't go in fear of their lives, tend to do better than students in more risky environments.

So one of the things is, are the students there to learn? This is the percentage of eighth grade students in schools where principals reported good attendance. Good attendance here means no absenteeism, no skipping classes, no tardiness coming in.

As you can see, in most of the Asian countries most of the kids are in good shape here. But 18 percent, only 18 percent, of the kids, the eighth grade students in the United States attend such schools.

What about time devoted to algebra and geometry, these being the two really difficult components of mathematics? You can see that all of the countries devote a substantial amount of time to these two subjects, usually more than half.

In Singapore, for example, it is 34 percent algebra, Chinese Taipei, 35 -- 27, 32 percent for Hong Kong. The United States is 41 percent, which is quite a lot.

But the interesting thing here is that in the United States there is relatively little emphasis on geometry, whereas the other countries also are teaching geometry. This may be partly because many of the other countries have already laid the basis for algebra in earlier grades and are now moving on to more challenging content.

What about technology and calculator use?

Here we can see that these are percentages of students who are not permitted to use calculators in TIMSS countries. In the United States and Hong Kong and in Singapore, essentially, all students have access to calculators and are permitted to use them. But note that in Chinese Taipei and Korea and Japan, about a third of the students are not permitted to use calculators and are still able to achieve quite a high level of mathematics performance. If calculators were the key, just imagine what these kids could do.

What about actually spending time on task learning mathematics, learning in the old-fashioned sense of the teacher lecturing and the students listening? Probably Jim will say more about this since he has done extensive analysis of what goes on in the classrooms. But just from TIMSS, we see that these Asian countries seem to spend a higher proportion of time than the United States just sitting and lecturing the students on their mathematics. The highest here we can see is in Hong Kong with 36 percent, Korea, 30 percent, and Chinese Taipei, 42 percent. In the United States, they don't do that. The students spend their time working on problems either with teacher guidance or by themselves. It is a major activity.

I am just finishing, thank you. That's

it. Right on schedule, Mr. Chairman.

(Laughter.)

Always happy to oblige.

DR. FAULKNER: Let me turn to Dr. Stigler, please.

DR. STIGLER: Thank you very much for inviting me. I haven't given a 10-minute talk in a while, so I am just going to launch right into it.

What I am going to do today is talk briefly about the TIMSS video studies that we have been doing since 1995, and then talk a little bit about implications for improving teaching. I am not going to be able to touch most of the topics in my presentation today, but Jim Hiebert is giving a presentation this afternoon. We are long-time collaborators on this work. So he will be able to answer all the questions that I raise.

I am going to start with just two assumptions that I am making that I think are critical for the panel to focus on. First is that the classroom is the final common pathway for improving mathematics education. All the things that we do to try to improve mathematics learning on the part of the students have to get filtered through the classroom and moderated and mediated by what goes on in those classrooms. That is an assumption that I make.

The other assumption that has guided our work is that teaching is something that can be studied and improved, not something that just has to vary randomly.

So let me talk just a little bit about the TIMSS studies, the TIMSS video studies, which, of course, are part of the larger TIMSS project. There really were two large studies. Data were collected in 1995, in 1999, and the methodology behind these studies was very simple. It was simply taking national samples of eighth grade mathematics teachers, but, in addition to giving them questionnaires, like survey researchers tend to do, we actually went out and videotaped a single classroom lesson in each of these classrooms. Then we got all these hundreds of hours of video back and set about trying to understand what was going on and how it differed across these different countries.

In the first TIMSS video study we only had three countries: Germany, Japan, and the United States. Only one of those countries was a high-achieving country, Japan. So you have to temper what you are learning from that study by realizing the "N" of high-achieving countries was only one, but still very interesting.

In the second TIMSS video study we

included a number of other higher-achieving countries such as Czech Republic, Netherlands, Switzerland, Hong Kong, and some non-Asian higher-achieving countries in mathematics also.

The goal of this research, I sometimes say, is to investigate average teaching. The reason I bring this up is a lot of people who hear that we are videotaping wonder why would we videotape a national random sample of teachers. Why not go out and find really good teachers to videotape, which is a very interesting thing to talk about.

But one of the answers is that it is really important to know what average teaching looks like. The reason that is important is because most students experience average classroom instruction. So when we look across these national samples, we are really getting a sense of what most students experience when they go to math class. By the way, it looks very similar to what I remember experiencing when I went to math class.

The other goal, of course, is to compare what we find in these classrooms in the United States with what we find in other higher-achieving countries, such as the Asian countries that Mick has talked about and some of the other countries.

I am just going to talk about a few

things, and I just say what I have learned because I couldn't possibly go through a lot of the findings of this research. I am trying to filter out what I think is most important and offer you a couple of ideas and findings that I think are worth thinking about.

First of all, teaching is a cultural activity, by which I mean it varies a lot more across cultures than within cultures. To me, one of the most important findings from the study was to just notice, when you looked across the United States, for example, and it didn't matter from where, how much homogeneity there was in eighth grade mathematics teaching. When you look at other countries, it is very, very different. So this, of course, raises the question, gee, how is it different and how are they teaching in these higher-achieving countries?

This leads to the second conclusion that I wanted to highlight, and that is that there is no single best instructional approach. Unfortunately, it is just not that easy. When we really looked at all the things that people talk a lot about when they are thinking about improving teaching -- for example, the large, superficial things like, should teaching be lecturing at the front or breaking students into groups, and so on -- we find that these things vary all over the place in the higher-achieving countries and there is no single one best way to teach.

Really, teaching is very contextual, and what works best in one country might not work in the other simply because you don't have the same students in different countries.

So what has happened is these different teaching systems have evolved over time, and they are multiply-determined. There are lots of things that tend to keep them the same. In fact, one of the characteristics of cultural activities is that they are hard to change.

So there is no one single best instructional approach, but we did find what I think is a key intervening variable. We found this when we went out and looked at how teachers implement not the routine practice problems, but the more rich problems designed to engage students with rich and rigorous mathematical concepts.

What we found is that this is one of the only things that actually differentiated the higher-achieving countries from the United States. The teachers, by whatever method, were able to get the students engaged in thinking about important, rigorous mathematics in the classroom. This is something that we didn't necessarily find in the United States.

By the way, in our second video study, we also studied science teaching, and we found pretty much the same thing, which is that in the higher-achieving science countries the teachers were able to use laboratory activities as a vehicle for engaging students in science concepts. In the United States often the activities became an end in and of themselves.

I put up this diagram, which was supposed to go off at a different time when I pushed the button, but, anyway, to just illustrate the point that I think that finding direct correlations between specific instructional approaches on the left side and student achievement is going to be very difficult unless we create some intervening or intermediate variable, which I think is going to have something to do with engaging students with mathematics.

I think there are lots of different ways that teachers can do that, and it depends on who the teacher is and who the students are that they are teaching, but if they can't achieve that, that's when I think it runs into problems. I think that is really the best hope. I think Jim Hiebert is going to talk more about that this afternoon.

Okay, let me just talk briefly about two things I would offer to the panel in terms of improving teaching. The first thing is what we call the ALFA project, Algebra Learning for All. This is a project funded by IES, one of the first teacher quality grants. The second thing I am going to talk about is the power of incremental, yet sustainable, improvements in the quality of average teaching over time. These are the two ideas.

Okay, the Algebra Learning for All (ALFA) project took place in a very low-achieving district in Los Angeles. It included approximately 70 teachers. One of the unique things about this project is that it was truly a random assignment study intended to assess the effects of a professional development experience on teachers on student learning. There are almost no studies like this. We now understand a lot of the reasons why that is, because it is extremely difficult to carry out this kind of research.

The hypothesis that underlies this research, however, came from our TIMSS results. Since we found that in high-achieving countries, the teachers were able to use rich problems to connect students to math, we wanted to know if we could use this as a lever for promoting change, by working with teachers with professional development about how to use and implement rich problems effectively in the classroom.

We have two findings so far, and one of

them I think I am going to show a graph on the next slide. It is quite interesting.

First of all, stable implementation sessions are a key to success, especially working in low-performing schools. One of the things that I truly believe after this project is, it is like if you ask someone to learn to play the piano, but they never have a time or place to practice, they are not going to learn. I think the same thing is true with improving teaching. If teachers don't have a stable setting to regularly work on improving their practice, then teaching isn't going to improve. So finding stable settings for teachers to work on professional development in the context of low achieving schools, particularly, is very challenging.

The second thing, though, is we did find positive effects. I was actually quite shocked, even though I wrote the grant proposal. We actually found positive effects on student learning on the district quarterly assessments simply as a result of the professional development, based on implementation of rich problems, but only for teachers with enough content knowledge. I know Wu is going to find this finding interesting.

I think this is an important finding because what we found is that the treatment effect was significant for teachers with high pedagogical content knowledge, but not for teachers with low pedagogical content knowledge. I think there is a lot more to learn about this, but I do think that teacher content knowledge is a necessary condition for being able to teach effectively. However, it is not a sufficient condition, because we found that that alone did not relate to student achievement in this study.

The final thing I was going to talk about is three strategies for improving teaching that I think have come to me. I am going to rush through them really quickly.

The first is this idea that we are going to improve teaching by recruiting different teachers into the profession. There is the idea that we are going to improve teaching by simply shifting who the teachers are. I think it is the strategy that gets that most attention, but also probably has the least likelihood of leading to long-term payoff.

The second strategy is improving teachers' competencies. So taking teachers who are the current population of teachers and trying to give them professional development.

The problem with this is, as teachers leave the profession and you replace them with new teachers, you keep going back to the beginning. So you never get long-term improvements over time.

The plea that I wanted to make is a strategy we haven't focused on at all, but which is to me most critical. That is, how do you improve the knowledge base for teaching over time so that not only do you improve the performance of teachers now by selecting better ones or soon by giving them professional development, but how do you develop a knowledge base that is shareable? So, that as you go 10 years from now, 20 years from now, 30 years from now, as teachers enter the profession, they are actually using a different kind of practice because it is based on a new and growing knowledge base.

I think that this is probably the strategy we should be emphasizing more right now and selection less. This is just an opinion and something to talk about.

So, in conclusion, teaching I think is the final common pathway. I believe it can be studied and improved. I think that we have to work on this problem of how to create a usable knowledge base to guide long-term sustainable improvements.

Thank you.

DR. FAULKNER: Thank you, Dr. Stigler.

Dr. LeTendre?

DR. LETENDRE: Members of the panel,

ladies and gentlemen, my name is Gerald LeTendre. Thank you for inviting me here today.

I am a professor at the Penn State University, and I am going to talk to you about TIMSS and the professional development of teachers of mathematics.

I was a member of the 1995 the Trends in Mathematics and Science Study (TIMSS) case study project and have worked analyzing the TIMSS data for the past 10 years. You can find summaries of that work in the technical notes.

I would like to thank my two colleagues who have largely set up the talk for me. I really am going to sort of embellish upon some of the points and take perhaps a little bit different view, but essentially providing much of the same message.

I am going to focus on the training, selection, and placement and professional development of math teachers. This is an area that is near and dear to my heart, as I am currently teaching 300 teachers-to-be an introduction to education at Penn State this semester.

To give you a little background context, however, the TIMSS offers researchers a very wide range of studies. We have heard about the test scores. We have heard about the video studies.

My work was on the case study project that was developed and organized by Dr. Stevenson, who should really be here giving this presentation. Dr. Stevenson passed away last year, but was a pioneer in cross-cultural studies of schooling and student achievement and organized a rather remarkable ethnographic study of schooling in the U.S., Japan, and Germany.

The case studies, which are online, are an innovative research component for the TIMSS-95 that was designed to look at the broader social context of education and educational reform. To my mind, this is an important balance to the sort of heavy media focus on test scores or horse-ranking of nations.

These kinds of studies provide detailed empirical data on the interaction of instructional practice, teacher work norms and teacher professional development, over the entire course of public schooling in these three nations.

I think, as you have already heard, and what the basic premise of my title is there's no silver bullet. You will see in the media reports about these international studies saying, well, this is the answer. Well, as you have already seen, yes, curriculum is part of the answer. Grade levels, subject matter, instruction, national cultures, national standards, preparing teachers, all of these are interrelated.

What the case studies show is that it is not one single factor. It is not something we can fix with a silver bullet that all of a sudden our children will be top in the world, as Goals 2000 wanted us to achieve, but, rather, we need to think about it as chain and weaknesses in links of the chain.

We start to improve, say, teacher training, and that shows up problems we have in curriculum. When you read the case studies, when you read that description of what it really means to be a teacher in the classroom, you begin to understand that we have to address this systematically. We can't just think of one link of the chain and fixing that and improving the whole system.

So I am going to focus on the teachers. One of the reasons I want to focus on that is that what the case studies intimated and what subsequent data have shown is the teachers we have are the ones we've got. By that, I mean that many of the teachers who are currently in the classroom now are still going to be there in 2026, when some of us, hopefully, will have retired.

Think about these data trends. I urge the panel to think about that because, if we are going to achieve long-term change in mathematics and student performance in mathematics, we have to think about, as Dr. Stigler pointed out, the teachers we have and how are we going to support these teachers in their ongoing efforts and improving their knowledge of math and math instruction.

In the TIMSS case study we have lots of evocative quotes. I picked one teacher, a relatively young mathematics teacher. She talked about the constraint that the teachers face.

This teacher's has four different grades in four years. She has another new set of curriculum books. She has responsibilities outside of instruction. But, most importantly, she feels that everyone is trying to blame her and that she really has nowhere to turn for help.

She said in the quote, and I quote from the case studies, "I don't know if this is what I should be teaching. Is it too hard for them? Is it too easy? I've never taught children this age before."

When you think about teachers, think about this conduit, this single line that all the curriculum and standards have to come through, and what goes on in the classroom. What I want to draw your attention to is that. In addition to different forms and different cultures of teaching, we have very different work roles, work patterns, and workforce problems. Again, there is no single silver bullet.

If you look here at what teachers do in each week, you will find that there's variation between the three countries in terms of instructional periods, the amount of time spent on supervising, and, indeed, the percentage of time that teachers are actually teaching in math, with, again, of course, the Japanese coming in quite high, but actually the Americans not doing too bad, the Germans coming in quite low in terms of teachers teaching outside of their field.

What I would like to argue is that we need to think about the teacher workforce. We need to address these problems of teacher attrition. We also need to address problems of distribution of qualified teachers.

What the TIMSS case study showed is that in other nations teachers are pooled at the district or regional level. There is regular rotation of teachers, which not only assures that there's more even distribution of, say, teachers of mathematics across a wider range, but that there's more interaction, professional interaction, among teachers.

When we think about teachers, we are

thinking about instructional quality, that opportunity to learn what a child gets in the classroom. I would urge the panel to think about the ways we can increase this engaging concept-based instruction that Dr. Stigler mentioned.

But to do that, we are going to have to face other problems. We are going to have to work on issues like classroom management. We are also going to have to address problems in tracking and reduce some of the dumbing-down for lower levels that we have seen.

In some of the subsequent analyses of the TIMSS that have been done, we find that this is a significant problem in the United States. If you refer to the technical paper that Dr. Akiba has done, you will see that there is a much stronger effectiveness in the U.S. than in other nations, according to her research.

One of the insights of the case studies was that there is a difference between a professional culture and professional development. Professional culture refers to this idea that teachers themselves see their profession as one of continuous learning, that they have long-term training opportunities, and that they promote sort of their own educator-initiated research on the subject and instruction.

Not only do the case studies show, but other studies have suggested that U.S. teachers have a weaker professional culture and one that does not tend to support individual efforts to improve professional knowledge as much as that of teachers in other nations.

Overall, then, U.S. teachers appear to represent a significant untapped reservoir of human capital. From the TIMSS, we know they are highly educated. They are active in in-service classes. We also have an infrastructure in the U.S. to provide professional development.

However, the working conditions, the workforce stability, appear to block efforts to maximize this potential. This is not as simple as providing another in-service session or adding another joint planning period to what teachers do. We need to systematically consider how to integrate the teachers themselves into the production and dissemination of subject-specific knowledge about how to teach the curriculum.

So, in summary, despite what the news media has said, good or bad, about the TIMSS over the last 10 years, there is no silver bullet. The single-answer solutions will not work.

What we need is more complex analysis of these data at an early stage in policy formation. We need to coordinate reforms not just of curriculum, but of standards, training, and professional development if we are to achieve long-term change.

Finally, and as I said, please remember the teachers we have now are going to be with us for many years to come. If we are to significantly improve math education or any education in any subject matter, we cannot ignore the professional development of our own teachers. We must consider how to engage teachers to continuously develop their own potential.

I would like to end with the quote of this teacher that I highlighted before. She says, "There's a pattern there. So I'm responsible. I'm supposed to send notes if a child is failing and have the parents sign them. I sent eight and none have returned them. I'm supposed to send progress reports every two weeks and keep track of homework assignments. All the tests are supposed to be signed at the bottom, but I'm responsible if all of this is not done."

We need to consider the workforce, the working conditions of our teachers, in addition to all of the things that you have heard here. I believe that the Trends in Mathematics and Science Study in its many forms and many studies offers us significant potential to learn not in a sort of rote sense what the Japanese or the Singaporese do and how we can do better, but what are the options? Where do we see areas that need to be changed, and what can we do as a nation to apply policy levers to make these changes?

Thank you very much.

DR. FAULKNER: Thank you, Dr. LeTendre.

We now go to questions and answers. Let me ask if the panel has questions, and I see that Deborah does.

DR. LOEWENBERG: Thank you to all of you for these presentations. They are incredibly important for our work.

I want to put a question to all three of you and ask you to respond. One of the things that continues to be discussed, when we talk about the improvement of mathematics education in this country, is we always end up talking about curriculum standards, accountability, but across the three of you there's some interesting themes that arise that are perennially discussed and yet never seem to rise to the level of any systematic improvement in this country. I would like you to respond to this.

So the three things I hear, among others, across all three presentations are:

One, the countries where we see high achievement among students, we see a national or common curriculum, which, therefore, leads to a kind of structure that supports teaching. I hear that particularly from the first presentation.

The second thing that I hear is that the organization of the teacher workday permits an ongoing investment in a teacher's ability to teach their students well. I hear that in more than one of your presentations. That is a second structural and critical element of what it means to be a teacher in these other countries.

And, Jim, in yours particularly, I hear something that you testified in front of the Glenn Commission, which was several years ago now, which is that investments in professional knowledge and skill, societal and culturally, could make big gains. You said that at the very beginning of the Glenn Commission work. You gave a compelling presentation that argued for that, and yet here we are several years later with all the investments having been made other directions.

So I would ask each of you to respond to these because they signal a kind of effort to make improvements in instruction that take us away from endless arguments about curriculum and move us toward what each of you in different ways has described as the key factor that influences what students have opportunities to learn and do learn.

I think this is crucially important for our work. I would like to hear each of you comment on this, about the structural ways in which teaching could be improved.

DR. MARTIN: Let me just start. I think -- and I was interested to hear Gerry say this, too -- that what we see in the countries that do well in mathematics and in science is what we sometimes think of as being coherence, that everything is organized towards a common goal. In these countries, they have national curricula, but it isn't just having a national curriculum. They have well-educated teachers who know their mathematics. They know how to teach that curriculum, not just mathematics in general, but that curriculum.

The students come to school ready to learn. Schools are safe and orderly places, and there are consequences to not learning.

So, all in all, we see this. You have to have all of these things, the system wide approach. Otherwise, if you press one spot, it just pops up somewhere else. So I think that would be the coherence and goal-oriented.

DR. STIGLER: I can pick up on that because I think standards are incredibly important for the improvement of teaching. Standards, the way they are constructed in this country, I\ is more of a political process. Experts in the domain do not construct them generally.

So you might have 48 standards for sixth grade mathematics in California. The problem is you could learn all those 48 things and not understand mathematics. Actually, there might be three of those things that are so critically important you could never go on without them.

The problem is there is no way to focus teachers on what the most important concepts are. It is a big problem.

I will just add one other thought, which is, yes, there's a lot of emphasis on teachers getting together to improve their practice. But one of the things I have noticed over the past five years or so when I have been working on a number of projects like this, is that just getting teachers together to improve practice is not enough. There needs to be a way to inject outside expertise and knowledge into that process. There needs to be a source of more ideas injected into that process. Otherwise, it is very hard to nudge a whole school's faculty, much less a nation, into adopting more effective instructional approaches.

DR. LETENDRE: I echo what our panelists said, but I would like to go back to the point that you made. It is a structural approach that we need to consider. In a country with 50 separate State Departments of Education. Some states such as Pennsylvania, deal with highly independent districts' boards of education. This is not an easy matter to achieve from a policy perspective. Stepping outside of TIMSS and thinking about, how are we going to then institute not just national curriculum and national standards, but to push forward a reform that gets teachers motivated and open and engaged in the kind of high-level professional development activities that we see in some of these countries is a major challenge.

I don't think it is insurmountable, but I think it is going to require some very concentrated and high-quality leadership at the federal level, not simply providing a kind of negative incentive, but, rather, working to coordinate probably with the largest states. It could start with looking at the professional development that is going on for teachers currently. Are we seeing here a kind of knowledge-based, expert, integrated, long-term professional development or are we simply seeing lots of different in-service classes, you know, that hit in-task standards in some vague way, and then put the teachers right back into the same conditions that they just were pulled out of?

DR. FAULKNER: Sandra Stotsky, then Valerie, and then Tom.

DR. STOTSKY: Thank you. I also appreciate all the information that all three of you provided in different ways.

One question relates to what seems to be a great emphasis on professional development and the ongoing training of teachers.

One of my interests -- and it comes from having been involved in a state department of education -- is what one does for pre-service programs, what the state authority can do to make sure that the incoming professional, before that person steps into that first classroom, and how we can assure the public that that person is going to be adequately prepared.

One of the pieces of information in the earlier presentation was that, yes, the mathematics knowledge base of the teacher is important. That is the beginning of our problems. What is the adequate knowledge base in mathematics that a new teacher should have? I don't know that we have the answer to that question. So it is then not clear to me what we do afterwards without having solved that one.

But I would like to have you address what pre-service programs or preparation of a brand-new teacher might include as implications from your studies.

DR. LETENDRE: Well, having been able to sit on the panel last night, I think one of the things that is clear is that we have to seriously consider the basic mathematics courses that our teachers are taking.

My students in Education 115 are talking about their basic math class. You saw this amount of relearning and reteaching the past to go on there.

So I think if we are going to set up a system -- and I agree with you, you can't disconnect the two; we have to think about pre-service at the same time that we think about professional development, but that is going to mean that we are going to have to address at a more systematic level what our universities do.

Of course, there is much afoot with regard to changing teacher education and going back to that. I am afraid I cannot speak as to what precisely pre-service teachers need to know in math. That is not my subject area. But what I do see is a need for a much more standardized and rigorous curriculum for these teachers. Classroom management is also an important area. We should not only teach them to be intellectually able, but I would say also emotionally and professionally able to survive the rigors of the classroom and perhaps reduce that attrition rate that we see in the first three to five years.

DR. STOTSKY: Do either of you have implications for pre-service preparation from your data?

DR. STIGLER: Not from my data.

DR. STOTSKY: Could I ask one quick question that related to Dr. Martin's presentation? It is interesting how poorly American grade eight students do. One hypothesis -- and I have no data and wondered whether you could tease out anything -- relates to the attitude toward testing that has no stakes.

For example, taking a TIMSS test in grade eight where there is no relationship to the grades they are going to get. Does this play in as a factor? I am familiar with the problems of state assessments and what happens when you finally have stakes attached at grade ten.

DR. MARTIN: Well, we don't have any direct evidence of this, but I am thinking that, if you don't know the mathematics, you can't do it, no matter how hard you try. So that this is one thing that sort of what we see is at least a lower level.

I think when you give students a test to do, they really do try to do their best. This may not be true, I think, of the twelfth grade, where it becomes more of an issue where students can just not show up.

But we don't have any evidence that students don't try in these things.

DR. STOTSKY: Okay.

DR. FAULKNER: Valerie?

DR. REYNA: This question is for Mr. Martin. I was wondering if you have ever conducted a multivariate analysis that would include all the putative factors that you discussed, as well as all the countries, to look and see which factors emerge from that as uniquely and significantly predictive, once you put them all in. Because, obviously, some of the lower-achieving countries may be scoring higher in some of these factors, and putting them all in together would allow you to -- well, you understand the implications of that.

DR. MARTIN: Lots of people have done, you know, enormous studies of this. But I think you get out of these studies what you put into it. I mean we have hundreds and hundreds and hundreds of variables, and just putting them into a big multivariate analysis doesn't really tell you anything.

I think what I tried to say earlier about coherence and basic things are really what underlie all of these studies.

DR. REYNA: Well, let me then rephrase it. What is the nature of the analysis that would allow you to lead to these conclusions about these as predictive factors? What is the nature of the data that would support that conclusion?

DR. MARTIN: I think it is from talking to all of these people and looking at all of these results and trying to make some sense of it. You can't do an analysis of all these data and have answers pop out like this. This just isn't how it works, you know.

DR. FAULKNER: We've got Tom waiting, then Vern, then Wu.

DR. LOVELESS: I wanted to thank the three presenters as well. It is really interesting stuff that you have given us today to think about.

I have a question for Dr. Stigler and the original video study. When I was teaching, you released the initial results of those studies. I was teaching an education policy course at Harvard. A member of the Administration came and stated that this study verifies that the math reforms of the 1990s are the way the United States should go.

As you know, those reforms were quite controversial. They still are. Could you comment on if that is a fair assessment of your work? Is that the conclusion you would like people to draw? If not, why?

DR. STIGLER: Well, absolutely, it's not a fair representation of our work and it is not the conclusion I would draw. I mean, first of all, in the first video study, there was only one high-achieving country. So no matter what you saw them doing in their classroom, it doesn't meant that is the only way you can produce high achievement.

And we never made that argument, but I am aware that many, many people on both sides of the so-called math wars would seize upon the work that we did and try to say that it argued for that side of the argument, but there were also people who seized on it and said it argued for the other side.

I actually think we never saw it as arguing for either side of the math wars. In fact, I think the subsequent study really bore that out because a lot of the so-called math reforms of the 1990s, it is very hard to map them onto a Japanese teaching. It is also extremely hard when you have Czech teaching and Dutch teaching and Hong Kong teaching.

So, no, I don't think that our data are relevant to that question particularly.

DR. LOVELESS: Just one follow-up: Another source of skepticism in regards to what constitutes higher-level teaching or teaching rigorous mathematics is that in many of the nations that are highest-achieving nations the teaching of basic skills is essentially offloaded. In Japan, for instance, Juku, two-thirds of eighth-graders attend school outside of school to be drilled in basic mathematics.

How does that affect your findings? Is it possible -- let me just put forth a hypothesis -- that classrooms can be, in a sense, freed up to pursue problem-solving and activities of that sort because someone else is taking care of mastering basic skills?

DR. STIGLER: Absolutely. Our study was never a study that could ever in its design have weighed the importance of various factors for improving student achievement. It really was a snapshot into classroom practice.

But it is extremely important to recognize that what happens in classrooms is part of an instructional system that includes families, schools outside of schools, and all these things work together. Schools become the way they are because the cultures that they reside in are the way they are.

So, absolutely, those things are extremely important to take into account. However, that said, I don't think we should make a lot of assumptions about what goes on inside Japanese Juku.

People are always making assumptions. When I first was studying instruction in Japan, I was studying elementary school instruction, and everybody said to me, "What you're saying, that's amazing, but it's completely different if you get to middle school." So we went to middle school, and it didn't look completely different.

So I think it is important to not assume that what they do in the Japanese Juku is drill basic skills. In fact, Gerry knows a lot about Juku. Maybe you would like to offer something.

DR. LETENDRE: I disagree a little bit with you, Tom, in the assessment that they can offload it all. For the first four years, very few children attend academic Juku. So their skill set is largely built in the classroom.

Then, as Jim says, beginning in fifth and sixth grade, you do see a lot of participation in cram school and you do see remedial. This, of course, has to be taken into account as part of a system that helps support that.

But you also see students going into these high-pressure cram schools, which are to get ahead. When we actually analyzed the effect of cram school participation around the world, we typically found that high participation in these cram schools or shadow education was associated with more lower-performing countries, where the school system was so poor, the kids had to go there. A few, like Japan or Korea, have these very highly developed, very well developed and sort of multifaceted systems of education outside to support that, but you don't see that very commonly around the world.

DR. WILLIAMS: I have a question concerning possible national curriculum. I am a middle school math teacher, and I have been teaching over 30 years. To be quite honest with you, I think I've gone through about 30 national curriculums. They are called educational fads.

My question is, do you think it is possible or do these other countries have national curriculums that are based strictly on content and not philosophy or politics? I will give you an example of what happened to us.

About 20 years ago, someone did some research on brain growth, and we were basically told that in seventh and eighth grade we weren't encouraged to teach any new material because students at that age were on a brain growth plateau and couldn't learn anything new. So we were to organize knowledge that they had accumulated for the first five or six years.

Now that, obviously, affected content. I think that is one difference between the United States and many of the high-performing countries. Yhey concentrate on content and they don't turn their educational system into a social playground, as we do.

So if we do ever come up with a national curriculum, do you think it is even remotely possible that it could be based on logic, commonsense, and content?

DR. STIGLER: No.

(Laughter.)

I don't know. I don't know a lot about that, but I would say that I think it should be. I think when people talk about a national curriculum, they are talking about how to structure the content First of all, what are the important learning goals for students, and then what is the best order and amount of time to focus on different parts of those goals, and so on?

So I think that is important, but I think there is something else that is even more important, which is that there also needs to be a mechanism in place for gathering data about how that curriculum is working and using that data to revise and improve the curriculum over time.

To me, this is something that has always been very impressive about Japan, in that they gather a lot of data, and then every 10 years they revise the course of study for a particular grade level and the textbooks for that grade level. They are constantly collecting data.

We really don't collect data relevant to our education policy in that sense. So whenever there's a new fad, it is not based on data. It is just based on, you know, somebody read some book by somebody and it was probably unfortunate. But I don't know.

DR. MARTIN: If I could observe, just to answer your question, that of all of the TIMSS countries, and there are currently about 60 of them, only the United States, Canada, and I think Australia do not have a national curriculum. Most of these countries, of course, are much smaller than the United States, but still that is the case.

The other thing about these curricula is they are almost exclusively organized around content, content goals, and content objectives. They all have some kind of philosophical introduction, of course, but, essentially, it is all about, in mathematics, content and what content should be taught, at what grade level, and sometimes in quite detailed specifications.

DR. WU: Thank you very much for very informative presentations. I have questions for Professor LeTendre and then one for Professor Stigler.

Let me begin with Professor LeTendre's statement in connection with the time, resources, and support for teachers, and you injected a note of optimism about the fact that our teachers are better educated than many of their international peers and that they engage in lots of professional development activities.

Now my personal observation and my personal experience is that such things do not warrant any kind of optimism concerning the state of our teachers because I don't know educated in what sense, in terms of what they need to teach in class, in the mathematics classroom. If they are educated in philosophy and music, it won't help. I think you have in mind that they are better educated in mathematics education or in mathematics, in the mathematics they need. I do not know that we have real evidence to the effect that teachers are better educated in mathematics for the classroom that their international peers.

Moreover, the professional activities, I have almost detected no trace of serious professional development that encouraged the acquisition of the mathematical knowledge that they desperately need for most of the teachers. Am I correct in my supplementary observation about your comment?

DR. LETENDRE: Yes, the optimism is that, in general, I mean we have educated teachers. More of our teachers have a Master of Arts (MA) than many of the teachers around the world. Again, I am not just comparing us to Singapore and Japan. As an internationalist, I compare us to a wide range of nations.

But I would say that that is optimism for the future. I think your assessment is quite fair. I mean there has been a great deal of studies to show that the basic knowledge about mathematics -- and I think Dr. Ma's book is a very nice example of that -- is quite sadly lacking.

The optimism is that, compared to many nations, we have the structures. Can we use them? Can we change them, so that there are higher levels of mathematics education, so that there is very high-quality professional development? Well, I am going to continue to be optimistic. I think that if we have the political will to do that, it can be done.

DR. WU: Thank you. I guess we agree on the perception that the structure is there, but our perception of what is in there is a little different. I think we are at ground zero and a total vacuum..

So let me change my line of questions here and ask you several.

DR. FAULKNER: Wait, wait.

DR. WU: One more.

DR. FAULKNER: Oh, one more.

(Laughter.)

Yes, we've got actually three more people ready to ask and we've got only a few more minutes left in the session.

DR. WU: Okay. So I guess let me take this one. Actually, I would like to know more about the Algebra Learning for All (ALFA) project.

But you said that you have no evidence that teacher content knowledge alone produces more students learning. How is that measurement made? What is the definition of content knowledge, and how do you measure student learning? Three questions. Sorry.

(Laughter.)

DR. STIGLER: Wu, I would be happy to share a manuscript paper that has a lot of details on that. But, basically, that was within the context of our study. We measured teachers' content knowledge using the scale developed by Heather Hill and Deborah Ball, the pedagogical content knowledge.

I know in some studies that relates to student outcomes. In our study it did not.

Student outcomes we measured in three ways: high-stakes assessments for California, district quarterly benchmark assessments, and some performance assessments intended to get at the core concepts we were focused on, which was fractions, ratio and proportions.

DR. WU: Sorry. I just have a quick question.

But what puzzles me is are you saying that the teachers who achieve on that test that Deborah's company made up, if they score well on that test, somehow over time the students do not learn more? What is this thinking about the time?

DR. STIGLER: Well, we're looking at how much students gain over the sixth grade year with a teacher who had a certain amount of content knowledge. Wu, this is just one study, and it is teachers who are at the very bottom of the distribution.

I think the important point I wanted to make is that, if teachers don't have any content knowledge, if you give them professional development focused on pedagogy, it doesn't seem to help the students very much because they are not able to figure out how to use a new pedagogy if they don't have the content knowledge.

But if they do have the content knowledge, that alone also doesn't help students learn more. But if you have teachers with higher content knowledge, and you give them some new ideas to help them do something different in their classroom, because most teachers just do the same thing, then you can get measurable effects on student achievement.

DR. WU: So I just want to make sure that that first conclusion is carefully qualified because, as it stands, it seems to be a generic statement. Content knowledge alone doesn't produce the learning.

DR. STIGLER: Right, in our study.

DR. WU: Yes, yes. It is a very special teacher population.

DR. STIGLER: Right. And I know other studies where it does. So it is not that we are just waiting for them to happen.

DR. FAULKNER: Then Skip, then Sandra, and then we stop.

DR. SIEGLER: I would like to ask all three of you a question that was elicited by a point that Jim Stigler made. This has to do with the intervening variable of engagement in rigorous mathematics. Jim has talked explicitly and in various degrees of explicitness, and for many of the people who have testified, this is identified as the key factor.

If each of you could do one thing to promote engagement with rigorous mathematical content for more students, what would you do?

DR. MARTIN: I don't know. I think you need to have teachers who can teach mathematics, who know mathematics and can teach mathematics. I think there is a gap there compared to the high-achieving countries.

DR. STIGLER: I think two things need to happen. First of all, I think there needs to be a way to communicate what that means and what it looks like. I think it is very rare to see that kind of engagement in mathematics concepts. So many teachers aren't familiar with what it would look like. That is the first thing.

Then the second thing is, once teachers have a sense of what that looks like, create a setting where they can work together on trying to figure out how to achieve that in their classrooms with their students.

DR. SIEGLER: How would you do that?

DR. STIGLER: That is a long answer, but I think we know a lot about how to, first of all, create stable settings. It is a lot of information. I would be happy to share that with you and the panel later.

But create a time and place where teachers can regularly meet and work 100 percent on improving instruction. There is a big interest now in professional learning communities. Many schools are getting teachers together to collaborate.

What we see when we actually go and look at these programs is that most of the teachers don't know how to use that time effectively. So it would be helpful to direct training of teachers in how to use that kind of collaborative time effectively. I strongly believe that the teachers have to be part of that solution. Because, as I implied in my slide, how you get students to do that is going to vary a lot depending on who the students are and what their previous background in mathematics and other subjects is.

I am increasingly skeptical that you are going to find a set of, quote, "best practices," that if you just train people to do those things, it will lead students to be engaged in mathematics. I don't think it is that simple.

DR. LETENDRE: I would just like to echo Dr. Stigler's points, but point to you, in the technical notes, I gave you Yad Gair's paper. This is not a mathematics problem. Gair found in his study that teachers secured students' attention less than 50 percent of the time at high school across a wide range of subjects. So it is something that we are going to have to address more systematically, and I think Dr. Stigler has well outlined at least the beginnings of how we go to address it.

DR. FAULKNER: Skip?

DR. FENNELL: I would like to follow up with Dr. Stigler on the engagement factor. Have you found anything relative to the setup, the prior knowledge, what it is that teachers who are effective in engaging students do to get them engaged? That is the first part.

Then the second part, because we use the language "engaging students with rigorous mathematics," could you talk a little bit about what rigorous means, just the sense of that? Then, similarly, you talk about rich problems. Tell us a little bit about what you mean in terms of the context for such a statement. That is really three different issues, Jim.

DR. STIGLER: Yes, and, fortunately, you

are going to hear a presentation by Jim Hiebert today.

DR. FENNELL: You keep saying that. You are putting a lot of pressure on Dr. Hiebert.

DR. STIGLER: I know.

(Laughter.)

But just to give you one example of what I think it takes on the teacher's part, if you look at math textbooks, they have a chapter on proportions, and then they have a chapter later on linear function, and they are never connected. To me, it takes a teacher who can point out to the students, that these are actually the same thing. They are just different ways of representing the same mathematical idea.

If the teacher is able to help students connect those topics together, then their knowledge of mathematics becomes more coherent and it is, actually, frankly, much easier for students to learn if they see two previously difficult topics as examples of similar underlying concepts.

So I think that is what it takes. I think I would just like to leave the rest for Jim Hiebert because I know there is a lot of time pressure also, but he is going to talk a lot about that, he told me.

(Laughter.)

DR. FAULKNER: Okay, Sandra, quick.

DR. STOTSKY: Okay, this is for Dr.

Stigler. It comes out of a conversation with a local school committee person who is very highly educated. He told me, in reference to the TIMSS study, that as a group, the school committee had learned from a TIMSS presentation that, indeed, Japanese teachers did not explain, did not lecture. Students dealt with problem solving on their own, constructed their own solutions, and only then did the teacher come in to do anything. They worked only in small groups.

I tried to point out that it wasn't clear that this was necessarily what one should have drawn as the conclusions. I just wanted to clarify, from what you have said, that, indeed, those were not the conclusions necessarily from your study.

But here we have other school committee people because I suspect that this was done at a larger meeting or conference. How does one in some way convey that these are not the conclusions of the TIMSS study, that, indeed, Japanese teachers do a variety of things but they may do actually very opposite, which we seem to see here. That is, they may begin with more lecturing, and so forth.

So how does this misinformation that has somehow been conveyed become clarified? Where is the responsibility for clarifying that with key policymakers? These are going to be the people who make decisions at local levels all over this country.

DR. STIGLER: Well, that is a very difficult question: Where is the responsibility? Maybe you are implying that it is our responsibility. We do explain our findings.

The problem is our findings don't fit anyone's point of view. So they have been used to argue both sides.

It is true that Japanese, in our first study, spent more time on student cooperative group work and students sharing solution methods, but the teachers also spent more time lecturing. The problem is we don't have a vision of instruction that includes both of those things simultaneously, and in Japan they do.

So different people pick out the part. I don't think it is a bad thing. I think the solution is to get the focus back on the actual video examples. Those are the discussions I have found most rewarding, is when people write articles or come to discussions not with just their point of view. Discussions such as “Well, I disagree.” or “That's what I think it found, but let's go back and look at some of these videos and tell me what you see, and I will tell you what I see.” Those have been very productive discussions.

I think that is the way we get past a lot of these disagreements, which is to not focus on ideology, but to focus on instruction. As soon as you sit down with someone, you find out there aren't as many disagreements, because you look at an actual lesson, and you tend to agree, this is high-quality, or I like this part of it; I don't like that. It gets down to what is actually happening.

DR. WU: A very short comment: Jim, in terms of responsibility -- sorry to tell you this -- this has, in fact, bothered me quite a bit for a long time. In your 1995, you know, the videotape, not the CD but the videotape, in the introduction you did say something about how Japanese teachers allow the students to discover mathematics, mathematics they had not been taught. I don't have the quote in front of me, but do you vaguely remember in that introduction you make statements to that effect?

I think many people are going to seize on that literally and so are having more a point of view of what you are now presenting. So I think that could have been one source for the misrepresentation.

DR. FAULKNER: You get the last word, Dr. Stigler, and then we're stopping.

DR. STIGLER: Well, the last word is, whenever anyone asks me if they can videotape my presentation, I always say, sure, and then they always come back and quote me, even 11 years later, and they don't even remember the exact quote.

But, anyway, I think that a lot of it is about definition of terms. Someone wrote an article about, are the students in this public Japanese lesson actually presenting different solution methods? This was a mathematician. He said, "These aren't different methods. These are the same method."

But, from our point of view, if you look at it from the student's point of view, often what looked like the same method to a mathematician looks very different to a student. So a lot of this is jut about words, and there's not going to be a single quote or conversation that resolves these issues.

So thank you.

DR. FAULKNER: Okay, we need to stop this session.

I do want to say that I was supposed to have said earlier: This session is being video recorded. If anyone has an objection to being video recorded, please excuse yourself now."

(Laughter.)

We will take a break here, not a break where everybody can get up. We are going to change the people in the front of the table or the front of the room here. We are going into the next session.

Thank you for the presentation.

(Applause.)

(Pause.)

DR. FAULKNER: We are ready to proceed with the session on National Assessment and Educational Progress (NAEP). I would like to ask that the presenters for the NAEP please take their place.

(Pause.)

We are going to go ahead and proceed to the NAEP session. The morning break does not come until after this. So let me ask that people please take their places.

The next session is on the National Assessment of Educational Progress, NAEP, "Our Nation's Report Card." I would like to once again acknowledge Tom Loveless, Bob Siegler, and Skip Fennell for their assistance in planning the session.

There are materials under Tab 9 for the panel in the panel's notebooks.

We are going to have two 15-minute presentations and 30 minutes of questions and answers. The presentations will be given by Sharif Shakrani, Co-Director of the Education Policy Center at the University of Michigan, and by James Milgram, Professor of Mathematics, Emeritus, at Stanford.

Let me invite Dr. Shakrani to proceed.

DR. SHAKRANI: Good morning. Thank you.

Just one correction I want to make because Deborah is here: I am from Michigan State University, not from the University of Michigan.

DR. FAULKNER: I just read what they put in front of me.

(Laughter.)

DR. SHAKRANI: I am honored to be here with you today. I am a Professor of Measurement and Quantitative Methods at Michigan State University. I am recent in my position. Prior to that, I was the Deputy Executive Director for the National Assessment Governing Board. Prior to that, I was the Director for Analysis at the National Center for Education Statistics. During that period, I worked on the National Assessment of Educational Progress.

The National Assessment of Educational Progress (NAEP), "The Nation's Report Card," is the oldest assessment in the nation. It is, in fact, the only assessment that gives us information about what students at the elementary, middle, and secondary school levels know and can do in mathematics, science, reading, writing, and other subject areas.

The National Assessment of Educational Progress (NAEP) started in 1969. The Mathematics

Assessment started in 1973.

NAEP has two assessments. One is called the Long-Term Trend, which started in the seventies, which maintained the same assessment. So they maintained the same measure, and we just compare the performance of students from one testing cycle to the next.

The second type of NAEP assessment is called the Main NAEP Assessment, which changes every 10 years or so. This measures the same subject areas, but the assessment changed to reflect new knowledge of the field, and, thus, the assessment changes accordingly.

NAEP is administered at the national level through sampling procedures, as well as at the state level and for the largest 10 school districts in the nation. Since the inception of the No Child Left Behind, all states in the country, as well as Washington, D.C., and Puerto Rico, participate in the NAEP assessment in the areas of mathematics and reading in grades four and eight.

As I said, NAEP is a sample assessment. So we do not produce any individual results, but we produce aggregate results at the national and at the state level and for the district. We also subaggregate the results by producing information for students by race, ethnicity, gender, economic conditions, and geographic areas across the nation.

The National Assessment of Educational Progress (NAEP) and the Trends in Mathematics and Science Study (TIMSS) also, which measure a sample, differ significantly in that TIMSS is normative in nature by allowing us to compare the performance of American students in relationship to other countries. NAEP is a standard-based assessment to tell us how our students are doing in relationship to a pre-defined set of standards of what students should know and be able to do.

The National Assessment Governing Board is composed of 26 members appointed by the Secretary of Education. They are reflective of our society in that they have two of everything, what in Washington is referred to as Noah's ark. They have two Governors, two State Chiefs, two legislators, two elementary school teachers, curriculum specialists, business representative, and so on.

Congress intended for NAEP, for the National Assessment Governing Board, to define what students know and can do and, thus, be a national input rather than a federal input. They did not want to note any national curriculum developed by the federal government. So NAGB, the National Assessment

Governing Board, has the responsibilities for developing what students ought to know and be able to do in the various subject areas at the key grades of four, eight, and twelve. The National Center for Educational Statistics has the responsibilities of translating these skills into an assessment that is administered periodically through a sample of students at these three grade levels.

The mathematics, reading, and science, as well as writing, is administered at the national and at the state levels. The reports are produced on a biennial basis for the states that participate in these assessments.

It is very important to remember that NAEP tells us where we are in relationship to these standards. These standards are, in essence, reflective of what is presently being taught to our students as well as what students should know and be able to do. So the information is very relevant to where we think we should go.

I have given each one of you the copies of what I have on the boards, but I added a couple of overheads that I am going to explain a little bit about in a minute.

But here are the results for the National Assessment for Educational Progress since the beginning of the seventies for students ages 9, 13, and 17. Age 9 students are the model age for grade four. Age 13 is the model age for grade eight, and age 17 is the model age for grade eleven. As you can see, we have seen a slight improvement in mathematics knowledge for students at grades four and eight, not so at grade twelve.

If you look at the second and third page of the material that I gave you, you will see the same thing reflected in the main NAEP. This is one that the states participate in. So it is very similar to the graph that I have on the board.

So, as you can see, we are moving rather well for grades four and eight, but not so on grade twelve, which is an area of concern to all of us. I will talk some more about it in a minute.

The framework for NAEP measures students' knowledge and ability in the various subjects of mathematics. As you can see, at the fourth grade level the major emphasis is on number properties and operation, but we also include some information about subjects like algebra, data analysis, and probability, but to a much smaller extent.

As the students move to grades eight and twelve, the proportion of materials that measure algebra, geometry increases significantly. Presently, the National Assessment Governing Board has made a significant change in the assessment at the grade twelve level, where the proportion of items that measure of algebra have jumped from 25 to 35 percent of the items. This is reflective of what the institutions of higher education say that students ought to know and be able to do in order to move efficiently in their postsecondary education. Algebra is necessary knowledge in order for students to be able to take credit-bearing courses in our institutions of higher learning, whether it is a two- or four-year colleges or universities.

One of the points in here is that over the last two years the National Assessment Governing Board has been reviewing very carefully what our students know and can do at the high school level, because, as I have pointed out, this is one area of concern to us. What we have determined is that there is a disconnect between the expectations of tests that would allow students to go to postsecondary education, such as the SAT or the ACT, and what colleges and universities expect students to know and be able to do. These are the placement tests.

Based on the placement tests that they take, we see a significant percentage of students who enter our colleges and universities end up in remedial courses. Our analysis of these tests indicated that it is algebra that seems to be the Achilles' heels of what students know and can do, especially the more rigorous algebra and geometry concepts that students are supposed to know.

So the new assessment at grade twelve that will take effect in 2009 will be reflective of a major change in twelfth grade testing. In our analysis of what other states are doing, we see many states, including my own State of Michigan, are moving to the direction of ensuring that students at the high school level are taking more rigorous courses in mathematics.

From my perspective, the most important point is not the courses, but how many students take these courses. In the State of Michigan, for example, as well as in other states, students that come from disadvantaged economic schools and disadvantaged minority students tend to lack knowledge and skills in the more rigorous mathematics that would propel them in postsecondary education, especially in relationship to courses such as algebra II or a more rigorous geometry.

This is a major concern to us. We would like to see a significant shift in terms of the proportion of students involved in these rigorous mathematics courses at the secondary level, so that they can move in their postsecondary education in an efficient manner.

I have some examples of items. These are actual NAEP items. It may surprise you to look at the results.

For example, do the students understand the idea of adding positive and negative numbers? At grade eight, only 68 percent of the students can answer the simple item correct. In grade four, only 23 percent.

Here is another item that is rather simple, to determine what is two-thirds of 15 marbles. This item is administered at both grade twelve and eight. Only 74 percent of twelfth graders are able to answer this item correct, and approximately 50 percent of the students at the grade eight are able to answer this item correct.

This is an item that was administered at the grade twelve over the past three assessment cycles. It is an application of a simple division. Yet, we see no significant shift or any change in the proportion of students that are able to answer a simple item correct.

I also included in my document some examples of what the students ought to know and be able to do at different grades and different context.

This is from the NAEP framework that was developed and approved by the National Assessment and formed the basis for testing at those three grade levels.

A more important one is what is being proposed for the twelfth grade. What you have here in the bold letters are the new mathematics knowledge that we expect students to know and be able to do. These are reflective of discussion with many educators, mathematicians, mathematics educators from across the country, and with states who are working on improving their mathematics program.

I will not go over these at length, but I think that you can see that the need for more rigor in mathematics at the high school level is essential. In most states, we recognize that the great diversity in the course-taking patterns of students is very much related to how well they do on the NAEP assessment at the twelfth grade level.

In the United States, there are very, very few tests that tell us what students know and can do at the end of the twelfth grade, NAEP being one of them.

An interesting study that NAEP conducted is called the Transcript Study, which is from the national sample of students who are tested at the twelfth grade. We looked at the course-taking patterns of these students over the past five years of their education. What we find is that students that start with a rigorous mathematics not at the high school level, but rather at the middle school level, students, for example, who take algebra at the eighth grade level, tend to perform highest on the NAEP. Because they end up taking algebra at the middle school, they take geometry, algebra II, trigonometry or pre-calculus or a course in statistics probability prior to graduation, and they do extremely well not only on NAEP, but in other courses as well.

Another thing that -- yes, please?

DR. FAULKNER: You're within a minute of your total time.

DR. SHAKRANI: That is fine.

The other thing that we want to point out is that the relationship of course taking to the NAEP achievement is not only relevant to NAEP, but that is the case with the ACT and the SAT.

So, in conclusion, I would implore you to look very carefully at the mathematics education program at our high schools to ensure not only that the rigor is improved, but also to ensure that students do not waste their twelfth grade in what was referred to as the senioritis problems. Our analysis indicates that the students who have not taken mathematics during their twelfth grade, they are the ones who tend to get the problem with the placement tests at the college and end up in remedial courses. Students who end up in remedial courses, their chances of ever graduating are decreased significantly.

Thank you.

DR. FAULKNER: Thank you, Dr. Shakrani.

I might clarify that the charge to this panel is to look at the mathematics and teaching that is necessary to get kids ready for algebra and success in algebra. We are not charged with the high school curriculum per se. So our look is a little earlier than the one that you ended your comments on.

Dr. Milgram?

DR. MILGRAM: Well, I am very pleased to be here, and as the only representative of Stanford who is testifying, I would like to welcome you to Stanford. We are delighted to have you here.

So what I want to talk to you about, rather than the structure of the National Assessment of Educational Progress (NAEP), are the problems with the NAEP. After all, the NAEP is our, in effect, national report card. It had better be a rock-solid test that gives us data that we can actually sensibly evaluate and is meaningful. As far as we can tell, as I will go through this, there are severe problems in all of these areas.

First of all, the NAEP is unfocused. I will make this clear at the end of my lecture, but will start in just a minute. I want to get the three things here.

There are far too many mathematical errors in the NAEP. This is, as we will see, genuinely appalling.

The level of the exam is far below the levels in high-achieving countries, which is really not anything we don't expect, given what we have heard already.

So let's look at the NAEP, the focus of the NAEP. Now here's a list of fourth grade standards, the numbers of them and the distribution of them, in a number of the states in this country. The most important thing is the right hand column, where you see 42, 32, 56, 89, which is an outlier, 48, et cetera. These are the rough number of standards in each of these states that relate to the mathematics that is going to be in the fourth grade.

Now here's the data for the NAEP. In fourth grade, there are 70, in eighth grade, 115, and in twelfth grade, 110. That is well up in the number of topics that are covered by a very finite length exam.

So let's now discuss the quality of the NAEP problems. So last year, Brookings Institute asked Roger Howe, Hy Bass, and me to review the algebra questions on the NAEP. To do that, they provided us with a group of questions that they had selected from NAEP questions, and I don't know if these were on the NAEP or simply questions that were in the list of questions that were available to NAEP.

But, in any case, they gave us these questions to look at, and here was what at least I found. Of the 41 eighth grade NAEP algebra problems, eight of them were mathematically incorrect and one was simply meaningless.

Moreover, about ten of the correct problems were just questions about vocabulary, not questions about mathematics. By that, I mean a question of the following nature: Identify in the following group of figures the square. That is what we would call a vocabulary question. It is certainly not a mathematics question.

Notice that eight out of forty-one is roughly 20 percent as an error rate, and that is very consistent across NAEP and across the state assessments that we have evaluated.

So in the fourth grade, there were 22 questions provided. Four were incorrect and four others were essentially vocabulary, but the most striking thing was the low level of these problems. Only one of them could be judged even mildly challenging at the fourth grade level. Again, four out of twenty-two, which is roughly 20 percent. It is a very consistent error rate.

Now I am going to show some problems here, and I have to do this. After all, I am a mathematician, an academic mathematician. So I just have to go and discuss these problems.

So here is a problem. I see that I can't even read it from here. So let me read it to you. This is one of the problems that were given to us. This is actually the comment section that I gave back to Brookings.

"A pattern of dots is shown below. At each step, more dots are added to the pattern. The number of dots added at each step is more than the number added at the previous step. The pattern continues indefinitely."

So you see this pattern. There are two dots. Then there are six dots. Then there are twelve dots. So here's the problem: "Marcy has to determine the number of dots at the 20th step, but she does not want to draw all 20 pictures and then count the dots. Explain or show how she could do this and give the answer that Marcy should get for the number of dots."

Actually, this is a well-known question. The correct answer for this question is any number greater than or equal to 267. The chances of an eighth grade kid getting the correct answer are maybe one in 10,000. The expected answer is 21 times 20, which is 420.

Now why is any number greater than or equal to 267 correct? Well, because what you are given is not that you are counting the number of dots in a rectangular array where the array grows by one in both the vertical and horizontal direction. What you are given is that at each step the number of dots added at each step is more than the number added at the previous step. That is all you are given. The fact that the numbers two, six, and twelve are represented in the array is completely extraneous to what you are given.

Now if you work from what you are given, then, you see, at the next stage you have to add at least seven. At the stage after that, you have to add at least eight, because the only thing you are given is you have to add more. So that gives you a lower bound of 267, but nothing ever said you have to add exactly the minimum. You could add any number you want.

As a consequence, you can get any number greater than 267. Now this is absolutely typical of the lack of precision that goes on in current mathematics instruction in this country.

So here is another problem, and I will do this at two levels. Again, the problem reads:

"If the pattern shown in the table were continued, what number would appear in the box at the bottom of column B next to 14?"

Well, you see, there is no rule given whatsoever now for this pattern. So the answer is really very simple: Anything you want to put there is legitimate.

But there is a hidden assumption in problems of this kind; namely, that the answer is a polynomial. So you look at the two; you see a five. You look at the four; you see a nine. You look at the six; you see a thirteen, and you look at the eight and see a seventeen.

The smallest polynomial that fits that data is a linear polynomial of the form one plus two "N". Therefore, the answer that they believe is correct is for 14 you should have 29.

Now, of course, this problem is representative of another of the problems with the exam questions in this country, namely, the prevalence of hidden assumptions. So not only is the problem on its face nonsense, but the correct answer depends on a subtle hidden assumption, namely, a minimal polynomial answer. A higher degree polynomial would produce anything you wanted in that position.

Now this comes to a head in the next problem, which we like. We call it the "puppy problem." I have just commented on this problem simply: "The problem is not well-posed. It shows all of the problems that the previous had."

But Hy Bass noticed a little more about it than I did. So he noticed that, well, yes, it is not well posed. So I should read the problem for you.

"John records the weight of his puppy every month in a chart like the one shown above. If the pattern of the puppy's weight gain continues, how many pounds will the puppy weigh at five months?"

So, of course, the answer is anything you want because you are not given any rule or any data, but, again, we know the hidden assumption is that you fit the data given to the smallest polynomial, and the smallest polynomial is quadratic. For this quadratic polynomial, the answer would be at five months the weight would be 24 pounds.

But the way we see that is from 10 to 15, the difference is 5; from 15 to 19, it is 4; from 19 to 22, it is 3. So your first difference decrease by one. The second difference is minus one, which is a constant. Therefore, it is a quadratic, which is a parabola opening down.

Well, now what happens at six months? Well, it hits 25. What happens at seven months? The puppy loses a pound. What happens at eight months? The puppy loses two pounds.

The correct question should have been, "When does the puppy disappear?"

(Laughter.)

Enough said.

All right, in general, this was a beautiful thing that was given to me by a high school teacher. What's wrong with patterns?

"After explaining to his students through various lessons and examples that the limit as "X" goes to infinity as "X" goes to 8 -- of 1 over "X" minus 8 is infinity, I tried to check if she really understood that. So I gave her a different example. This was the result.

(Laughter.)

Okay. So this is something that mathematicians don't like. It is not mathematics, and there is way too much of it.

But that is only one of the three

problems. Let's look at a basic problem here of topic, subject matter itself. Very little attention is paid to basic operation and essentially none to skills with fractions.

Specifically, there are very few fraction standards at all in grade eight. There are none in grade four. But here are two of them:

"Provide a mathematical argument to explain operations with two or more fractions and interpret rational number operations and the relationships between them."

Well, both of them are vague. The second one I could make sense of. The first one, I literally do not know what it means.

There is no mathematical argument to explain operations with two or more fractions. If you mean add or subtract, multiply or divide, the only thing you can do is define what they mean.

Then you can justify the definitions by showing how they work in specific cases and models for fractions, but you cannot. There is no mathematical argument to explain why you did this. It is just not a mathematical argument. This is, again, typical of the level we are dealing with.

Now here is a classic example of totally vague. There is exactly one grade eight standard that asks for operations with integers or fractions.

"Perform computations with rational numbers." Well, these standards are supposed to guide an exam. How do you guide an exam with "Perform computations with rational numbers"?

Okay, so the question we have to ask ourselves is, when the report card is flawed, what do the grades mean? All that this tracks back to a refusal to involve real math experts in test development. Now I will get a little personal.

A few mathematicians, including the two mathematicians on this distinguished panel, have been members of the NAGB, but were not even allowed to access the exams. As far as I know, and judging by the type of problems we have seen, there was no professional mathematician input into the collection and selection of these problems.

So the thing you want to think about also is in the numbers I gave you earlier, where I showed you 70, 115, and 110 standards, compare that to what goes on in the focal topics and what goes on in foreign countries. In foreign countries and in the focal topics, there are six basic subjects that are emphasized through grade eight: 1) place value and basic number skills, 2) fractions and decimals, 3) ratios, rates, percents, and proportions, 4) functions and equations, 5) beginning algebra, 6) measurement and geometry. That is it.

And the test should, likewise, be focused in just this way. It is inexcusable, the kind of all-over-the-place stuff that goes on there.

Now I had put in a bunch of slides showing how the focal points just focus on these six topics, but you have already had some discussions of the focal points, so I will skip that. I will simply say that the process of constructing the NAEP has to be improved. At a minimum, experts in both math and math education have to be involved in test construction and validation, but even more is needed, as we have indicated.

The sooner there are new NAEP standards, the better.

Thank you.

DR. FAULKNER: All right, now we will proceed to questions and answers.

Tom?

DR. LOVELESS: I have two questions for Sharif and appreciate both of you testifying today and giving us information on this test.

Sharif, I know you were around from the inception of the main NAEP. As you know, I have done quite a bit of research of my own on the content of the main NAEP.

I am going to ask two questions, one about fractions and one about computation skills. In terms of fractions, there was a Department of Ed study that compared the main NAEP to TIMSS and looked at the percentage of fractions items at grade eight. If I recall, the percentage of items on the grade eight test was only 17 percent on NAEP.

The test is truly dominated by whole numbers. Now those whole numbers may be placed in the context of a problem, but, nevertheless, do you think the NAEP at eighth grade does a good job of assessing student competency with fractions?

DR. SHAKRANI: I think it does. I think that for NAEP to be both reflective and lead, we must make sure that the type of knowledge that we test the students on is something that we know they are taught. So we need to be reflective of what is being taught to find out whether they learned what they were taught.

The test would not be valid if it was measuring something that was not taught to the students. So from the perspective of, when you are working with a limited number of items that you can assess, you want to be reflective of what the framework says that there is in there.

Now I know, Tom, that you feel that we

need to have more computational skills on the assessment, both in terms of whole numbers and fractions. I think, to a degree, the mathematics educators and the mathematicians, especially at the elementary and middle school level, they are also asking us whether the students can apply these skills into a practical situation and to make relevance.

So it is essential not only to ask procedural knowledge, but also to measure conceptual understanding. My contention is that fractions are tested not only on procedural knowledge, whether the students know the algorithm involved in adding proper fractions, but whether they can apply the conceptual understanding into problem-solving.

So if we increase the number of items in this area significantly, then we are taking from other areas that are maybe essential for us to know how well students are doing on them.

DR. LOVELESS: So you are comfortable with a fractions/whole number split in terms of the divisional labor on the eighth grade test of, I believe it's 17 percent fractions, 83 percent whole numbers? You are comfortable with that as far as assessing students' ability to work with fractions?

DR. SHAKRANI: I am comfortable if you look not only at the procedural knowledge, but also to look at the students' ability to apply fractions into a problem-solving situation. If you look at the problem-solving aspects of NAEP, in solving the problem, the students apply skills in adding, subtracting, dividing, and multiplying fractions. So fractions are also included in that part as well.

I would not be very comfortable of adding more into the procedural knowledge in fractions or with the whole number system if it is going to take away from something else that it is essential for us to know.

DR. LOVELESS: Yes, well, I am just focusing on fractions right now.

DR. SHAKRANI: Right.

DR. LOVELESS: To get to computation. Are there any computation items? What I am addressing here is the sort of public concern about when they go to a fast food restaurant and the power is out and they can't get change back. Are there any items on the main NAEP that strictly assess the ability to compute?

DR. SHAKRANI: I contend yes. In fact, some of the items that I showed you -- for example, the student should be able to compute what is two-thirds of 15 -- is a computational item.

There are also computational items at the fourth grade level that are strictly asking the students to be able to add a column of numbers. There are also some conceptual understanding problems, whether the students can understand, if they buy two pairs of socks and each one costs $3.75, how much would they get back from $20. So they have to apply these skills.

DR. LOVELESS: No, I understand that. They have to be able to compute to answer those, and I will stop here. But that is not what I am asking.

Is there anywhere on the main NAEP a problem such as this: Eight and two-thirds times three and one-fourth?

DR. SHAKRANI: Yes, there are. That is a proper fraction. Not only are there computational problems like this, but there are also computational problems in understanding the concept of converting eight and two-thirds into a proper fraction in order to do addition.

DR. LOVELESS: I will just stop with one comment. I have never seen a strict computation item from the NAEP.

DR. SHAKRANI: Well, I will be glad to share with you in private.

DR. LOVELESS: Great.

DR. SHAKRANI: They are secured items, but

I can show you where they are.

In fact, if you would not mind, if you go to the website there is something called the test specification document that translates the general statement that you saw in here that Dr. Milgram referred to into specific skills and knowledge that will help inform the item writers write the items.

These documents are available on the website, on the NAGB website, www.nagb.org. That would show you examples of the computational item that you are talking about.

Tom, I am sure we can arrange for you to see the secure items that would address that particular area. I would be happy to share with you which booklet these items are in for the present eighth grade assessment.

DR. LOVELESS: Thank you.

DR. FAULKNER: Wu?

DR. WU: Hi, Professor Shakrani. I would like to address one very specific issue.

The year 2000 NAEP Steering Committee secured a written commitment from NAEP to increase the computational items. In fact, I heard you lecture to other groups saying that NAEP had been asked to increase those items. Now that doesn't square off with what Professor Jim Milgram has just said about the absence and also what Tom just said.

I was quite taken back because I thought, with that written agreement, the number of fractions, computational fractions items, would significantly increase. So there seems to be some discrepancy in the facts of that commitment.

DR. SHAKRANI: The 2005 assessment that was released not a long time ago, which is the latest assessment, there was emphasis in concert with the agreement to increase the computational items at the fourth and eighth grade level.

This, I want to say, was due to the study that Dr. Loveless released not a long time before that. Because in our analysis of the NAEP assessment, we could not discern why students, for example, at the eighth grade were not able to do some of the problem-solving questions. We needed to find out, was it because of their lack of knowledge in the number system?

So in the 2005, almost 60 percent of the items that were released and were replaced were replaced with computational items. That is in concert with the agreement that we made to the Planning and Steering Committee.

DR. WU: But this is about the year 2005?

DR. SHAKRANI: Right that is the last

assessment.

DR. WU: Yes, but the agreement was made in the year 2000.

DR. SHAKRANI: Right.

DR. WU: So what happened in the five years in between?

DR. SHAKRANI: Well, because the assessment is done every two years, and the assessment before the 2005 was in 2003, and it takes time from the time you develop the items to do the field testing. So it was too late to include it in the 2003. So the first opportunity is the 2005.

DR. WU: So that means we expect to have more computational fraction items in the year 2007?

DR. SHAKRANI: Indeed, yes. That is why I was secure in answering Dr. Loveless that I will give him examples of fractions and computational items from the 2005.

DR. LOVELESS: And just to clarify, I have not studied any items that have been developed after 2003.

DR. FAULKNER: Sandra?

DR. STOTSKY: A quick question to Dr. Shakrani: This is a question about the membership of these various committees that guide the National Assessment of Educational Progress (NAEP) assessments, the Steering Committee, Planning Committee, and then the Specs Committees as well.

I was on the Reading Revision Assessment Committee on the Steering Committee, and noted there, too, that we had very few, if any, literary scholars as part of the membership of that Committee to give input on literature items. I constantly raised this as a concern.

We have the problem of few mathematicians that have been part of apparently the guiding committees for the NAEP assessments and also on the Test Specs Committees possibly, who are looking at the items or helping to construct them.

Who determines the membership? Where do the guidelines come from? The bottom-line question is: How do we get for all of the NAEP assessments in all of the areas beyond math and reading the scholars, the experts in the disciplines, as well as test assessment people, as well as educators in that particular area?

But we somehow seem to be missing those content experts in at least these two areas.

DR. SHAKRANI: Thank you.

The National Assessment Governing Board is responsible for the identification of the people who work on the Planning and Steering Committee. The congressional mandate states that the people who develop the assessment, the framework, must include people in the field as well as people from the general public, a proportion of them from the general public.

The National Assessment Governing Board, which is in charge for development of the framework, issued the RFP. Usually it is national organizations such as the Council of Chief State School Officers or some other organization that is in that field, such as the National Geographic Society for geography, that proposes a list of people from different disciplines. In the area of mathematics, we insist that there be mathematicians, mathematics educators, practitioners, as well as users of mathematics, people from industry.

The Board reviews these names to make sure that we have geographic coverage, we have ethnic, racial, and gender coverage, as required by law, and then makes some changes with that.

The list of these people in each subject area is pointed out in the documents themselves, both who work on the Steering Committee and on the Planning Committee.

So I would contend, if you look at the framework for mathematics, you will find mathematicians, you will find mathematics educators, and you will people from industry who employ mathematicians and mathematics educators, as well as parents. Also there are people from professional organizations such as the National Education Association (NEA) or the American Federation of Teachers (AFT).

DR. STOTSKY: Right. No, I understand that you have all of these people represented. The question is, how to get more of a representation from the content experts themselves on these committees, so that they are not so overbalanced or isolated.

DR. SHAKRANI: Right.

DR. STOTSKY: That is really the issue. It is a congressional issue.

DR. SHAKRANI: That has always been a problem. That is always a problem in some areas, especially in the area of reading, which you were on, because there are different points of view and you have to work with a committee of 15 people. So sometimes you would find one area that you may feel that you don't have enough people from that perspective.

But the National Assessment Governing Board reviewed that very carefully, and they receive a lot of input from people from the field. They try their best to get that balance from the different perspectives.

DR. FAULKNER: Skip?

DR. FENNELL: Thank you both for your presentation.

Dr. Shakrani, relative to the table of specifications for the NAEP, percentage of items within the content cells, am I correct in assuming that it is the same for both the long-term and the main NAEP?

DR. SHAKRANI: No. Indeed, they are different.

DR. FENNELL: Okay.

DR. SHAKRANI: The main NAEP, the percentages change every 10 years. For the long-term, the same as it was before.

DR. FENNELL: And we are looking at the main NAEP?

DR. SHAKRANI: We are looking at the main NAEP. This is the main NAEP.

One thing I want to point out is that NAEP is a sample assessment. NAEP measures a whole lot of objectives, as Dr. Milgram pointed out. But any one student takes a very small portion of it. So we can afford to measure a whole lot of things that students should know and be able to do. We can afford to measure things that we think students should know but maybe are not taught.

But the proportion and the configuration of the main NAEP versus the long-term trend are significantly different.

DR. FENNELL: And so, for instance, the new NAEP for grade twelve will take away your ability to compare grade twelve scores because of the difference in cells that is forthcoming?

DR. SHAKRANI: Indeed, that is the case. With the new NAEP for grade twelve, we will not be able to keep the trend for the main NAEP. However, for the long-term trend we will be able to keep the trend because the test would not change.

DR. FAULKNER: Bob and then Wu.

DR. SIEGLER: I would like to ask Dr. Milgram a couple of questions regarding the critique that sometimes has been labeled the inch-deep, mile-wide kind of criterion. I don't doubt there is some problem here, but I wonder whether the slipperiness of language and grouping makes it seem more dramatic problem than it might actually be.

So, for example, when you are telling us that there are only six goals in high-achieving countries, you are grouping together place value and basic numbers skills, and certainly they have some mathematical relation, which is true. But in the standards, these are broken down not only as place value being separate from basic number skills, but basic number skills. In turn, they are divided into addition/subtraction, multiplication/division and multi-digit multiplication/multi-digit division.

So I wonder if you or any other authorities who you know of have actually tried to maintain comparable categories in these comparisons to get a sense of how different the U.S. practices from the high-achieving practices are on this dimension of the variability of topics.

DR. MILGRAM: Well, with reference to the last question, to this point, no. Next week, as one of the people involved in the National Comprehensive Center for Instruction, I will be presenting a project to a national meeting of all the Comprehensive Centers in which we propose, more or less, exactly that. We will propose that we bring in the materials and the research that is going on and has gone on in the high-achieving countries. We'll propose that we translate it, make it accessible and understand what it is that they are actually doing.

There is an issue I would like to question a little bit in the first part of what you said. When you talk about number operations and place values, in fact, they are inseparable in the sense that the number operations are defined abstractly. In terms of doing any operation whatsoever with numbers, except the smallest numbers, the only way we have of doing that is the use of an extremely efficient method such as place value and place value algorithms.

So you really can't separate these things out at more than the absolute most primitive level. The minute you get into operational efficiency, they are inseparable. So there is a reason why we group them.

DR. SIEGLER: Yes, I wasn't at all disputing that. I was just saying that the state standards separate them, and so it creates a --

DR. MILGRAM: Yes.

DR. SIEGLER: -- noncomparable comparison.

DR. MILGRAM: And that is very true. That is a problem with the state standards.

DR. SIEGLER: Yes, the other question is closely related to the first one, is the chart that you showed that was very illuminating about the number of different standards in different states. It shows there is a lot of variability. So I believe North Carolina with 26 was at the low end, and Florida with 89 was at the high end.

It seems like we could look at a correlation between progress in these states or absolute scores in math achievement in these states on the one side, and the other variable is the number of standards that are specified. If, in fact, this is an important factor, there ought to be a negative relation between the two.

Again, have you or anyone else done that?

DR. MILGRAM: Well, no, it hasn't been. The development acknowledging in this country that there are only a small number of topics that matter is so new, dating I believe officially from September 12th. We really haven't had time to explore these issues.

That is a very good question you raise. Could we do a correlation correspondence on achievement against the number of standards? Of course, we probably could, but we hadn't even thought of it.

I would caution, however, that there is also the issue of the selection of standards and the overall objective. It isn't just the standards in one year. It is the way they build and the way they fit together and the objectives that are contained in it.

But putting all that together, I think that would make a very interesting study.

DR. FAULKNER: We need to conclude this session. Wu will have the last question.

DR. WU: I seem to perceive some

discrepancy between two statements that you just made. It caught my attention.

One was about fractions in the discussion with Tom. You said that fractions are not taught, therefore, you could only pose questions because they are supposed to reflect what is actually taking place in our classrooms.

Later on, you talked about the fact that NAEP can afford to ask questions over a wide range of areas because students take small portions of questions. If that is the case, then I think in terms of fraction computations, NAEP is obligated to pose questions that are necessary for the learning of fractions. This is the next step beyond grade eight that may not be taught yet. However, if NAEP asks it, and makes it clear, that all the school districts know it, they would wake up to the fact that they should be taught.

Therefore, you can afford to pose questions on computational fractions that may not be taught but should be taught. So how do you mediate between the two?

DR. SHAKRANI: Thank you.

I may not have made it very clear. I said NAEP reflects and leads. Both have what is being taught as well as what the mathematics educators and mathematicians tell us should be taught. Because NAEP can measure a whole lot of things because of the matrix sampling technique, in fact, it contains both.

Just to give you an example, when I first came to Washington in the early nineties, the eighth grade had no algebra, but mathematics educators tell us that students should be exposed to algebraic concepts at the eighth grade. So we started assessing algebraic concepts at the eighth grade.

Less than 20 percent of the students in the United States were able to answer these questions. That percentage is now in the neighborhood of 40 percent, due to more students being taught the algebraic concepts that the mathematics field tells us should be taught.

So they contain some of these items that you tell us students should know and be able to do, and that is one way that NAEP can influence what is considered essential for students to know in order to progress efficiently in their academic ladder.

So it contains both. The results clearly show the relationship between what students are taught and how they do on these specific items that are taught to just a few percentage of students.

DR. WU: But what I perceived was that there is a lack of recognition of the urgency in posing more questions on computational fractions or fractions. I mean I did not get a sense that NAEP seems to be aware of that. NAEP should put greater emphasis on computational fraction, yes, even perhaps at the expense of other areas. There is a national urgency.

You want to achieve algebra? I can give you a reasoned mathematical argument, entirely cogent and convincing, that until students can perform reasonably in fractions and rational numbers, there is absolutely no hope of learning algebra.

I don't sense the recognition of the urgency of this situation. That is what puzzles me.

DR. FAULKNER: This is the last word, Dr. Shakrani.

DR. SHAKRANI: Thank you.

Dr. Wu, I agree with you, and I think that these are not only the essential skills for algebra, but they are essential skills for any mathematics. It is important to be proficient and knowledgeable in understanding how fractions and rational numbers work and how to apply them in many situations.

The contention, of course, of the people that we are working with, with the Steering Committee, is that there is an appropriate number. Now there may be some disagreement that there should be more in the area of fractions.

Since I am no longer with the National Assessment Governing Board, I certainly will convey that to the people who are working in there, that it may be necessary to conduct a special study in prelude to the 2007 assessment to look at the configuration of items.

The National Assessment Governing Board has never found it difficult to get the best thinking across the nation of what changes should be made. That is the power of NAEP, is that it can adapt and change to reflect recent research in this field.

Thank you.

DR. FAULKNER: Thank you both for taking the time with us today.

We are now going to break for 10 minutes. We will reconvene at 10 minutes before the hour.

(Whereupon, the foregoing matter went off the record at 1:41 p.m. and went back on the record at 1:55 p.m.)

DR. FAULKNER: Let me ask everyone to start finding your way back to your place.

(Pause.)

We are ready to convene. We are ready to begin the next session.

Let me ask Tamra Conry to come forward and take a place in front.

Okay, we are now ready to go to the open session for public comment. We have been taking time at most of our meetings for comment open to first-come, first-serve registrants.

The speakers who are registered for public comment are identified for the panel at the beginning of Tab 5. We will have nine speakers this morning. I want to acknowledge those who have been on the waiting list, and I would like to express regret that we can't accommodate everyone who has asked for time, but we are accommodating those for whom we have time.

Each speaker is limited to five minutes. You have an indicator right in front of you. If time allows, panelists will have an opportunity to ask questions after the speaker has concluded.

But I would like to remind the panel that it is our obligation to listen to what these folks have to say. There won't be time for prolonged discussion about the speakers' comments.

With that, let me begin with speaker No. 1, who is Tamra Conry.

MS. CONRY: Good morning, members of the Mathematics Panel.

My name is Tamra Conry, and first and foremost, I am a middle school math teacher.

Let me first take this opportunity to thank the members of the panel for this invitation to share the thoughts and views of the leaders and members of the National Education Association.

All children deserve no less than the best mathematics education that we can provide, and we applaud your attention to this important issue. As Robert Moses has argued, mathematics literacy is a civil right and is tied directly to equity in this country. From our view, an equitable education is tied directly to closing the achievement gap.

The National Education Association (NEA), representing 3.2 million educators in public schools and institutes of higher education throughout the country, believes the great public school is a basic right for every child. Our vision of a great public school includes seven points, but for my time with you, I am going to focus on one of our criteria, a qualified, caring, diverse, and stable workforce. We believe that this relates directly to one of your focus areas, teaching.

Mathematics researchers have asserted that reform is not a matter of paper, but a matter of people. A qualified, caring, diverse, and stable workforce in our schools requires a pool of well-prepared, highly-skilled candidates for all vacancies and high-quality opportunities for continual improvement and growth for all teachers.

NEA believes all newly hired teachers must have received strong preparation in both content and content-specific pedagogy. Teachers struggle with providing in-depth instruction in the numerous mathematics topics presented in today's state curriculum frameworks and textbooks. Mathematics pre-service teachers need content instruction that is focused and deep in the content that they will teach.

We support federal government funding programs that provide financial incentives for qualified individuals to enter the teaching profession and for collaboratives between school districts, teacher unions, and institutes of higher education for the development of programs that would facilitate the recruitment and retention of a qualified, diverse group of teacher candidates. We support funding programs that speak directly to increasing the numbers of mathematics teachers from diverse backgrounds.

The National Education Association further believes that prospective mathematics teachers should benefit from programs that have earned professional accreditation from the National Council of Accreditation for Teacher Education, NCATE, the only accrediting body that is both standards- and outcomes-based.

To reach the diverse students that fill our classrooms, strong content knowledge must be connected closely to a variety of teaching strategies and methods of instruction. Differentiated instructional techniques and strong content knowledge can be achieved through supported partnerships among teacher education colleges and schools, departments of mathematics, local and state organizations representing teachers and other educators, and state and local school districts.

NEA believes that all newly hired teachers should receive quality induction and mentoring services from trained veteran teachers to ensure a successful experience in the first years and decrease the turnover of new teachers.

Further, all teachers should have access to quality and effective professional development. In 2002, the National Education Association (NEA) supported the work of the National Staff Development Council, which resulted in the What Works in the High School and the Elementary School results-based staff development.

The guides recognized that advances in student achievement are closely linked with increases in teaching quality and that teaching quality is influenced by the nature and quality of professional learning available to teachers throughout their careers.

The National Education Association (NEA) calls for federal policy directed toward providing states and school districts with the resources and technical assistance to create an effective program of professional development and professional accountability for all employees. These programs should help struggling teachers improve professional practice, retain promising teachers, and build professional knowledge to improve student success. In the end, professional development programs should be strongly tied to increasing student achievement.

As a nation, we are struggling with how to increase and retain mathematics teachers. Many strategies have been suggested and examined, including pay systems that directly link teacher compensation to student test scores. The NEA remains opposed to such systems. Such merit pay systems fail to recognize that teaching is not an individual isolated profession. Rather, it is a profession dependent on the entire network of teaching professionals where the foundation for student achievement is built over time for each of the student's educators. Further, merit pay undermines the collegiality and teamwork that creates a high-performing learning institution.

The NEA's leaders and members are strongly committed to providing a great public school for every child. We believe in excellence for every child. We support equitable education environments for every child. Together, we can provide a great public school for every child.

Thank you for time and attention, and I wish you success in your endeavors.

DR. FAULKNER: Thank you.

Are there any questions from the panel?

(No response.)

Thank you.

Next is Mandy Lowell.

While she is setting up, let me ask that, if you are next in line, come up to the front, so you will be close to the place to go on to the table.

My michrophone was not on when I introduced her. This is Mandy Lowell.

DR. LOVELESS: Mr. Chairman, just one quick question: The order in which the speakers are presented?

DR. FAULKNER: We are skipping John Ward because I don't think he is here.

DR. LOVELESS: Okay. Maybe somebody, if you could just give us the number on our chart?

DR. FAULKNER: This is speaker No. 3, Mandy Lowell.

By the way, there was also a replacement for No. 1, which is another reason why you are confused, I think.

Okay, we are now on speaker 3, Mandy Lowell, and we will be going directly in order after this.

MS. LOWELL: Members of the National Math Panel, thank you for this opportunity and, more importantly, for your work, which I hope will increase college-readiness for a larger portion of students. To do that, schools need to focus on elementary grades, where many of the deficits begin.

In our outstanding district we have teachers who are collaborating in professional communities engaged in developing their own rigorous instruction. At the secondary level this results in coherence and rigor, but in the elementary level this results in simplistic and guess-and-check problems and uneven preparation of our students. Maybe the best thing the panel can do is specify the problems kids should be able to solve in elementary school. Let teachers focus on how to get kids to solve these problems rather than developing what they see as rigorous.

While I would agree, we need to improve elementary teachers' math knowledge, pay higher to get the best and brightest, and include time for reflection; these are long-term and expensive approaches. As a school board member, I can tell you that important needs in math, which is your focus, are matched by important demands for funding and professional development in other subjects. These include reading, writing, science, social studies, civic participation, and the whole child and behavioral techniques.

The challenges before elementary school students who already have full plates are great. They are being reflective at least about as many topics as I have just listed for you.

You have already heard about the challenges in teacher turnover. Even if feasible, instilling better content knowledge will take many years to come, and not only the current teachers, but the current education school instruction force will be with us for decades to come as well.

To allow teachers to reflect, our district allows students out once a week an hour and a half early. We have 20 student class sizes.

But our secondary teachers find that just one in two students are developmentally ready for algebra in the eighth grade. So my question to you is, are Asian and Czech kids genetically superior? Are they more mature or are they better prepared? I think that is something. Are we asking too much when we ask our kids all to do algebra? These are questions our teachers have proposed to us.

Rather than having elementary teachers engaged in developing rigorous problems, I hope you will be very clear and unambiguous in your specifications. If you want kids to learn automaticity, that should be said rather than to just know or learn. Because many education people have told me that to know or learn would mean to answer six times seven would mean that you use friendly numbers and a multi-step approach to being able to derive that answer rather than just knowing it.

So I hope you will look at the findings from cognitive psychologists on the importance of over learning and rehearsal and effective encoding and reliable retrieval from long-term memory.

Principals tell me they are reluctant to have students memorize math facts because students become resistant and lose creativity. Please be clear that the use of algorithms will not thwart conceptual understanding or critical thinking on whether guess-and-check problems equal algebraic thinking.

Third, I urge the panel to promote reliable and specific classroom assessments. They should not be merely multiple choice, which tests recognition memory, but open-ended questions that confirm recall. Actually doing many problems with fractions will help. Please look again at cognitive psychology research on the effects of extensive practice.

Please don't let perfect be the enemy of good. That is, having career professionals, content-knowledgeable, reflecting on teaching, could be the enemy of good, which is materials that offer opportunities for students and teachers to work through many mathematical problems. Good, explicit textbooks and software are immediately effective strategies that will help our kids now.

The homework sets can be differentiated to address student needs. The book can serve as a content skeleton, which the teacher can flesh out. But giving good problem sets encourages comprehensive coverage.

Point four: Don't look at districts like ours -- I am from Palo Alto -- for evidence of what works. We have 11 applicants per teaching position, and some education professionals may earnestly believe that familiarity with numbers and a few deep problems precludes the need for solving multiple problems. Our engineers, physicians, computer scientists, and recent immigrant parents don't share that view. As a result, they supplement their kids' classroom assignments.

Please look at what works in districts where parents are not filling gaps, where kids have less-enriched home lives. Look at areas where you can get transferable techniques because the purposes of public education are thwarted if we look only at the top-end kids or if achievement depends on extra effort by educated parents, because not everyone comes from that sort of home.

DR. FAULKNER: Your time has expired. Please sum up.

MS. LOWELL: Thank you.

My final thing is please address the different pace at which students learn math.

Thank you.

DR. FAULKNER: Thank you very much.

Are there questions or comments from the panel?

(No response.)

Thank you.

We now go to speaker No. 4, Jim Ryan.

MR. RYAN: Good morning. My name is Jim Ryan. I have 10 years experience in public education, both as a high school math teacher and as an administrator. Additionally, I spent seven years in the science, technology, engineering and mathematics (STEM) fields, including as a programmer and analyst for Apple Computer. I now work for Key Curriculum Press, a provider of mathematics instructional tools, technology-learning tools.

Earlier this year at a California State University Summit on Mathematics and Science Education, a nationally board-certified math teacher stated, "Making instructional decisions is what teaching is about. It is about looking at my students and thinking, what do they need?" This teacher defines the mission of this panel: What do my students need?

Our country's diverse student population needs a broad array of quality instructional materials. Teachers need a variety of instructional approaches at their disposal for their heterogeneous classes. Students need clearly defined standards of success and flexible means by which success can be achieved.

Currently, over 90 percent of the high school math textbooks used nationally come from only four publishers. As you evaluate these widely used algebra and geometry sequences, you will be struck by their similarity in both content and pedagogy.

In California the textbook selection process has been most restrictive. For example, in 1999, only three algebra textbooks were approved for eighth grade. The results are disheartening. On the 2005 National Assessment of Education Progress (NAEP) exam, 43 percent of the eighth-graders scored below basic in math. Fewer than one in four showed proficient understanding.

In January the Los Angeles Times reported that 61 percent of the Los Angeles ninth-graders received a "D" or an "F" in algebra in 2004 and only a quarter of those who retook it passed.

The January Los Angeles Times article is titled, "A Formula for Failure in the LA Schools." In that article, Tina Norwood, a student in the LA Unified who was taking algebra I for the third time, wrote to her teacher on a chapter test, "Still don't get it. Not going to get it. I guess I'm seeing you next year."

Tina's sense of futility is, no doubt, a consequence of her repeated exposure to a curriculum she lacks the ability to decode. The fact that she returns year after year is a tribute to her resolve.

For us as educators to ask Tina to open the same textbook and turn to page 1 next year is to abdicate our role as a teacher. Tina needs an algebra class that differs from her past struggle. Tina's teacher needs access to a breadth of quality instructional materials to address the needs of all their students.

Can all students' mathematical needs be addressed by simply giving teachers curricula flexibility? Of course not. Enlightened school systems would not only provide teachers with a variety of curriculum, but, equally important, the professional development to enable teachers to understand the content and to use the curriculum wisely.

At Key Curriculum Press, we have found a particularly effective union between curriculum and technology. We know that to embrace technology in math education requires a new approach to the curriculum.

Critical concepts, more effectively learned with no technological component, must be taught alongside far-reaching concepts only enabled through technology. Just as it would be silly to ask a child to go to the corner store in an airplane, it is equally ridiculous to ask a student to aspire to fly to the moon on a bicycle. We shortchange students by not employing technology in a curriculum with this type of careful construction.

You, as the leaders in our field, will serve the needs of students well by approaching your task without philosophical prejudice. You serve Tina Norwood by advocating for quality of content and avoiding a myopic view of how mathematics should be presented to students.

If we are to improve teaching and learning with our diverse student population, teachers need equally diverse instructional tools. By unshackling teachers from a curriculum that does not address their students' needs and giving them the breadth of quality tools and training necessary, we will close the achievement gap and significantly improve student performance.

Thank you for this opportunity.

DR. FAULKNER: Thank you very much, Mr. Ryan.

Any questions from the panel?

(No response.)

Okay, we go now to Martha Schwartz, speaker No. 5.

MS. SCHWARTZ: Hello, and thank you for giving me this opportunity to speak to you.

My name is Martha Schwartz. I am a former math teacher. I am a geophysicist, occasional educational consultant, and parent. I come out of the Parent Vote Movement. So I guess I am one of those combatants in the so-called math wars.

I want to acknowledge that the National Council of Teachers of Mathematics (NCTM) has recently made a very encouraging step in the right direction with the release of its new elementary school focal points. The national press, however, had a field day upon the focal points released, proclaiming that basic skills were once more in.

This press coverage produced some predictable consternation among 1989 standards fans. One of them wrote a letter to the Seattle Times defending NCTM against the calami that it had somehow retreated from teaching for understanding. I can sympathize with that a great deal since myself and my friends have been accused of the same thing. I would say only in a bad newspaper story would anybody deny understanding to school children on any subject.

What the math wars are really about is mathematical content, what is taught and when, and mathematical pedagogy, how to transfer that content with understanding to students. We have usually argued on the basis of content, on the supposition that it was most important to guarantee what students learn. There are, after all, many reasonable teaching styles, but content is inevitably connected to pedagogy. Pedagogical adherence will argue for content based on what they think their favorite pedagogy is able to deliver.

With the focal points in mind now, we have some agreement on content, and, more importantly, measurable goals. It is time to break with the past and use my few minutes to talk about competing pedagogies.

In today's American educational scene, the most popular instructional scheme varies around some variant of constructivism. As an epistemological theory, constructivism is intuitively appealing and quite possibly correct. However, it has been interpreted into too many indirect kinds of teaching styles with very little supposed or less emphasis on instruction by the teacher.

But I don't think that that kind of pedagogy necessarily follows from the learning theory at all, and I think that students can, from my experience, make their meaning also, and maybe more efficiently, from reading and from teacher explanation, emphasis on explanation.

Highly-unguided and moderately-unguided pedagogies have been pushed relentlessly in recent years by teacher training institutions. They have been equated by improved instructions. They have billed as innovative and new and the great break with the model of the past. I don't think that they are.

While most teacher training programs have their eggs firmly in the minimally-guided basket, their institutions do house a few educational cognitive psychologists, folks who talk about things like working in long-term memory who hold a radically different view.

For example, a recently widely-circulated summary paper, Kircher, Sweller, and Clark, goes so far as to state, "The goal of this article is to suggest that, based on our current knowledge of human cognitive architecture, minimally-guided instruction is likely to be ineffective."

The past half-century of empirical research on this issue has provided overwhelming and unambiguous evidence that minimal guidance during instruction is significantly less effective and efficient than guidance specifically designed to support the cognitive process necessary for learning.

I am going to skip some of what I've got, but they make comments on problem solving. "The problem-solving approaches overburden limited working memory and require working memory resources to be used for activities that are unrelated to learning. As a consequence, learners can engage in problem-solving activities for extended periods and learn almost nothing."

DR. FAULKNER: Your time is coming to an end.

MS. SCHWARTZ: Okay. I will make a note that what I gave you has some data on it, and kind of sum up and say that constructivist pedagogies are very popular. Not everybody thinks that they are the best way to go. I personally believe that there's probably some mix of different teaching styles, which are effective in different places.

But what I would urge this panel to do is to look very rigorously at various teaching styles and see which of them are actually best able to meet sensible goals like the new focal points.

And I will leave it at that.

DR. FAULKNER: Thank you very much, Ms. Schwartz.

Questions from the panel?

(No response.)

All right, we go to John Stallcup.

DR. FENNELL: Mr. Chairman? I'm sorry.

DR. FAULKNER: Yes? Please, Skip.

DR. FENNELL: Relative to the focal points, I appreciate the comment.

DR. FAULKNER: Thank you.

John Stallcup, you are No. 6, speaker No. 6 on my list anyway.

MR. STALLCUP: Welcome to California. I thank you and the panel for this opportunity.

I am the initiator and co-founder of Apremat USA. Apremat is the most effective Spanish language elementary math program in existence and in use by about 2 million children in Latin America today. Apremat USA was formed to bring this program to the United States and offered free to any student in the United States.

Spanish language students in those first three grades are pretty much not proficient at math, and that shows up in the dropout rates in high school as well.

I want to point to four areas of opportunity that need the panel's attention.

First, there is a lack of focus, attention, energy, or concerted effort on effective early elementary math education in general, and specifically for English language learners. There is no one person or entity in charge of early elementary math education at the federal or state level. There is also no major grant-making authority, either public or private, that funds early elementary math programs that reach large numbers of students, even though efforts to improve reading are well-funded across the board at every level and included by corporations like Toyota and State Farm.

The lack of effective early elementary math instruction creates the pervasive lack of computational skills in middle grades and is a primary cause of future problems learning algebra and higher math. You can reasonably expect the average student to be able to master algebra without having learned their computational skills to the level of automaticity.

There is a National Institute for Literacy, a National Science Foundation, a Reading First Initiative, and support from all levels of the government, nonprofits for reading programs, large and small. Not only is there not a national institute for math or a national mathematics foundation, there isn't even a mathematics second initiative.

There are no government organizations or initiatives, present company excluded, focused exclusively on mathematics education, let alone early elementary math.

Symbols and heroes matter a great deal. Laura Bush and many other celebrities champion reading. Who will champion mathematics?

Without focus, you get failure. Without funding, you flounder. Without attention, there is no energy.

If mathematics education is mission-critical, you sure can't tell by where the attention, energy, and resources are going.

Second, math is a world language and fungible skill. There are a number of proven, well-researched, early elementary math instruction programs employed around the world by literally millions. I would be willing to bet most of you had never heard of Apremat before I got here. It has been around since 1998. This is emblematic of the problem.

A couple of examples: There's nearly universal use of the abacus in China. It enables their 5-year-old students to acquire a number sense and compute large columns of figures easily. It also helps crosswire the brain. They get a two-year head start on our best students. It is, in essence, an advanced placement system wide.

Many countries in Latin America use the Apremat program. It was first initiated in 1998. Over 2 million kids use it. Unlike the U.S., if you don't pass the math exam for your grade, you don't go to the next grade, which I think we should do here.

If you think we have problems finding

qualified math teachers willing to work in harsh environments, try the jungles of Latin America with no roads, no windows, dirt floors, no college degrees, no money. I left off the guerillas and bandits. Yet, the second-poorest country in Latin America, Honduras, created an effective, easy-to-use, consistently administered, inexpensive, research-based instructional practice for teaching math on the radio.

Two million Spanish-speaking first, second, and third-graders in the United States are not proficient. Hispanic students taking the California high school exit exam fail to pass the math portion more often than the reading course. The words "destination disaster" come to mind.

Third, we can choose to use the Internet to empower math education or not, but we can't say that we cannot do it now. With the acquisition of YouTube by Google, there is a method that is, in essence, free. You could take Jaime Escalante and put him on a year's worth of calculus instruction and have it work fine.

The future of math education may in a large part be determined by how well educators organize and integrate online distance learning with a classroom.

Fourth, mathematics needs new narrative.

The brand math needs to be repositioned. When you listen to the majority of Americans discuss math, you get the distinct impression that something, our bottled water or our Starbucks coffee, has given us a mass case of math-phobic dyscalculia.

This includes many educators. In America, we are ashamed when we are illiterate, but it is okay to be innumerate. The far-too-commonly-accepted refrain, "I'm just no good at math," implies a cultural belief in ability over effort.

You've got to two things. Parents must understand how high is up. The fraud of proficiency must be eliminated, and that is due to No Child Left Behind allowing the states to define proficiency. It could be as easy as placing a National Assessment of Education Progress (NAEP) quiz online and letting parents have their students take it. You could also post the Trends in Mathematics and Science Study (TIMSS) release questions.

The gross rating points of mathematics in the media need to be significantly increased. The availability of high-quality, excellent, relevant television programs that either directly, like the Discovery Channel, or indirectly, like CSIs, teach us science and history is in the thousands of hours; the number of hours of mathematics programming is too low to mention.

DR. FAULKNER: Your time has expired.

MR. STALLCUP: Gotcha. I'll just say this: Although the federal budget only provides 8 percent of the funding, you will determine the agenda for the next decade.

Thanks for the time.

DR. FAULKNER: Thank your, Mr. Stallcup.

Any questions from the panel?

(No response.)

Then we go to Sherry Fraser, who is a substitute, No. 7 on my original list, No. 8 I think on your list, and the sixth speaker, if you want to keep up with the mathematics.

Sherry Fraser?

MS. FRASER: Good morning. My name is Sherry Fraser, and I have a degree in mathematics and 30 years' experience teaching high school and developing secondary mathematics curriculum and professional development programs.

I am troubled from reading the transcripts of this panel's meetings, and I have five points to make.

No. 1, we have failed our kids in the past when we paid most of our attention to the list of mathematical topics that should be included in a curriculum rather than focusing on teaching and learning.

How many of you remember your high school algebra? Close your eyes and imagine your algebra class. Do you see students sitting in rows listening to a teacher at the front of the room, writing on the chalkboard and demonstrating how to solve problems? Do you remember how boring and mindless it was?

Research has shown this type of instruction to be largely ineffective. Too many mathematics classes have not prepared students to use mathematics to be real problem-solvers.

Unfortunately, my experience, and probably most of yours, is what we refer to as the "good old days." This is when students knew what was expected of them, did exactly as they were told, and learned arithmetic and algebra through direct instruction of rules and procedures.

Some of us could add, subtract, multiply, and divide quickly, but many of us just never understood when to use these algorithms, why we might want to use them, how they worked, or what they were good for, and it showed. The First, Second, and Third International Study reinforced what we should have already known: We were doing a poor job of educating our youth in mathematics.

No. 2, this crisis in mathematics education is at least 25 years old. I remember in the 1980s when the crisis in school mathematics became part of the national agenda through such publications as An Agenda for Action, A Nation at Risk, and Everybody Counts. Our country was in trouble. We were not preparing students for their future.

Sure, some could remember their basic facts, but that wasn't enough. Something different needed to be done in our country if it was going to compete in a global economy.

It was the end of that decade that the National Council of Teachers of Mathematics released their Curriculum Evaluation Standards for School Mathematics. This set of standards had the potential to help the American mathematics educational community begin to address the problems articulated through the 1980s.

Shortly after publication, the National Science Foundation began funding the development of large-scale, multi-grade instructional materials in mathematics to support the realization of the NCTM standards in the classroom. Thirteen projects were funded. Each of the projects included updates in content and in the context in which mathematics topics are presented.

No. 3, these NSF projects were developed to address the crisis in mathematics education. They did not cause the problem. They were the solution to the problem. Their focus went beyond memorizing basic skills, to include thinking and reasoning mathematically.

No. 4, these model curriculum programs show potential for improving school mathematics education. When implemented as intended, research has shown how a different picture of mathematics education can be more effective.

In 2004, the National Academy of Sciences released a book on evaluating curricular effectiveness, judging the quality of K-12 math programs. It looked at the evaluation studies for 13 NSF projects and six commercial textbooks. Based on the 147 research studies accepted, it is quite clear the NSF-funded curriculum projects have promised to improve math education in our country.

No. 5, you might be asking yourself, well, why hasn't math education improved if we have all these promising data from these promising programs? Let me use California as an example.

In 1997, California was developing a set of mathematics standards for K-12. A State Board member hijacked the process. She gave the standards, which had been developed through a public process, to a group of four mathematicians to fix. She wanted California's standards to address just content and content that was easily measurable by multiple choice exams.

The National Council of Teachers of Mathematics (NCTM) standards, which the original California standards were based on, were banned, and a new set of California standards were adopted instead. This new set punished students who were in secondary integrated programs and called for algebra I for all eighth grade students, even though the rest of the world, including Singapore, teaches an integrated curriculum in eighth grade and throughout high school.

The four mathematicians and a few others called California standards world class, but saying something is world class does not make it so. In fact, we now have data to show these standards haven't improved mathematics education at all.

Most of California's students have had all of their instruction based on these standards since they were adopted almost 10 years ago. Yet, if you go to the California Department of Education's website on testing and look at the 2006 data, you will find only 23 percent of students are proficient in algebra I by the end of high school, a gain of two points over four years.

At the algebra II level, only 45 percent of California students actually take the course, and only 25 percent of those proficient. This is a loss of four percentage points over the last four years.

DR. FAULKNER: Your time has expired, please.

MS. FRASER: Can I finish?

DR. FAULKNER: Can you wrap up, please?

MS. FRASER: Okay. Three years of college preparatory mathematics is required, four recommended for entrance. Yet, less than 12 percent of California's high school graduates now have the minimum proficiencies expected by higher institutions, and these numbers don't even take into account the 30 percent of California students who drop out of high school. World class? Hardly.

Why then do we read in newspapers how terrible the mathematics programs developed in the 1990s are and how successful California is? It has to do with an organization called Mathematically Correct whose membership and funding is unknown. Their goal is to have schools, districts, and states adopt the California standards, and they recommend Saxon materials as the answer to today's problems. They are radicals, out of the mainstream, who use fear to get their way.

I urge this panel to look at the data and make recommendations based on the desire to improve mathematics education for all of our students. Direct instruction of basic skills does not suffice. Moving backwards to ineffective habits does not make sense. Our children deserve more.

My written comments expand and support each of these points. Thank you.

DR. FAULKNER: Thank you.

Questions from the panel?

MS. FRASER: I left out lots of data. Any questions?

DR. LOVELESS: You mentioned the study of the National Science Foundation curriculum, the 13 --

MS. FRASER: Yes, this book right here.

DR. LOVELESS: Yes. Could you summarize that again for me, what your conclusion was from that?

MS. FRASER: My conclusion is that, based on the 147 research studies accepted by this panel, it is quite clear the NSF-funded curriculum projects have promise to improve mathematics education in our country, and I can show you data to prove it.

DR. LOVELESS: Just a follow-up question.

MS. FRASER: Okay.

DR. LOVELESS: Didn't that report go on to say that, however, despite the promise, that there wasn't any real concrete evidence of effectiveness in terms of promoting student achievement?

MS. FRASER: The report went on to say that, if you look at the NSF programs as a whole, there is not enough concrete evidence to say for sure that they are effective. However, study after study after study shows they are very promising and, with more research, I am sure we would find they are very effective.

DR. FAULKNER: Okay, anything else? Vern?

DR. WILLIAMS: I just have one question. Do you think the organization Mathematically Correct was the only group that thought there was a problem with the math standards in California before the new ones were adopted?

MS. FRASER: Some of you in this room were in California during the 1980s and the 1990s, especially 1995 to 1997, when we were giving public testimony about the California standards.

Yes, there were thousands of people who testified. Teachers were behind the original California standards. They had process standards in there as well as content standards.

Someone on the Board, who I could mention, decided that they were too, quote, "fuzzy"; that they needed to focus just on content and content that could be measured by a multiple choice exam.

So I am not sure if there were many people outside of that Mathematically Correct organization because I am not sure who was in that Mathematically Correct organization. You can't find out and you don't know who funds them.

DR. FAULKNER: Deborah?

DR. LOEWENBERG: One of the things that I think is striking for all of us in listening to this testimony is the immense need there is for public education about education in this country. I am curious about whether you have any reflections, since you seem to be expressing very strong impressions about the way the public discourse has evolved, whether you have any comments for us about what kind of public education about mathematics education that would enable progress in the improvement of mathematics education.

I don't want to be sitting here in 10 years hearing the same sorts of comments and not yet having been able to improve what our young people get. Do you have thoughts about that?

MS. FRASER: Yes, I do. I think if we go back and look at all the public documents in the 1980s, they spelled out the problems and they spelled out some of the solutions.

We all know that students need to know the basic skills, how to add, subtract, multiply, and divide. There is not a person in this room who will argue with that.

It is not enough. They need to be able to problem-solve. They need to be able to apply their understanding. They need to understand what they have learned and why they have learned it.

It is impossible to go on in mathematics if you don't have an understanding of what you have learned. So just teaching basic skills without focusing on the wide variety of areas of mathematics that support basic skills and use basic skills will put us right back where we were in the 1960s, the 1970s, the 1980s, and today.

If we are going to have any change, we have to expand what we have done, and we don't need to repeat history. We can just go back to the eighties and take a look at what had happened and take a look at the National Council of Teachers of Mathematics (NCTM) standards that were developed because of all of those reports.

No one has asked me about data about ethnic groups in California. I'm surprised.

Skip?

DR. FAULKNER: Well, actually, Skip, you have your hand up? Okay.

DR. FENNELL: If you could just give us kind of a quick profile about all kids --

MS. FRASER: Okay. All of this data comes off of California's website. If we look at eighth grade and we look at the Hispanic population in California, 46 percent of eighth grade students are Hispanic. In algebra I, by the time they finish high school, less than 10 percent of those students, Hispanic students, are proficient in algebra I.

If we look at algebra II, less than 15 percent actually take the course, and less than 2 percent of them are proficient. That makes less than 3 percent of Hispanic students proficient in three years of college-prep math.

That looks good compared to the African American population. Eighth grade, 8 percent of our population is African American. Less than 2 percent of those are proficient in algebra I. Less than 3 percent of African Americans take algebra II, and out of those students, less than one-third of 1 percent is proficient.

So if we look at our data, our data tells what we are doing in California is not solving the problem. It is making the problem worse.

DR. FAULKNER: Tom? This is the last question on this.

DR. LOVELESS: I take it by your testimony, and then the presentation of those data, that you are blaming the current California math framework for those figures. Here's the question I have: What were those same figures under the previous framework? Were African Americans and Hispanics more successful at algebra under the previous math framework?

MS. FRASER: Unfortunately, we don't have that data. The data only goes back to when these particular standards were developed.

These standards aren't the only problem. This just has made the problem worse.

So it is hard to tell because we can't compare because we don't have that particular data. But when we didn't have a requirement for students to take algebra in eighth grade, we had about 17 or 18 percent of our students taking geometry in the ninth grade because they had taken algebra in the eighth grade. Now that it is required for all eighth grade students, 10 years later, we now have 21 percent of our students taking geometry in ninth grade.

So it hasn't improved course taking. It hasn't improved achievement, and I think it has made it worse, based on the data.

DR. LOVELESS: But what data show that it is getting worse?

MS. FRASER: Go to the California Department of Education. Look under the California standardized testing and reporting. The data shows up in detail, and it shows up as a table where, in 2003, 29 percent of our students were proficient in algebra II. In 2006, it is down to 25, a decrease of 4 percent.

Yet, when you look at integrated, if you look at an integrated III exam, 34 percent are proficient after three years, and that is an increase of 13 percent.

So the data tells the story.

DR. FAULKNER: I think we are going to have to move on.

Thank you very much, Ms. Fraser, for your comments.

MS. FRASER: Thank you.

DR. FAULKNER: The next speaker is Richard Rusczyk. I may not have pronounced it correctly, but you can pronounce correctly. What is the correct pronunciation?

MR. RUSCZYK: Hi. My name is Richard Rusczyk.

DR. FAULKNER: Okay.

MR. RUSCZYK: I run a company and a foundation that designs materials and programs for eager math students. I work online with many strong math students all over the country, including several members of the U.S. Math Team, around half the Clay Jr. Fellows from the last few years, and winners of the Siemens, Intel, and Davidson research competitions.

But the students I work with are not just good at math, they also love math. However, whenever I ask a group of my students, "What is your least favorite class at your regular school," by far, the most common answer is math class.

Yet, these students spend dozens of hours a week on our site, which is artofproblemsolving.com, and in our classes, and our classes aren't even for credit. Why this dichotomy? The answer is because the standard math curriculum is not designed for students who like math. It is designed for students who are being forced to learn it.

Even honors classes focus far more on perfecting simple algorithms than on reasoning and problem-solving. The result? Our best and our brightest are turned off from math in droves. They want to be challenged. They want to think about beautiful ideas. They don't want to memorize tricks for tests or punch buttons on a calculator.

But the curriculum they are presented seems almost designed to kill interest in math among our most eager young students, and it is working brilliantly at that.

It is not just the students who are being taught to hate math, it is the teachers, too. I once had a student thank me for giving him the chance to have a teacher who liked math.

As a result of the joy and beauty of math being sucked out of the classroom, many of the best students simply quit, and so do many of the best teachers. And the worse thing about all this is everyone knows the kids who want to learn are getting shortchanged. The kids know. The teachers know. The parents know.

Moreover, as restrictive standards and state testing become more and more important, schools have less and less interest and incentive in doing anything but getting students who don't want to learn above some minimal level. As a result, we are stopping the eager students dead in their tracks.

Now I am not asking you as the National Math Panel to come in and tell the teachers exactly what to do to engage the best students. These teachers and students, they don't need to be told exactly what to do. They are getting too much of that already.

They need suggestions. They need guidance, not restrictions. They need the freedom to do what needs to be done. What we need is more flexibility, more experimentation, more options for students and teachers, and more ways for them to be engaged and shine.

We must provide teachers options for dealing with these eager students. I often get asked by teachers or parents what to do with those three or four students in every single classroom that the teachers can't teach without leaving the rest of the class behind, and the answer is easy. Our role as teachers and parents of these students is to deliver useful resources, create opportunities, remove obstacles, and stay out of the way.

The resources are out there. The curriculum isn't well-designed for eager students, but there are good materials out there for students who really want to challenge themselves. Opportunities are all over, and inexpensive ones at that, if only teachers are given a little support and guidance where to look.

Removing obstacles and staying out of the way, these are not strong suits of the educational system. The barriers confronting a teacher who would like to present options to the students are immense. Textbook adoption is a nightmare that only giant companies can navigate, and that squeezes out small publishers who are the only people writing for the top students anymore.

Administrations pour money on their football team, but this Wednesday I am going to a middle school to teach parents how to help the teachers at their school in their fight with their administration to form a math team for the students who actually want to learn. This is a math team for which my foundation is providing all the funding and the teacher training. And still the administration is blocking its formation.

Look, there's no silver bullet. There is no one-size-fits-all solution to math education, and the more we try to find one, the worse the problem gets.

So I ask you to use your position as the Math Panel to do what I ask school teachers to do for my students. I ask that you provide resources, make opportunities, remove obstacles, and to stay out of the way. Let our great young minds develop. Don't hold them back.

We have all heard people argue, "Don't worry about the smart kids. They'll be fine." That attitude is pernicious to the students. It is dangerous for our future.

Technology has put us in a position to leverage the ability of the few to the benefit of the many. And who are those few who are most likely to benefit the many with advances in science, engineering, technology, and medicine? It is our most eager math students in middle school who are the ones who are going to make the breakthroughs in the next generation.

Yet, we continue to hold them down and chase them out of math, which hurts not only them, but all of us. Because once students turn away from math, you can hear the doors closing to them and to all of us.

Thank you.

DR. LOEWENBERG: The premise of your argument seems to be based on sorting students into those who want to learn and those who don't. As a public education panel, I am curious about how you can sort students into those who want to learn and those who don't and what the implications are for the responsibility of this Math Panel for all students in this country.

MR. RUSCZYK: So let me make sure I understand. You are asking how to figure out which students actually want to learn?

DR. LOEWENBERG: How do you know which students don't want to learn? Are you saying there are students who don't want to learn mathematics? That seems to be your claim.

MR. RUSCZYK: Yes, I think it's true.

DR. LOEWENBERG: And how do you know who those students are?

MR. RUSCZYK: I think the teachers know.

DR. LOEWENBERG: I have taught for a great long time and I don't think I can tell.

MR. RUSCZYK: You can't tell when you are in a room when you have a student who is engaged and wants to learn more and when you have a student who is completely put off by what is happening in the classroom?

DR. LOEWENBERG: So is this innate to the students?

MR. RUSCZYK: Is what innate?

DR. LOEWENBERG: Is this intrinsic to students? Some students come wanting to learn and some don't?

MR. RUSCZYK: Oh, no. I mean I think teachers, definitely teachers, can get students who are not interested in learning it and turn them on, and that is an extremely important skill for teachers to have. Not all teachers do it.

I think some of it is cultural. Some of it comes from home. Mom and Dad say, "Well, I wasn't very good at math. Math's not important." Kids pick up on that.

Some of it is cultural from their friends. The friends don't think it's important. They don't think it's important. It turns off.

I don't know where it happens, where students lose the interest, and I am not an expert in turning the students around. That is not where I focus. My focus is on the students who have already made that decision, that say, "I'm willing to spend extra time to do this. You know, these other people are going out and playing football, playing in the band, or doing whatever. I want to do math." And there are a lot of those kids out there who are getting bored to tears in their classroom.

DR. LOEWENBERG: Thank you.

DR. FAULKNER: Tom?

DR. LOVELESS: As you know, one of the movements in education over the last decade or two has been towards heterogeneous grouping and moving away from tracking and ability grouping. Could you just comment on that in terms of your own experiences with high-achieving kids, what effect that may have? Do you see any role that that is playing in what you just talked about?

MR. RUSCZYK: With high-achieving kids and students who are really interested in math, the best thing in the world you can do is getting them together. You know the students feed off each other. They will teach each other as much as the teachers will teach them. I strongly believe in peer culture, and if you can get high-achieving students together, there is a multiplier effect on that.

If you put very high-achieving students in the same room with very low-achieving students, I don't know how to teach a room that has both of those groups of people. There may be people out there who can do it. I certainly can't.

The mandate in the public schools is to get those low-achieving students up. The only thing you can do is just stop teaching the top students.

If you can provide ways to engage those top students outside the classroom like giving them extra curricula work and challenging problems while you are instructing the others, that is great.

Again, these aren't problems that I work on. I don't profess to be an expert in how to integrate students who are not really engaged in the classroom or low-achieving students with high-achieving students. My background is in working with the students who have already decided and who are already high achieving and who want to do more.

DR. FAULKNER: Camilla?

DR. LOVELESS: I just have a second question, a follow-up.

DR. FAULKNER: Okay.

DR. LOVELESS: My second question is about this idea of engagement and students enjoying math. In the early 1990s and late 1980s, on the NAEP test, when we surveyed students and we asked them how much they liked math, math did very well. Math actually was a favorite subject. It was not a subject that they shunned.

But those numbers are declining. They have been declining throughout the nineties, and they continue to decline.

Is there anything that we have been doing in the 1990s or since 1990 that may explain that? When you talk about student boredom, what's going on there and why would it be different now?

MR. RUSCZYK: Anything I would say to answer that question would be completely speculation because I have not studied the system. Just to make a guess at it, it would be to focus on engaging the students who are already above that minimum level. But that is purely a guess.

DR. FAULKNER: We have Camilla, then Vern, and then we stop.

DR. BENBOW: From your experience -- this is anecdotal evidence -- what would you say is the most helpful thing that you can do to stimulate students in math and science? It is not very helpful for the Committee to say to get out of the way because that is not very much of a recommendation. So if you were going to make a recommendation on how to stimulate the best and brightest students and how to keep them engaged in mathematics, what would you recommend?

MR. RUSCZYK: Show them interesting, challenging problems. You still have to put in the time and practice to get the basic skills down, but once they have those skills down, don't make them keep doing it. Show them challenging problems. Show them multi-step problems that require multiple areas of mathematics.

One of the things you see a lot with top kids, and it starts usually around middle school, is acceleration. What they will do is they will take the student who is bored in seventh grade and can ace everything and just stick him in a tenth grade class. It doesn't solve the problem. The tenth grade curriculum isn't written for that student either. They are just in a room with students who are older than they are.

Instead of continuing to learn how to do one- and two-step problems with more and more complicated tools, show the students five-step problems. Show them problems that require them to use ideas in combination to go much more deeply into mathematics.

If you show the students beautiful math and elegant ideas, they will really turn on, and they will really enjoy it. But if they are in a position of just memorizing for the next test, they will eventually stop.

DR. BENBOW: Isn't good enrichment for them to be accelerating?

MR. RUSCZYK: I'm sorry?

DR. BENBOW: Isn't good enrichment eventually accelerating, just like good acceleration has to be enriching?

MR. RUSCZYK: I mean good enrichment will be accelerating the student, yes, but when I say, "acceleration," I don't mean just move them along in the class track, because the average tenth grade curriculum is no more challenging to a really bright seventh-grader than the average seventh grade curriculum. If somebody is very bored in their honors seventh grade math class, they are going to be bored in the honors tenth grade math class. They are bored because the problems aren't deep enough. They are too shallow.

DR. FAULKNER: Vern has the last question.

DR. WILLIAMS: I get many questions from parents as to how to cure their kids from being bored to death basically at the school that they are in. I just wanted to make a comment that Richard is focusing on very, very bright kids, and they are getting turned off daily.

The only thing I can tell parents, if their students are not at my school, is to access maybe a site such as his. Because on his site, bright students can communicate and associate with other bright students. That is what they miss at schools.

Also, at their school they may not have a teacher that is involved in content enough to really do some of the engaging problems that you are discussing. So I think he is doing a service for a lot of students.

MR. RUSCZYK: Thank you.

DR. FAULKNER: Thank you very much for

testifying. We appreciate it.

MR. RUSCZYK: Thank you for your time.

DR. FAULKNER: Now we go to Steve Yang.

MR. YANG: Hi, everybody. My name is Steven Yang. I'm a Massachusetts Institute of Technology (MIT) graduate, and I'm also the founder of a software company called mathscore.com.

I believe that the National Math Panel should emphasize a solution that can easily be duplicated across every school within the United States, regardless of teacher talent, access to computer technology, and budget.

Other proposals to hire staff, train teachers, entertain students, and integrate technology all have merit. None of those types of proposals will scale effectively to meet the needs of every school in the United States.

According to the findings in the Trends in Mathematics and Science Study (TIMSS), Asian countries such as Singapore, China, and Japan greatly outperform the United States. They consistently outperform us without having made any significant adjustments to the way they teach math for well over 100 years.

What they do differently is so basic that it surprises me to see such confusion in the United States. In Asian countries, students are forced to focus on math facts by regularly doing timed tests. By the end of fourth grade, nearly 100 percent of all students in these countries have complete mastery over their multiplication and addition math facts. Kindergartners are typically exposed to addition, and by second grade, addition math facts have already become second nature. By the end of fourth grade, without question, these kids know their multiplication facts.

Furthermore, these students typically demonstrate superior critical thinking skills. This is because students who know their basics have a proper foundation on which to build critical thinking skills.

According to student usage at mathscore.com, less than one in five of our fifth-graders that we see have mastery over the multiplication math facts. Let me repeat that. Less than one out of five of the fifth-graders that we have seen know their multiplication facts.

That is the source of the problem. That is the most single glaring difference between competencies in math in elementary in the United States compared to foreign countries.

I have a lot of data that can demonstrate this, that can prove this. If you want to see some of the analysis, please ask me afterward.

As a solution, I believe the National Math Panel should suggest a mandate on regular timed math tests starting with first-graders. There should be a standard on the number of problems, difficulty of the problems, and the time allotted at each grade level. This way, regardless of school resources, every teacher in the country can unambiguously adhere to this approach. I also believe knowledge of math facts should be tested on state tests.

This solution is simple. It is measurable. It is repeatable. It can easily be implemented in every school in the United States, and it even aligns with the NCTM focal points.

So for schools with computers, I believe technology can help. Mathscore.com provides customizable, printable math facts worksheet generators at no charge.

I believe these generators can make the process of producing appropriate math facts worksheets as painless and efficient as possible. We can also provide a patent-pending adaptive learning system for schools that have Internet access.

I believe the proven improvement in test scores seen by users of our system validates the approach of starting with math basics before focusing on critical thinking skills.

If there is anything I can do to help, please feel free to let me know. Thanks.

DR. FAULKNER: Thank you, Mr. Yang.

Any questions?

(No response.)

Thank you.

Our final commentator today is Charles Munger.

DR. MUNGER: Good afternoon. My name is Charles Munger. I am an experimental physicist and a member of California's Curriculum Commission. This Commission advises the California State Board of Education on the Curriculum in our State's public schools. I am the present Chair of Science. Last year I was Chair of Mathematics, which is relevant to your charge.

But today I am here to speak for myself and not as an official delegate from that Commission. What I would like to bring before you is the figure of 4 percent. As you leave California, I want you to remember that one figure, 4 percent.

In 1997, California dissented from the advice of many national education organizations and wrote its own rigorous standards for what students should know and be able to do in mathematics at each grade level.

In 1999, California completed its own guidelines, the Mathematics Framework, for how best to get students to master the mathematics in those standards.

California has had publishers design new and appropriate instructional programs, and the first such instructional program hit school districts in the year 2000.

Standards-based tests are administered statewide, in particular, in grades K through 8, to measure student achievement relative to those standards.

Now surely its worst detractors, including one of the speakers you heard earlier, would concede that this is one of the largest-scale, longest-duration experiments in mathematics instruction ever.

California has 10 percent of the school-age children of the United States. Its total population would make a respectable country all by itself under a TIMSS study.

After six years, what is the result in this experiment? Four percent. The fraction of students scoring at proficient or above on those State tests has risen 4 percent each year, compounded now for six consecutive years, a 25 percent gain overall.

That 4 percent annual figure is uniform across all grades K through 8 for students in rural or in urban districts, across all ethnicities, across all economic classes, across all degrees of learning disabilities, is the same whether or not English is a second language, and is the same over all six years.

Something must be radically and profoundly right in California about how students learn mathematics and what mathematics students can learn to take an education system the scale of California's and to get this consistent, uniform progress.

Here in California we have made these things work by focusing on these areas: standards and assessment, determining which are the critical skills and skill progressions needed to learn elementary mathematics, algebra and more advanced courses, and the process used by which students of various abilities or backgrounds learn math.

I share with one of your earlier speakers, No. 7, a strong desire that you hit the California Department of Education website and study the California experiment. Read our standards. Read our framework. Examine the instructional materials unique to California and at work in our schools. Confirm the test results I have reported to you.

California has something that will help

the rest of the country, and I request that you study it and learn from it.

If this panel is to consider what kinds of national standards might be appropriate for the entire United States, it would behoove it very much to consider when we have standards for 10 percent of the nation's children. We have an extensive system which would be similar to the kind of system you would try to establish nationally.

Thank you very much.

DR. FAULKNER: Thank you, Dr. Munger.

Questions from the panel? Russell?

DR. GERSTEN: In reading, there is pretty good evidence of a reduction in the gap between native English speakers and English learners, and I am not as familiar with the math data in California. Is there any similar reduction that you have noted?

DR. MUNGER: There is not a significant reduction in the gap. Part of this is due to the sad fact that in inventing a system of standards, accountability and instructional materials aids the least-well-performing students in our State. We somehow failed to construct a system that helps the students who are already doing pretty well.

So what we have, with the 4 percent rise across all classes, is that if you have a lot of students who are already doing well, they are doing much better, and the students who were doing less well to start with are doing better, too. They're going up together, so the gap isn't closing.

We have in California, of course, designed instruction materials to help these students. We have this coming year the first round of materials coming in which are designed expressly to help students whose performance is not one year, but two years below grade level and also students who arrive in grade eight unable to master algebra. We hope to help in this matter. We expect about 40 publishers in total to be submitting in California this next year, distributed over basic programs, an intervention program and a program for algebra-readiness. We expect about 60 programs in total for districts to be able to choose between in a few years' time.

DR. FAULKNER: Camilla?

DR. BENBOW: Since there seems to be a difference in opinion about the progress made in California, I am curious to find out how you actually calculated the 4 percent. You can look at the same numbers but arrive at different conclusions. Exactly what is that 4 percent improvement? How do you arrive at that?

DR. MUNGER: I am quoting nothing that you can't find on the State's own website, which is in the paper copy which I have submitted here. Our tests are norm-referenced. We have administered them for six years. You can pick any slice of the population, grade three, Hispanic, rural districts, female, free or reduced lunch, and ask what fraction of the population scored proficient. That is recorded over each of the last six years. And it has gone up roughly 4 percent a year.

So if you had 10 percent originally, then after six years at 4 percent, you get about another quarter. You would wind up with about 12.5 percent of the people in that category are now scoring at proficient.

It is true that the absolute numbers of students who score well, particularly at the higher levels, are still low. We don't have as many Hispanic students, black students or impoverished students scoring at proficient as we would like.

But however great the burden a particular student has, it appears that something we have done in the standards system is causing more of that kind of student to be able to perform at the proficient level.

DR. BENBOW: So I am still trying to figure out why there is a difference. So you disaggregate the data and you look at it for various different groups, and you find 4 percent. You aggregate it into one figure and you get a 4 percent improvement overall, is that right? Are you adjusting for any changes in the population, demographics? I am just trying to get at why you come to one conclusion and somebody else looking at the same data comes to another conclusion.

DR. MUNGER: Part of it is that I am looking at, given where it started in the year 2000, how has it increased? And I'm saying it increased 4 percent to get up to 2001. It increased another 4 percent to get to 2002. Other people look at the absolute level in the year 2000 and say, "Gee, that is a very small number to start with," and aren't looking at the improvement in a small number. They’re only looking at saying the number itself in absolute terms is very small and, therefore, unacceptable.

I also find it very small and unacceptable, but I am focusing on the fact that we are managing to improve it successfully year by year. Therefore, something we are doing is right.

I am sure there are more things we can do that are right, but that is the essential difference in how we are looking at the statistics.

DR. BENBOW: Thank you.

DR. FAULKNER: Deborah?

DR. LOEWENBERG: I know that as an experimental physicist there are many requirements that go into the design of an experiment. Today you are reporting to us not just descriptive data, but implying causality. Causality in education research, I think you know, is very difficult to attribute.

I am curious about how you as a scientist have come to the conclusion that you can attribute cause in a State where there has been such a large number of interventions and efforts to improve math education over the last two decades.

We have all looked to California over the last two decades as a laboratory for learning. However, the numbers of things that have intervened in the State over the last two decades is enormous.

How have you come to the conclusion that the particular factors that you are claiming are the ones that have caused this improvement that Camilla has just asked you about? How have you drawn that conclusion?

DR. MUNGER: Well, first, we are in the fortunate position of having much more data to work with than anybody had before the year 2000. Because if you have statewide math tests that are norm-referenced in grades K through 8, that is a tremendous fund of data. So you are not going by anecdotes. You are going by computations for vast numbers of students.

Causality is a severe problem, and it is perfectly legitimate. There are several questions one could ask about this. The first and obvious one is that the best way of getting 4 percent annual progress each year is to cheat on the exams and make them 4 percent weaker each year. That would be one cause.

Another cause would be that you did something before you started your experiment whose good effects you are finally beginning to see, and that the actual things that you started in 2000 don't have an effect.

One would have to go over what education initiatives have happened in California from 1998, say, onwards that would have this effect. One significant datum is that in 2003 we had a severe fiscal crisis here, and the education budget was raided for billions of dollars in order to keep the State solvent. It has not been a flush time for experiments in education in general for the last several years. This 4 percent is, nonetheless, continuing.

I would be willing to listen to someone who could point to another profound statewide change that would explain these data, but I don't have such a leading contender.

DR. LOEWENBERG: I just think it is important for you not to, given that we are being expected to be as rigorous as possible, mislead the panel about what it might take to do the analysis of all the factors that could explain that. I think it is important for you to be as clear as possible about the range of factors that might be combining or individually affecting whatever outcome it is you are showing us. That is important for our panel to consider.

DR. MUNGER: I would agree. You, I am sure, have considered various forms of draft standards. I am sure you have considered various forms of how standards could translate into assessment, what kinds of instructional practices should appear.

What I am here to do today is not to come before you and say California has the answer so copy it slavishly, and let's move on. This is a great experiment of very large scale which seems to have some positive net outcomes, perhaps not correlated with the things that we think are there, but I commend this panel a very careful analysis of this California experiment. California did dissent from much advice to create its own standards, examinations and instructional materials. It provides, therefore, a point of comparison that may be useful for the panel to consider.

DR. LOEWENBERG: This may have as much to do with the enormous investment in teacher development and teacher professional work over the last two decades as anything else, for example. It stands out among states for that.

So there are a lot of variables that we are going to have to, as a panel, examine. So I appreciate the chance to consider that in the context of this State.

DR. FAULKNER: Bob Siegler, and then Sandra.

DR. SIEGLER: Very interesting data that you talk about. One question I had was, in a number of states around the country, there have been great improvements on state-specific tests, perhaps as teaching becomes more aligned with what those tests are measuring. However, there are lesser gains on more national tests such as the National Assessment of Educational Progress (NAEP).

My impression, though I am not sure of it, is that California has also showed pretty impressive progress on the NAEP in math and reading. Is that the case?

DR. MUNGER: I won't say whether that is the case one-way or the other. One of the reasons the California standards tests were invented was because the State, having gotten its standards, lacked a measure. So we did create our own measures. They are, of course, cross-correlated against the NAEP. But I am not an expert on how those cross correlate.

DR. FAULKNER: Sandra has the last question.

DR. STOTSKY: Thank you for all of the illuminating information.

I would be curious to know what have been any connections with teacher education specifically since the standards came about and the curriculum frameworks were produced. Have there been any specific results, changes, directions in which teacher education has taken place with regard to mathematics?

DR. MUNGER: California has always had fairly consistent efforts in teacher education in the pre-standards universe and in the universe we now live in. So certainly part of the success of the standards would be due to the fact that you are training teachers in how to use them properly.

I am not aware of any significant departure in total scale, however. I don't believe that in California, when the standards were invented, we decided to double the budget for teacher preparation or training. It was redirected, but I don't think extraordinary efforts were made. Obviously, if there were such extraordinary efforts, one could then argue that perhaps those alone, independent of whether the standards were there, are responsible for the improvement in scores. But that is precisely the sort of question that I would recommend the panel look at very carefully.

DR. FAULKNER: Thank you, Dr. Munger.

We are over time by about half an hour. We are going to make up 15 minutes of that in the next lunch period, and we will restart at one o'clock.

Thank you.

(Whereupon, the foregoing matter went off the record at 12:12 p.m. for lunch and went back on the record at 1:03 p.m.)

A-F-T-E-R-N-O-O-N S-E-S-S-I-O-N

(1:03 p.m.)

CHAIR FAULKNER: On the record. Let me ask people to take their places. Okay. I think we are prepared to begin the Open Session - Invited Testimony on Instructional Technology. I'd like to thank those who come from elsewhere to be with us today and let me also acknowledge Tim Magner, Director of the Office of Educational Technology for the U.S. Department of Education, who provided a good deal of assistance in developing this session.

We have presentation materials for the panel at Tab 10 in your book. And before us are several folks. There are going to be two ten-minute presentations on overview and additional research, three twenty-minute presentations on demonstration of the research and then forty minutes of Q&A. That's the plan.

Mark Schneiderman is the Director of Educational Policy Software --

MR. SCHNEIDERMAN: It's a mouthful. Software and Information Industry Association.

CHAIR FAULKNER: You're Director of Educational Policy of the Software and Information Industry Association. Right?

MR. SCHNEIDERMAN: That's right.

CHAIR FAULKNER: All right. We have Richard Schaar, Executive Advisor of the Office of Educational Policy of the Education and Productivity Solutions Division of Texas Instruments. We have Denis Newman, President of Empirical Education Incorporated. We have Steve Ritter, Chief Product Architect at Carnegie Learning, a Cognitive Tutor company. Matthew Peterson, Co-founder and Senior Institute Scientist and Chief Technological Officer of the MIND Institute and then we'll be going to Additional Research, Barbara Means who is Co-director of the Center for Technology and Learning at SRI International.

Thank you all for being here and we'll begin with Mark Schneiderman.

MR. SCHNEIDERMAN: Thank you very much, Mr. Chairman and members of the panel. Thank you for inviting me here today on behalf of our member high tech companies. I was invited to outline what, how and why technologies are being used today in mathematics education. I'll help set the stage for the other panelists who will demonstrate and discuss the related research.

My testimony is divided into three sections. I'll talk first about the drivers of educational technology use, the types of technologies used and some of the research issues. First, I will give some information about Software and Information Industry Association (SIIA). Our member companies depend on the nation's schools for a skilled, high tech workforce. Our concern is with the inadequate performance of our students on science, technology, engineering and mathematics. We seek employees with 21st century skills including the areas of problem solving, information literacy and the ability to be self-directed life-long learners. We view technology as a core component of modernizing our educational institutions and practices to meet these goals. Many SIIA members, including those I'm joined by today, develop and deliver educational software, digital curricula and related technologies and services for use in education. To that end, they're all looking forward to the findings of this panel to inform their research and development efforts.

So what's driving the use of technology today in education? For students, they mature in a digital world but are too often forced to leave these skills and aptitudes at the classroom door. As a result, students are increasingly disengaged from the traditional learning process and medium. What does this mean? Not simply that they're looking to play video games in class but, for example, when they play video games, they received instant feedback and that feedback will be something that is important to reach today's students. They will also apply their math knowledge in a technology world. So it makes sense for them to learn with some of these same tools.

For educators, the drivers are that they increasingly recognize that their traditional methods and materials may not be working as well with digital age students. In addition, No Child Left Behind (NCLB) accountability has, of course, raised awareness about the performance gaps of many of our students. As a result, educators are looking to individualize instruction through differentiated methods, mediums and time-on-task and they need tools to address these different student needs.

One other driver is the need to provide access to quality curriculum, courses and instructors for all students regardless of traditional barriers of geography, mobility, language or disability. According to a recent survey of the 2,500 largest school districts, over 75 percent of district superintendents agree or strongly agree with the premise that ubiquitous technology can allow teachers to spend substantially more one-on-one time with each student and personalize the education experience to each student's needs.

So what does this all mean? First, there's concern that traditional methods, mediums and practices are not meeting education's evolving needs and taking advantage of the current technologies. As a result, secondly, the education community is turning increasingly to these educational technologies.

As stated in the U.S. Department of Education's 2004 report, *Toward A New Golden Age in American Education*, meeting the No Child Left Behind (NCLB) vision and goals will require not only a rethinking and realignment of the industrial age factory model of education, but a rethinking of the tools available to support such change. From the back office to the classroom, schools of the information age will need to be effectively employ technology to meet the needs of all students, parents, teachers and administrators.

Let me now turn to the technology types and uses and provide an overview. You may first think of computers when you think of technology. Of course, the hardware used in a math classroom ranges from computers to calculators to smartboards to cameras to probeware. I'll try to divide these into their educational uses looking primarily at curriculum and instruction and teacher-instructional supports. The hardware, of course, provides a platform for delivering a lot of those applications.

Teacher-instructional supports include computer-based assessment, observation tools, professional development, instructional management systems and communication tools, to touch on just a couple. Technology-based formative assessment are also used increasingly for high stakes testing provide educators with real time data on each student's learning of each learning standard on a scale not otherwise possible. Without use of some of these technologies, educators sometimes can only estimate where student learning is at a given point, awaiting for the return for paper/pencil tests and often are forced to teach to the perceived class mean. Technologies create an ongoing feedback loop to better engage students in the learning process.

Professional development. We talked a lot about we know that a lot of teachers are teaching out of fields in terms of algebra readiness. Online learning enables teachers to get access to courses that may otherwise be out of reach due to barriers of time and place. Email and websites create virtual professional communities ending or at least helping to end teacher isolation and providing them support when they need it, where they need it.

Instructional management systems and other teacher instructional support provide educators with a single platform by which to manage or integrate otherwise disparate elements of the curriculum, content, assessment, professional development, etc.

Let me now turn to the second category of technologies that I'll discuss. That is curriculum and instruction. I will divide them into three areas, courseware and digital content, technology-mediate distance learning and learning tool.

First, I’ll talk about the coursewaring content. These applications are understood, of course, to integrate to varied degree of information and pedagogy. They address declarative, procedural and conceptual knowledge and the interaction of all of them. Categories include tutorial skill building and practice, problem solving, simulation, educational games and other areas. In practice, a lot of these categories are blurring and may work best in the abstract as technologies merge and evolve. Most of these technologies are highly interactive and adaptive. Many are intelligent and preprogrammed to anticipate student misunderstandings and react with instruction. Many provide scaffolding to help offload the learner's cognitive task at times and provide anchored instruction. Integrated assessment in many of them provides for immediate and ongoing feedback to engage the student. Many times content is representation in alternative modalities including visual ways to better rely the content. It adapts support for differential learning. Many employ contextual problem solving approaches and they provide enhanced accessibility for students with disabilities. One other benefit is the ability to keep knowledge current, information accurate and the pedagogy updated.

The panel may be interested to think about the fact that many of your recommendations and their print, *State Textbook Adoption World,* may not find their way into students' textbooks for six to eight years. With electronic materials, that time is reduced dramatically. Some software is used independently by students, and some in whole class instruction. It can be used for direct instruction. Others allow for learner construction. The point being that technologies can incorporate any number of cognitive and pedagogical learning theories while in each case adding functionality and utility not available in traditional methods. Many are designed and used under the premise that no single instructional material or medium is appropriate to meet the diverse needs of all students.

The third and final category is learning tools. They help us gather, organize and present information. They often are subjecting neutral such as a word processor. With math, I'll touch on a couple of these areas. Simulation tools provide engaging graphical representation of math concepts, allowing students to manipulate variables and observe outcomes and make the otherwise abstract more real. Examples include geometrical sketchpads, electronic manipulatives, and presentation software. The calculator and graphing calculator are of course the most common tools and are often reserved for students once they've mastered skills. They can also assist students in gaining that knowledge. Graphing helps students develop math spatial and representational skills, improve understanding of graphical concepts and make connections between functions and graphs. They have evolved significantly over the years.

I won't spend time on technology mediated distance learning, but we know that distance learning can provide access to courses otherwise not available. There is also increasing use of online tutoring.

Let me turn now to the third part of my presentation and outline several research considerations. Years of research provide sound theoretical bases for technology's impact on teaching and learning and many examples of promising impact.

The other panel witnesses will discuss some of this and we invite the math panel to review that research in depth. At the same time, we do realize that the research is ongoing and more work is needed.

Let me point out four areas of consideration. While much of technology's impact depends on its design itself, just as important is the fidelity of implementation of that technology. Are the teachers trained? Does their software match the learning needs? Is the infrastructure there? The fact that schools are still ramping up their technology infrastructure and implementation creates barriers to fidelity of accurately implementing the technology as designed to be used. We would encourage our research to take these issues into account to provide valid and reliable and useful information for educators.

The second issue is differentiating the tool and medium from the design and pedagogy. As I touched on, instructional technologies can follow any number of pedagogical models and instructional designs. It's important to spread the learning theory from the technology value and look at them independently and interdependently. Technology is only as good as the cognitive learning research that underlies it.

The third issue is outcome measures. Technology ultimately is intended to improve student achievement, but it makes many indirect contributions to those goals and there are many intermediary manners for addressing that. Equally valid --

CHAIR FAULKNER: Time. Wrap it up.

MR. SCHNEIDERMAN: Okay. Just wrapping up, in conclusion I would ask that the panel take a look at the research and technology, recognize some of the values it provides in terms of differentiated instruction, engaging the learner, looking at varied methods for examining that research and to engage in the public/private partnerships that are needed to advance this research. Companies are continually challenged by the ability to do this research, to find schools to participate in random control trials, etc. And that partnership is needed. I have expanded on all of these points in my written testimony. I would encourage you all to review that. Thank you for inviting me and I look forward to the rest of this discussion. Thank you.

CHAIR FAULKNER: Thank you, Mr. Schneiderman. I think we go now to Richard Schaar.

DR. SCHAAR: Thank you. I appreciate the invitation to be here. I also want to thank the staff for helping me to look at the topics that I was going to cover today to make sure I was responsive to what your needs are.

With that in mind, I'm going to cover Texas Instrument's (TI) approach to improving students' mathematical knowledge. I'm going to first touch on the history. Then I'm going to move to finding common ground and how that interplays with some of the work that we've done, our systematic approach to solving these problems, and then I'm going to turn over to Denis. He’s going to talk about the research that has underpinned all of the work that we've done over the years.

To talk about our history, it really began in 1986. We were visited in Dallas by two mathematics professors and they discussed at that point a twenty-year decline in SAT math scores. The first ten years were demographics. The second ten years were achievement. They asked for a little bit of money. We gave that to them as we have always funded a number of things over the years. But more than that, we assigned two people with education backgrounds half time to see if TI could help in other ways and the answer was yes it could.

And with that in mind, we began to develop products, materials and training with the help of leading educators and mathematicians. Most of them were aligned with National Council of Teachers of Mathematics and the standards that they had come out at that particular point in time. Ironically, the initial products were used in remediation of basic skills and then the teaching of fractions as fractions.

In 1990, we began to ship our first graphing calculator for precalculus, the TI 81, and that as you can imagine became an instantaneous best seller and had impact far beyond what we had ever anticipated. We're currently shipping about four million graphing calculators a year. They're required in nine states and permitted, or other various forms, in 28 other states for use in algebra and above.

What was the benefit? I think, talking mostly about graphing calculators, it was the power of visualization. Students could visualize mathematics more accurately than they could previously with just pencil and paper. It allowed for multiple representations. You could look at tables, graphs and just points on a curve and trace those points and manipulate things as never before. It literally turned mathematics into an experimental science for many of these students, allowing for different learning styles and other approaches.

As we did this work, we had two

fundamental principles. One was the augmented product. Let me give you a definition because it wasn't just the physical calculator. It was all the training materials and the professional development and everything that went with it. At that point, it was printed. Now of course that material is online and easily accessible. But it had to be integrated into the curriculum and instruction. That's what we were aiming for in working with the educators and mathematicians. Therefore, the product had to be appropriate to the instructional need because of that level of integration.

Soon however, there were some issues that arose and especially in the 1990s. The use of simple calculators in elementary schools became an issue. The fundamental question was, “Did their presence cause students to not learn basic number facts, or did their presence allow students to solve more complex problems leading to deeper understanding?” In addition, because all of a sudden you could do decimals in the way you can on a calculator, did their use prevent students from learning fraction arithmetic?

We looked at this issue for long periods of time and we began to analyze these questions. Fundamentally, we've discovered that many teachers did not use our elementary products in appropriate ways. We had proper professional development available for this. We have trained in both the use of the augmented product and in mathematics in general. We trained over 100,000 teachers in this period. We had a great deal of difficulty getting to sufficient elementary teachers to have an impact. We knew what they should be doing and how they should be doing it and we just couldn't reach them. So in 2002, we decided to limit our marketing to elementary schools that instituted a full program.

Now it's this concept of appropriate use and the fact that it's integrated into the curriculum and instruction. When we found it necessary to see if we could pull some of the disparate elements in what has been characterized early as the "math wars" together, we didn't have a fundamental problem in coming out with some of the fundamental premises that the Finding Common Ground people worked on. We believe basic skills with numbers continue to be vitally important. We believe that mathematics requires careful reasoning about precisely defined objects and concepts. We believe students must be able to formulate and solve problems.

When we look at the Finding Brown paper, which I know has been furnished to you in some of the materials that TI submitted, we really believe and understand that it's important students have automaticity in basic number facts. You can't go on to concepts if you have to continually go back and try to figure out the answer to a simple problem. We think and agree that calculators have a useful role when used appropriately, both in elementary work and in graphing calculators for advanced work. But once again, it has to be integrated into instruction in the curriculum. The learning of algorithms is very important. It's a stepping-stone. Fractions are very important and teacher knowledge depends on the fundamental understanding of the material that they're teaching.

Now the Finding Common Ground work, which I’m very proud to have facilitated, I think was very significant. It started a dialogue between all sides and agreements are being forged. For example, the focal points are an output of a process very similar to the one that we used in coming up with the Finding Common Ground paper. And we see more mathematicians, mathematics educators, and others getting involved in this Finding Common Ground process and that's important. We need to have more and better from everyone involved.

When we did the Finding Common Ground

work, we did it kind of based on first principles. There is an additional research agenda that needs to get formulated that matches that work. I would ask the committee to think about that and what needs to happen to give some of these principles really firm footing.

But the bottom line is when mathematicians and mathematics educators work together, systematic interventions can be developed and I'd like to talk a little bit about one of them. First, in general, what do I mean? When you look at the education system for mathematics, it's a complicated system and if you're going to take an approach, as was said earlier, there is no silver bullet. You have to look at all pieces of the puzzle. You have to look at leadership, parents, administrators, teachers, and math coordinators. You need to look at professional development that leads to improved achievement and I'm not just talking about mathematics knowledge. I'm talking about classroom practices. I'm talking about understanding teachers' perceptions of their own students and do they think they can succeed.

In the classroom itself, you have to put everything together and get it integrated. You have to look at the curriculum. You have to look at the assessments and you have to look at formative assessments so you can really understand what's happening on a day-to-day basis. From our technology standpoint as I keep emphasizing, it has to be integrated into the total system. It's a component of the instruction, the curriculum and the assessment.

I don't know if anyone today will do a product demonstration. I will not because to do a demonstration of drawing a graph without considering what's being taught, how it's being taught and how it's going to be assessed is not where we need to be. We need to look at the whole system.

Now applying these principles, we went into a district outside of Dallas, Richardson Independent School District. With the help of experts, we were asked to look at the achievement gap in middle school mathematics. This is a district in the state of transition. And we went in using this total approach, this coherent integrate approach. We conducted surveys and performed analysis of what was going on. Using the University of Michigan materials and some of their people, we looked at teacher content knowledge. We addressed and looked at the key components in the system. We looked at structure, time, planning, administration support and the instructional components. We also looked at what needed to be taught, how was it going to be taught, and what technology needed to be implemented.

While this is a very new program using this coherent approach, we're very excited by the results. If you look at students who failed the Texas test in 2005, in 2006, we passed one-third of them. They passed. The teachers helped them pass. Everything worked together. When we looked and we had been doing research the teachers' mathematical knowledge and the growth of this knowledge was positively correlated with the results of their students. The students reported that the math trading helped their understanding so they could explain things better to the students. Our technology helped student engagement and increased their algebra readiness.

In this case, we used TI-Navigator, which is a machine, a technology, that allows for pretty instant assessment and a graphing calculator. The TI-73 is designed for pre-algebra and algebra readiness, but it was used as part of an integrated whole. And while the research is at an early stage, I want to turn it over to Denis who will talk about that research and other research that we've done in our calculator business.

DR. NEWMAN: Thank you. I want to really thank the panel for giving us this opportunity and for

TI for including this research in their part of the presentation.

Empirical Education is an independent, 20 -person, Palo Alto-based research company. Our mission is to improve school decision making by providing scientific evidence. You can use experiments to do this. So we are specialists in field experiments in school districts. They are mostly randomized experiments.

I want to go through the work that we're doing for TI and put it into a broader context. First of all, there is meta-analytic summary of experimental results. We call it a What-Works-Clearinghouse style review, meaning that we are looking for the research from the past 20 years that had a comparison group from which we could derive a difference between students using and not using.

So that was the first. A year ago, we began undertaking a two-year experiment, a set of randomized experiments, in two California districts. It's actually a single multi-site experiment. As part of this, we are conducting formative analysis of the professional development and the implementation. What I want to talk about is not just the numbers and so on. In fact, just to be up front to begin with, I'm not actually going to report the results at this meeting. The results will be ready a little later in this season here, this winter.

Research and calculator use is a topic of great interest to researchers and there's been quite a paramount of work. I'm not going to talk about very much of it. Our review found 13 studies that met the standards that we have set. Many of those were very typically small scale, fewer than 100 students, often one classroom per condition, but nevertheless in the context of putting them altogether, we were able to find some useful information.

There has been a tremendous amount of descriptive studies. We are simply trying to figure out whether it has an impact on test scores. And I think one of the fundamental things that we really find, and again, consistent with what Richard just said, is that what we're really looking at is the integration of calculators into specific curricula or teaching approaches.

Our focus is on graphing calculators and especially in algebra and geometry. So when we conducted the meta-analysis, we focused on a small number of studies that actually addressed that particular context. If you're familiar with meta-analyses this will look familiar. If you're not, the points of .44, .52, .91 and so on are the standardized effect size found in each of these studies of the 95 percent confidence interval. And you'll see that, for example, with the first one it would actually be statistically not significant, but in this context the data point is very useful. Once you take all of this data, you see the last on the far right. You get the average effect over a whole bunch of studies that had different kinds of measures, different kinds of ways of approaching it. You also shrink the confidence interval, which makes it more useful.

So what do we want to say about this? There were four studies. Some of those studies had multiple results so that it had more lines and that's the number of studies we have to work with, between 45 and 300 students. Most of them are very small. Many of them are using tests that are customized to focus on specific strengths. For example, does it have an effect on problem solving? You would have a problem-solving test and, yes, you would find a large effect.

The strongest impact we found in that meta-analysis was actually in many respects not a test of graphing calculators at all. It was a test of the University of Chicago math curriculum, which just happened to be very welcoming of the use of graphing calculators. It was used very intensively compared to control groups. The smallest impact, but actually still substantial in our terms on that previous chart, was actually the curriculum, but just using calculators in one and not the other. So again, we're looking at the curriculum that’s being used. We can't pull the graphing calculator out of that and just say that this is sort of a general effect.

I'm at the end. I should go back.

CHAIR FAULKNER: That's part of our enforcement mechanism.

(Laughter.)

DR. NEWMAN: So I'm out of time. That's all right. Thank you very much. It is possible that the two slides that actually concern the research are missing. So let me just tell you what they say. There is a sponsorship of a randomized experiment that's underway using graphing calculators in algebra and geometry. We are addressing the professional development, the implementation, the curriculum integration and technology. We are using 33 teachers and about 1200 students in two California districts that were randomized by teachers. We got the teachers together, found out which of the teachers were most similar to each other, and essentially tossed a coin. One went and got the training from Texas Instruments. The other just continued teaching the way they would normally do.

The first year the contrast was basically between what Mr. Schaar called the augmented use and just conventional kind of use of calculators. And what I mean by that is everybody in the classroom has the same kind of computer with the teachers trained to see how to actually illustrate various kinds of problems with the graphing calculator. We expected much greater usage of the calculator.

We actually did not find a huge amount and I'm not going to give you the results because we are still finalizing them. We did find that there wasn't a huge difference. One of my favorites is that all of the groups used calculators. In fact, the students are pulling out their cell phones now to do calculations even in the treatment group. But we did find, when we conducted observation interviews, surveys, and tests (the California Standards Test (CST) and the Northwest Evaluation Association (NWEA) tests were collected at the beginning and end of the year) that the introduction of a wireless technology called Navigator in some of the classrooms made a fundamental change in how the teacher was able to get the entire group of students to focus on a problem. We identified that work with TI to say let's focus on that and that is now currently the experiment we're running comparing that with the previous control group now trained with the last year's implementation. So it's a fairly tight experiment.

CHAIR FAULKNER: Your time expired a couple of minutes ago. Now wrap it up please.

DR. NEWMAN: All right. So let's take it that a meta-analysis is just a starting point to know what you might want to look at. We need randomized control trials large enough to look at teacher characteristics and enough studies and so on to look at the impacts and demographics. In order to do this kind of work we have to get beyond some black boxes studies and we need to be collaborating and working both with the vendors and with the school districts. Thank you for your patience.

CHAIR FAULKNER: Thank you. We will go to Steve Ritter, Chief Product Architect at Carnegie Learning, the Cognitive Tutor Company.

DR. RITTER: Thank you very much. Thanks for providing us the opportunity to talk about how we're applying research to mathematics education and that is going to be the focus of my topic. But before I start on that, I want to give you a little bit of background on the products that we offer. I am going focus on the software component of our products primarily. To give you the context, our full curriculum and products include textbooks as well as software and teacher training.

The recommended model that we offer is students will spend 60 percent of their time, typically three days a week, in the classroom doing activities that are guided by the textbook. The other two days a week the students will be using the software one-on-one, one student per computer. The software is self-paced and individualized. So each student will be working at his or her own pace.

When we talk about applying research to curriculum development and improvement, we think there are four basic components of this. One component is having a solid theoretical background in learning science. The next is clearly applying that theoretical background in the product. Then evaluations are essential to the process to understand that the principles are actually working in the classroom context. Finally I think the most important aspect of what you need to do is have a methodology for improving over time, knowing whether you're doing well or not and at a fine level of detail. I'll walk through those four steps one by one.

The theoretical background that we've adopted is primarily based on ACT-R. This has been the primary focus of John Anderson's academic work in his career as ACT-R as a general model of learning, knowledge and performance. It was not developed particularly for education or certainly for math education. Its primary use has been in explaining basic facts and learning memory and performance. That's the cognitive psychology circle or oral diagram at the bottom. It has also been used in a number of practical application including human computer interaction, training and education.

And ACT-R is a relatively complex theory. We certainly don't have enough time to go over the entire theory but I'm going to talk about three aspects of it that are particularly relevant for mathematics education. One is that complex knowledge is composed of simple cognitive skills. So any complex task can be decomposed into its individual cognitive components. These skills or cognitive components are strengthened through active use. So the more a student practices those individual skills the more efficiently and less error prone those skills will be. The implication for education is that it will be most efficient when it's focused on the specific skills that individual students need to practice.

I do want to caution people when I use the word "skills." It has a slightly different meaning than we might be talking about here in terms of basic skills. These you can think of them as components of knowledge. So mathematical basic skill, the ability to add two fractions together, might be composed of 50 or 100 smaller cognitive skills or knowledge components.

Okay. I'll talk a little bit about how we take those basic principles and incorporate them into our product. Fundamental to this view when I'm talking about breaking a complex task down into its component skills and understanding what those skills are. Not only should we understand what cognitive skills are involved in the expert performance of the task, but what skills are involved in student performance of the task as they are learning.

One technique that we've used to try and understand has had students think about problem solving by eye tracking. So what you're looking at here is kind of a mock up of a Cognitive Tutor word problem. In this case the students are told that daily income has risen $4 per year in the time since 1980. In 1980 the average daily income in the United States was $55. And what the student is being asked to do is complete this table here, which is a partially completed problem. The student has said the independent variable here is time. The dependent variable is income. Time is being measured in years.

Income is being measured in dollars. Students define time as X and said that the expression for the income is 55 + 4X. The students also put this five here which corresponds to this question here. Given that average, what was the daily income in 1985? Since the base year is 1980, that's five years later and so the student has said that the time with respect to that first question is five years.

What the student is going to work is this cell here. What's the income corresponding to five years. The student is in this eye-tracking device, which is able to look at where the student is looking as they work this problem. This mark here will show you where the student's looking as they go through this.

So when I ask people what they might think a student would be doing is they are filling in the cell. They know the general expression 55 + 4X. They know that in this case X is five. We've done studies and asked teachers and other experts what students will do. Say you'll substitute five for X here and get something like 55 + 4(5) or 75. Okay.

Now I'm going to play this. This is a movie and you'll be able to see where the students look as they work through this problem. So now the student is looking at the answer cell. That's where he's going to type. Looks at the five a little bit. The student looks at the answer again and back at the expression. Typed 55 - 4. Backed up 55 + 4(5). So you can see the student focused on the five here, the formula here and actually typed it in. The tutor does allow them in this unit of instruction to type in an unsimplified expression like that and it will do the calculation for them. So the student did exactly what you might expect the student to do in this case.

Let's look at another one. This is actually a different student, different problem, but the same basic state and the same setup. In this case, you've been saving money. You have $20 saved up for video games. You're spending $4 an hour. The first question asks how much money you will have after two hours. As in the other problem, the student has filled in time and money as the names for the variables. Time is in hours. Money is in dollars. The student coded time as X and the amount of money left is $20-4X and has also put in two corresponding to the two arrows asked in his first question.

So let's look at where the students' eyes go in solving this problem. The student looks at the two, looks at where the answer is going to be typed. That's all fine. Now goes back and starts reading the problem. How much money will you have after two hours?

Now goes up $20, $4 per hour, $20, $4 per hour, two hours, and $20, two hours. Nothing happens for a second and then the number 12 appears in the cell there.

Now probably the most surprising and interesting thing to note is they now glance at this thing over here, which is the expression for the amount of money. So clearly, the student is not using this expression to calculate the answer and you can imagine what the student is doing here is kind of rethinking through the problem in the terms given in the words over here. Start out with $20. Going for two hours. So let's see, $4 per hour. I subtract $4. I'm down to $16. I subtract $4 again. I'm down to $12 and then they just write in the $12.

So it's a very different method. There are a lot of things that I can talk about in terms of this research but really kind of two high level lessons I think I want to leave you with from here. One is that students will solve problems in ways different from what you might expect and if you want to understand what a student is learning from the experience of solving that problem, you'd better understand how the student is solving that problem.

The second point is to kind of think about this from the student's point of view and how the student thinks about what's going on in the math class year. The student's teacher probably makes it clear that finding this expression is really kind of the main goal of math class. And from the student's perspective, I think what the student might be thinking is this is really why math makes no sense to me because I can solve this problem. I can get it right. I don't know why the teacher wants me to focus on this. In fact, we have other research that shows it's easier with simple problems like this for students to solve the word problem than to do the equivalent symbolic problem.

So there's a real disconnect between the student's common sense, correct understanding of what's going on here, and what's being taught in the math classroom. And as a result when you look at the way we present word problems in the kind of Cognitive Tutor curriculum early on, this is what this actually looks like. It doesn't look all that much like that mock-up from the eye-tracker, but this is a very simple situation.

A eucalyptus tree is growing three centimeters a day with the student constructing a similar table. In this case we put that expression row at the bottom because what we want students to do is reason numerically using their real world understanding of how change happens in the world. Then we want them to use induction to get to the mathematical expression and that's what we want them to do first.

As the situations and equations get more complicated, we do want students to go directly from the word problem to the expression. So later on in the curriculum this expression will be at the top of the table and students will work on the expression first and then use the expression to do calculations to solve problems. But as a way of letting them understand that their existing understanding is related to the mathematical understanding that they're getting in this class, we have them work through that way.

I'll talk a little bit about some of the evaluations that we've done of the curriculum. The first one I'll talk about is the study that was recognized by the What-Works-Clearinghouse as matching evidence standards as a randomized control trial. This was done in Moore, Oklahoma. It was an interesting study because it was a within-teacher study and so teachers' classes were randomly assigned to either use Cognitive Tutor or to use the curriculum that they were currently doing.

The dependent measures included the

Educational Testing Service (ETS) Algebra I end of course exam, course grades as well as student attitudes towards mathematics. Both their confidence in mathematics and their belief that mathematics is useful outside of the classroom were measured. On all those measures the Cognitive Tutor students or cognitive classes outscored the traditional classes.

Miami-Dade did a correlational study from the 2002-03 school year data looking at Florida Comprehensive Assessment Test (FCAT) scores based on whether the students had Cognitive Tutor in their classroom or traditional curriculum. You can see on the left that Cognitive Tutor students do outscore the traditional students. The advantage for Cognitive Tutor is especially magnified in that middle graph of Exceptional Student Education (ESE) students, which are essentially special-ed students. We think that's because of the Cognitive Tutor's ability to individualize instruction. It seems very effective with that group.

On the right are limited English proficiency students. This was kind of a surprising result for us because the curriculum does involve a lot of reading and writing, but we think we have a reasonable explanation for what's going on. We have seen this in other instances where we're especially effective with students whose English is poor. It's important to note this was a very large study, ten urban high schools, over 6,000 students.

Finally, I want to talk about our methodology for improvement. One of the really nice things about having this theoretical background and incorporating that in a very real way into the products is that we can test whether the products are working in real time. We don't have to wait for the final exam and what I'm going to talk about here is a relatively complex analysis. What I want you to think about is how you might see students learning over time in the classroom.

If you were a neutral observer and watched students in a classroom day after day and the students are learning, you should expect them to make about the same number of mistakes every day. Why? Because although they're learning and the things that they are learning should reduce the mistakes they make and also increase their response time or decrease their response time so they can respond more rapidly, the curriculum should be also getting more challenging over time. So in fact, you want to keep the error rate about constant and that this is this graph on the left side, which is from 88 students taking our geometry course last year. Every time they picked from a menu, type into a text cell, anything they do in the software is immediately evaluated as being correct or incorrect. You can see the percent correct is roughly constant over time.

If you look at student performance though and you break down performance into those skills, into the individual cognitive skills that we're tracking over time, you should see an increase in percent correct or equivalently a decrease in error rate. This graph looks at just one such skill in the geometry curriculum, which is the ability to code the area of a polygon when the base is horizontal. However, you can see an increase in percent correct over time. So this is a way of looking at the way we think that students actually learn. Aggregated across a number of students and looking at individual skills, we can tell whether our cognitive model, which essentially an analysis of what the skills are that students need to learn in the particular segment of curriculum, is right or not and whether we are effectively increasing performance on particular skills.

I think that this is over time going to be a huge bit of leverage for us in proving our products. This is partially because of increase in statistical models and being able to mine this data, but also because now that we're able to develop this over the Internet. We from last year have data from over 3,000 students using our bridged algebra problem and over 8.5 million observations, which amounts to one action every 9.5 or 10 seconds that the student takes two days a week for the entire school year. So it's an observation of what students are actually doing in their math. It's a tremendous resource for us and we expect it to be a real tremendous opportunity to increase the ability of our software to teach students.

Now I want to very quickly give you a view of what the Cognitive Tutor looks like. We don't have time for very much of a demo here, but I wanted to show you at least a little bit from one lesson. You'll see that there's a window up here that we call the Skillometer. This is visible to the student. What it represents to us is those cognitive skills. This is a visualization of the breakdown of skills in this section of the curriculum. You’ll see the activity that we are giving as I got through the problem. I don't know how well you can see the green there on the projector, but these bars will go up or down depending on whether I'm doing things correct or incorrect.

The framework for this lesson is helping students understand the relationship between the algebraic form of a function and its graph. In this particular question, the student is given a function, $g_x = 3(2^{x-4})-2$, and the student is going to graph that function by talking about what each parameter in that function means both verbally and graphically. There are other problems in this unit that would start with a graph and have students construct the algebraic form from the graph. There are yet other problems that will give a verbal description or a table of values.

So the first thing a student is asked to do is identify the parent function both verbally as a general equation and as a curve and you can see my bars starting to go up here, so I'm doing okay. Now I can see the parent function on the main graph down here, and what I'm going to do is identify transformations. Since in this problem the student is given the symbolic form of the function, I'm going to edit that first. So I have my parent function. I'm going to add -2 here to do one of the transformations here. Graphically, what does that do? Well, it shifts down by two units and I can say transform that and you can see now here's the transformed function 2^{x-2}.

Now I want to do the next transformation here. Algebraically, let's put in the X-4 and graphically what's that going to do? Well, a common error here is students might say that that shifts it to the left by four. You see the student gets immediate feedback and when we can diagnose an error when it's an error that makes sense, we provide a diagnosis to that feedback as well. In fact, we're shifting right here.

CHAIR FAULKNER: You're coming up on your expiration.

DR. RITTER: Okay. I am almost done. I just have one more transformation. You get the idea here that the key points in the instructional model are that we give students immediate feedback. We've broken down the task into individual components and so when the student is changing a parameter in the function, the graph and a verbal description of what the effect of that parameter is visible. Thank you very much.

CHAIR FAULKNER: Okay. Thank you. We now go to Matthew Peterson, Co-founder and Senior Institute Scientist and Chief Technical Officer of the MIND Institute.

DR. PETERSON: Thank you very much for inviting me to be here today. I am very excited with the new focal points, the creation of this distinguished panel, and that there is a turning point in education, math education. I'm very excited about it. I'm from the MIND Institute and we're a nonprofit organization committed to improving math education and we've developed a program called ST Math. ST stands for Spatial Temporal Space and Time and you'll see why that is.

It's a supplemental math program and goes along with a textbook. Right now, we have kindergarten through fifth grade and a middle school intervention. We're working on an algebra array in this problem to be submitted for adoption in California. All of our software is aligned to the California state standards and comprehensively. And one distinguishing characteristic of our software is there is a minimal reliance on language proficiency in order to learn the mathematics and I would like to demonstrate why that is and how that works.

This right here is a sequence of chapters in a curriculum. This right here would be like first, second or third grade, and I'm going to go into this chapter right here and here is the sequence of lessons. I'm going to go into this lesson right here and this lesson is called Balance Pies. There's a sequence of difficulty levels and you have to pass level one in order to get into level two and pass level two to get to level three and so on. I'm going to go into level one first.

Here you can see there's a minimal reliance on language proficiency. There are not any words, numbers or symbols at all at the very beginning. And this is a tutorial telling you how to play this particular exercise and it says click on here and I click on that circle and then it says click on this small penguin. I click on the penguin and the penguin is able to get by. So I say this is a very simple game. All I have to do is click on one circle and then click on the penguin and it's as easy as that. No. That did not work because the goal here is not to click on one circle. It's to balance the two sides of this balance beam and so very quickly we can explain these relatively sophisticated rules of this game without any language.

When you jump up towards the end of this particular exercise, you start getting into some fractions here. Here we have 1/3 + 1/3. On the other side, we have a 1/4. So you're balancing these two sides. I'm going to add 1/3 on this side and add 3/4 to this side and when I click here they will rearrange themselves to show that you have two wholes and therefore it's balanced. This right here doesn't have any symbols in it or numbers.

But right after this game, I'm going to go out of this exercise and go into this next one. On the bottom here, there's this LI. This stands for Language Integration and here we start bringing in symbols. Here's another tutorial. It says click on this and I click here and it's going to show me what it means. So 1/2 means you have two parts and you're going to take one of those parts. The penguin is going to go by and then you are given more questions to answer. I'm going to go the end of this particular lesson. Before there was a mixture of symbols and spatial visual representations and now it's all symbolic representations. So I'm going to balance these two sides now completely symbolically and then the symbols will turn this time quickly because they are familiar with how the symbols map to this representation.

That's just the basics on how we present these concepts and how students interact with it. That's at the second grade level. We did a controlled study in 2002 and 2003 and then we repeated the study again in the next year with 27 California schools and over 5,000 students in grades two, three and four and the control and treatment groups were from the same schools and the same grades. So some students were in this program with their teacher and the teachers are trained on how to use this program.

I should mention something very important. We did not expect students to get deep mathematical understanding from what they just interacted with on the computer. The explanation, the mathematical explanation behind what they just interacted with is the role of the teacher. So there is a very important connection. The teachers need to provide the mathematical explanations and details of what the students are doing when they're interacting with the computer.

I'd like to show you the results of the study. This CST stands for the California Standards Test. So this is the far below basic, below basic, basic, proficient, and advanced level of the CST. The number of students, percentage of the students and the blue is the control group who was not in this program and just received the classroom basic instruction. The treatment group is the students who also had the ST math supplemental software and there is a shift at all levels up towards the proficient and advanced. That was at second grade. This is third grade, a similar effect and fourth grade, which I guess a similar effect. The end is relatively small and so it's not as nice as what we would like. But if we look at one of the highest performing schools that were involved, this is one class that was in the program and the rest of the classes were not. You'll see that the purple shifted more towards the proficient and advanced when they had the supplemental program.

One important component is that when we analyzed the data, we found that how much they got through the lessons and how many lessons they actually were able to get exposed to, directly contributed to their increased scores on the California Standards Test. So what we tried to do is how do we get more students to complete more of the program. So what we did is we added a real time progress report for the teachers so that teachers in real time can see where each student is at and what they're doing. Here is an encoded code of each student and we also flag students that look like they're having problems. So this student right here is working on a module called Using Money and is working on a lesson called Buy Items and they've tried 13 times and have not yet successfully completed level two. So we flag that. The teacher then is able to go and maybe interact with the student and find why they do not understand something and help them along.

These are places are where students get stuck. At first we thought that these would be places where there would be abrupt change in difficulty level. Although that's true, often what we also found is that those are places where there are extraneous complications or distractions caused by our design of the software making it too video game-y. Those video game elements, although we thought they would be good because the kids would like them, were actually distractions and caused some problems for the students to move on.

One type of thing would be timing components that are unnecessary, extra visual elements that are unnecessary and other such features. I'm going to show you one example. This is Pie Monster. This is one of the games from third grade. Let's go into this third level. Here there is a single whole pie in this Pie Monster's stomach that's missing and you need to fill this Pie Monster's stomach up perfectly. There is a half of a pie plus a quarter of a pie and you need to add another quarter of a pie in order to fill that up perfectly. The penguin feeds the monster and out of gratitude he burns down this blockage so the penguin can get by. If you get this problem wrong, I'm going to get it wrong right here, he feeds the penguin and let's see what happens. He simply cannot get by.

When we first designed this problem, when you get it wrong, the Pie Monster will get mad, take a big bite out of the conveyor belt, blow fire out of its mouth and chase the penguin off the stage. What we found was that students liked that and would get it wrong on purpose. (Laughter.) And we also had other places where when in video games when you get something wrong it's exciting. Something blows up. Something bad happens and it's very exciting and that does not work well in an educational setting. So what we did is we changed it so that when you get something wrong, it's relatively boring. The penguin cannot get by and it shows you that is was because you did not fill up all the holes perfectly. If something is done right, then it's relatively exciting. Fire comes out of the mouth and something gets blown down and the kids like that and so they want to get it right.

DR. LOVELESS: Can we see it long enough to see that?

DR. PETERSON: We've removed that. Yes, it was almost like Pixar had done it. Here is the next version. This is language integration. I'm going to go into level five and now they're doing the same activity, the same exercise, but now done with numbers. You have 3/4 here, plus what, equals 1 and 1/4. Early on in the levels we kind of show what this mixed number means. So here you need obviously a 1/2.

So I'm going to add a 1/2. The 1/2 is that. 3/4 is that. Rearrange the formal whole. This means you have a whole. You have four parts and you take one of the parts, so you have 1 and 1/4 and then that fills up this thing. So we do a lot of visualization of what these numbers mean.

I showed you that big controlled study with thousands of students. Most of our research is these small mini studies where we do some research on a hundred students or a six-year smaller number of students. What we do is we have a pretest, a subset of this ST math exercises and then a post-test. I am the designer of all the software and so I come up with some great idea that I think these kids are going to understand this math so much better and we go out and test it and we get a result like this.

This is the pretest in the red and the post-test in the green. We’re very shocked to see that the students not only didn't improve but could even be going down as a result of my software. So I get very depressed. While it’s in the R&D stage, and before release it, I go back and I do a revision and a revision again until we get a signal for this particular case. This is a place value module. On the third revision, we start to get a signal. So eventually we see they did learn something and the test right here is not our test. We take release questions from the California Standards Test (CST) and derivatives of those. So our stuff doesn't look at all like CST. So it's great to see that students actually improve on those types of questions when they are interacting with the type of things that you just saw.

After we get a result like this, we go into a control study. So here is one class where the teacher is teaching extra time, the same amount of time in math instruction as these students, but part of the time for this treatment group, they are on the computer one-on-one and here is just extra instruction in the classroom. This was a higher performing school that we tested at, but again under this control study situation, we see results. Once we see results like this, then we release the software on a broader scale.

One of the places that we continuously find that we need to add it to the lessons is number line, lots and lots of exercise dealing with the number line. This right here is just asking where does this number fall in this number line. Sometimes students see a five and they click on this five and they say, no, it's over here somewhere. It's between zero and 1,000. So I just lost a life there. So I'm now going to go somewhere between zero and 1,000. I'm going to zoom in. It's between 500 and 600. I'm going to zoom in there. It's between 520 and 530. And then it's going to be between 530 and there. Then there it is. I got to the number and so it says, yes, you are right. Then it's going to zoom out because we zoomed in all that much and we zoom out and we said that's where it was.

So this is an example on the use of the number line. It’s just a small tiny component of our place value module number line with fractions. With fractions, here is an example. So where is 3/3s located? I click on this blast platform and it says 1/3, 2/3, 3/3. It's located at one and it's able to take the penguin off the screen.

So now where is 2/3 located? Now this is estimation, but basically just giving them a sense of where are these numbers located on the number line. So that's going to be located somewhere around here. It takes three equal jumps to get to a whole and I'm going to select two of those jumps and that's where 2/3 is located.

Now where is 4/3? Okay, so 4/3 I'm going to take three equal jumps to get to a whole and then I'm going to take four of those jumps. So it's going to be bigger than the whole. My estimation skills are pretty good this time and let's see what happens when you get it wrong.

So 2/5. Now I changed the denominator on them. So they think two last time was somewhere around here. So let's click here. Okay. For some reason, it's not working but that because I'm integrating it with the PowerPoint I'm sure. This is nothing.

So negative numbers. Where is -3/4? It's over here. So it takes 4/4 to get to a whole. I'm going to take three of those. The negative number means the opposite side of zero. So I flip it around and now I'm on the opposite side and now let's look at where -3/4 is and so it's going to flip it twice. 4/4 gets you to a whole. Take three of those. The first negative sign flips it over to the negative side. The second negative sign flips it back over to the positive side. That's where the penguin ends up and then I get off the screen.

Long division. It's an extremely important skill for understanding rational numbers and this sometimes terrifies students at first. However, when they go through these activities, they end up loving it even when they're doing it by hand on paper. So here is 7 divided by 2. Two goes into seven how many times? There are two trucks and I want to divide up these seven blocks between these two trucks. Of course each truck can get three blocks. So they get one, three. The next three and it pulls it off the screen. I have a remainder of one.

Actually, let me go back and see what would happen if we get it wrong. So let's try to give each truck four blocks. One truck can get four blocks, but the next truck cannot get four blocks because there's only three left. So that was wrong.

Let's look at what would happen. Why is two wrong? Each truck can get two. So why is it wrong? One truck can get two. The next truck can get two, but each truck could have gotten one more. That was also not correct. So the penguin cannot get by for that one either. So the correct answer is three. They’re learning division with a remainder.

But at the end of fourth grade and fifth grade, you need to get into decimal. So here is the remaining block broken up into ten parts. I'm going to take 5/10 to give to one truck and 5/10 to give to the other truck and that should clear the entire path. There you go. So now the penguin should be able to get by with no problem.

One type of fraction that students have a hard time understanding is these 4/3. It's bigger than a whole and sometimes learn that fraction are parts of a whole. Here is the one that's bigger than a whole and also when this gets turned into a decimal expansion, the threes go on forever. Why is that? If you just punch this into a calculator, you don't get to see those threes going on forever and you don't even get to see why they go on forever. The long division algorithm really starts to let you see why this decimal is the way it is.

Let's look at that in this activity. So here we have four blocks and we divide them up among these three trucks. So that's four divided by three. So each truck here can get one block. I give one block to this, one block to this one and one block to this one and I have a remainder of one. Let's break this up into ten parts. So I broke this up into ten equal parts. Each truck now can get 3/10 of this remaining block, 3/10, 3/10 and I have a remainder of one again.

So now this time, let's zoom in. Let's zoom into this remainder block. So we're going to zoom in, expand it so it's bigger. Now we have hundreds here. So each truck is going to get 3/100. 3/100 to that guy, 3/100 to that guy, 3/100 to this guy and a remainder of one again. By this time, the students are probably saying I saw this happen before. We get a remainder of one again.

Let's see if I can clear this time. So

here we go 3/1000. Okay. Each truck gets three of these remaining blocks and let's zoom in again. So we zoom in again. By this time, they're going to say this is going on forever. This is an infinite loop. Three, three, three, I would have a remainder of one again and by this time, the students are saying, "When is this going to end? The threes are going to go forever. Teacher, can I stop now?"

We have them do it one more time just to make sure they see it and then we have a remainder of one again. This time we zoom out. Okay. So we have this remainder of one.

CHAIR FAULKNER: You only have one more minute to finish this problem.

(Laughter.)

DR. PETERSON: Zooming out, yes. And so when we zoomed out, then why was the penguin able to get by? Because you had divided that up so many times that it's so small now and the penguin will not stumble on it when the penguin tries to work over it. First of all, they see why the threes go on forever. They start to like this long division because it's fun. They like this and then when they do it by hand they actually enjoy it a lot and at some point, why can you stop? If the threes go on forever, how could you ever write the number? Why is it okay to stop at some point? You've reached a precision that is precise enough to solve the problem at hand. I think that's important.

I'd like to conclude with a longitudinal study. One problem that we see that we would like to try to help solve is that as you go in the grades, the percent of students in the proficient or advanced level in the CST goes down, and that's very troublesome. We did a longitudinal study looking at students from Madison Elementary, which is in Santa Ana, 98 percent English language learners, Hispanic. Started at the second grade level. We didn't have California Standards Test (CST) scores for them at the second grade level. This is where they scored at third grade. In fourth grade, they moved up more into the proficient and advanced. In fifth, I guess they moved up a little bit, and then in sixth grade we have this nice progression in the number of students that are advanced.

But this next slide is the punch line. These students were in a program multiple years. These students, when they tested at the sixth grade, (they didn't have our program in the sixth grade because we only go K through 5) they were the highest performing students in the entire district at every category. The categories included ratio, performance, percents, operations with fractions, and algebra functions. They’re the highest performing in the entire district and these other schools have much fewer percentage Hispanic and English language learners than these. So since we used a nonverbal approach to introduce the mathematical concepts and then transition into a symbolic and language based representation at a secondary stage, we are able to bring a lot more of these language learners along. I'm done. Thank you.

CHAIR FAULKNER: All right. Thank you. Let's go to Barbara Means for the last presentation. She is Co-director of the Center for Technology and Learning down the street.

DR. MEANS: Thank you. Thank you, Mr. Chairman and Panel Members. I usually think it's bad to be the last speaker before lunch, but being the speaker after the blasting penguin is really bad. (Laughter.)

I'm going to try to round out this panel in the very short time available by talking about some of the research in areas that hasn’t already been touched on. Because there is relatively little time for this, I'm mostly going to reflect on the experience we've had at the Center for Technology and Learning (CTL). CTL studied a variety of supports for learning that are provided by technology and tried to point out some of the challenges to both conducting and also interpreting results from research on the effectiveness of interventions that are supported with a technology component.

The first point I want to make is perhaps a very obvious one. I can't tell you how many times people ask me does technology work and they want a yes or no answer. Whether you're talking about learning in general or mathematics learning, it's clear from what we've heard already there are a large number of different ways in which different technologies can be used in different contexts. So the answer is not going to be as simple as yes or no. We need to be wary about anyone who tries to answer it that simply and really take a deeper look at just what the use of technology in what context and how learning is being measured.

I started to try to pull together some of the research base to present to you. The earliest applications of software for mathematics really tried to do it all and that's where we have the largest corpus of studies. There are literally hundreds of studies looking at early computer assisted instruction or integrated learning systems. These systems typically were designed so that they would cover the whole year grade's curriculum or multiple grades' curriculum. They provided both tutoring on math concepts. They provided a practice environment, immediate feedback and an instructional management system for the teacher. So they tried to do it all. They didn't have the kind of more sophisticated interface we can have today and that you've seen demonstrated.

We have lots of studies on these and as you kind of get a flavor from some of the recent meta-analyses. What happens is that on average you get a modest positive effect from these studies. But there's quite a range reported in the various meta-analyses and a lot of the individual studies have confidence intervals that include zero.

So you might ask yourself, why is it? We can clearly see that although it's helpful in general on average, there are a lot of differences and what are some of the differences in the study? Well, the effects tend to be smaller in studies that have the same teacher to both the treatment and the control classroom. Effects tend to be greater if the outcome measure was designed by the researcher or the teacher rather than one that's a standardized test. Effects tend to be greater if the study was short term rather than long term. So studies of an intervention of three weeks or less tend to have bigger effects.

There are a lot of limitations of the individual studies that go into many of these meta-analyses and different analysts have different criteria by which they eliminate studies because of issues of methodological quality. Nevertheless, I think we'll hope to build a base where we have stronger studies going into this kind of meta-analysis. But I want to illustrate that we haven't turned the corner yet.

In the next slide, I went and I looked at 1998 survey of teachers. When math teachers were asked what kind of math application was most useful or the best, they cited the kind of application where you're interacting with geometric constructions. There are some of these that are available commercially and I looked for studies that were controlled studies of effects. If you can look at the kind of studies available, and you've heard a lot of this in some of the other presentations, the studies are small. There are methodological weaknesses in the study and they are a hodgepodge of different places, grade levels, and outcome measures. We don't even really have enough for a meta-analysis in this area even though this is something that is considered a very valuable tool by many teachers. We just don't have the research base we need.

Newer applications raise some additional issues. I'm illustrating those here with some work of Miguel Nussbaum, which he's done in Chile and the U.K. He has networked, wireless PDAs and students are trying to match a graphic representation to a numerical representation of fractions and decimals. The kids are working in groups and as they agree on an answer, they send the answer to the teacher. He's trying to incorporate the kind of frequent formative assessment that other researchers have said can be very useful. If you look on the left there, the teacher gets this near real time representation of which problems are hard. You can see problem three is a difficult one for most of the groups and you can also look at the individual groups. You can see some of the groups are just kind of swimming along and group number seven is having some difficulty.

So as we start trying to incorporate technology tools rather than those full purpose applications, it becomes really, really clear that what we're talking about is not the effect of technology per se. We're talking about the effect of a complex instructional intervention and we really need to know that. We really need to document what it is and understand it in a richer sense. I think the instructional -- we call it the instructional triangle from Cohen and Ball is very helpful here. When you think about instruction emerging from interactions between teachers and their knowledge, students and what they bring to the situation and the instructional materials, and then you realize that for these newer applications, most of them are supplements. They're very rarely the core curriculum and often times the teacher is expected to provide the conceptual knowledge that goes with the technology.

So we're not really, for example, in Nussbaum's case, trying to test the effects of the PDAs. It's really a rich activity and a lot of it depends critically on the teacher. So everything we heard this morning about the TIMSS results and the difficulty of finding what is causing, what is related, to higher and lower achievement in different countries that applied in that TIMSS research, we really have the same difficult in technology. It's just that people think it's a lot simpler.

So I just want to make the point that everybody has said there's no silver bullet. There's no silver bullet here in two ways. One, implementing these things does not guarantee you're going to get the desired effect because there's a lot of variation across classrooms and schools. Secondly, technology is not the encapsulated bullet that a lot of people thought it was. Just dropping the laptop, the PDA or the piece of software off in a school is very, very far from really implementing the intervention that you want to know about. Because so many of these are supplementary interventions, you also raise issues around coherence, how well matched is the instructional content, the language, the representation of mathematics and the technology to what the kids are getting when they're not using the technology and we see that causes difficulties in many classrooms.

So finally, I want to turn to one last application and try to give you a sense of the complexities of research in this area. SimCalc is a curriculum software and professional development around specific topics of rate, accumulation, proportionality and linearity. These topics run through pre-algebra, algebra and beyond through calculus. The idea started with Jim Kaput, a mathematician, and the math world software that goes with it includes different kinds of representations. You see the graphs and animation of movement here. There are also formulas, narrative statements, and tables. Students can work with one of the representations and it revises the others, similar to what you've seen demonstrated in some ways.

This research started back in 1994 and they worked in a large number of areas. It was in different course contexts on different platforms. What this was really designed to do early on was to tweak that intervention, to find out that you needed to do professional development, and to find out the other parts about it.

When you really want to test the effectiveness you need a much larger scale study. My colleague, Jeremy Rochelle, is currently writing one in collaboration with the University of Texas Austin's Dana Center and there they actually are in 94 classrooms for this scaling study. The Dana Center recruited teachers in eight regions of Texas and including some very rural regions and some of the poorest regions, majority Hispanic schools. SRI International randomly assigned the teachers either to the treatment or the control condition. All of them got professional development from the Dana Center on the topics that are covered in SimCalc and then the treatment teachers also got professional development on how to implement the software with their kids.

Now what I want to illustrate about this isn't to show that there is a nice main effect here. I wanted to talk about the assessment issue. One of the reasons SRI decided to do the study in Texas was because proportionality, which is central to SimCalc, is also central to grade seven standards in Texas. Texas is one of the states known for good alignment between assessment, professional development and teaching.

But when we went in to actually look at the state test that was being given in those states, and we looked at the number of items in proportionality, it varied across years and it varied between zero and three. So because the technology based intervention focused on specific concepts, we could really not expect to find an effect, no matter how good it was, unless we actually developed our own assessment. That ended consuming a large proportion of the resources in this research because you have to develop a demonstrably valid, reliable assessment that has had external review. The point I want to make here is we need to match our assessments to what the target of our intervention is. That needs to be done in a much more professional way if we're going to have research that tells us anything. If the learning outcome measure is either not relevant or not valid and reliable, we can't expect to get a research base we can make sense of.

CHAIR FAULKNER: You need to wrap up here. You're behind.

DR. MEANS: You know what? I'm just right at the right last slide. So my final point is that I think our research needs to focus less on the presence or absence of technology per se and more on the instructional content and pedagogy. We have to describe the full intervention, as it's enacted, not just the way it was intended. We need more attention to high quality instructionally relevant assessments and well-designed studies large enough to let us look at interactions between practices and effects.

I think the grant announcement structure of support where you can go from early research, refining the intervention, to studies of efficacy and then effectiveness is a good structure for doing this. I'm glad that technology studies need to compete with other studies for getting those research funds because they need to be up to the same standard of evidence of other research. Thank you.

CHAIR FAULKNER: Thank you. Let me thank all of our presenters for the comments that you've made and now let's turn to questions and answers. Sandra.

DR. STOTSKY: Thank you. First of all, thank you all for such a very comprehensive overview of a complex issue. I know that all of us are interested in how technology can best be used and I know that we have regulations often coming from legislatures that want technology used in the classroom in teacher training particularly which I'll get to. We have standards that ask for it and we also have the charge as a panel to look at teacher preparation in particular and ways that we might strengthen or improve that. We know from one of the earlier pages that you gave to us that elementary teachers in particular do not necessarily show appropriate uses of technology and in math, that's usually the calculator.

My question is based on the assumption that one of the major ways most teachers learn how to teach is through whatever experiences they had as learning. I have often wondered over the past few years as I looked at the problem in getting incoming teachers to know how to use technology better. Have you thought about going to pre-service courses for your research to work with faculty in wherever the programs are, whether they are in higher ed institutions or elsewhere, but to work with the faculty of math ed courses and a prospective elementary teacher where you might then get a multiplier effect because that teacher then comes into the classroom having experienced a better understanding of how to use certain technologies. In this case, it would be pre-service calculator training. This would include not only thinking about how to embed training in how to use the calculator in pre-service courses but also making sure in some way that the student teaching experience is with a model teacher who knows how to use the calculator properly. The idea would be to have frontloading as opposed to backloading because this is what really seems to come through almost all of the research. It's on how to improve that teacher already there in the classroom to use this equipment appropriately.

So my question is has there been any thinking about how to get that research to take place one step back so that we get a multiplier effect.

DR. SCHAAR: I'm going to make the assumption that was kind of meant for me.

DR. STOTSKY: For you, but it could be for any of the others doing research with teachers.

DR. SCHAAR: We have had a great deal of difficulty working in pre-service.

DR. STOTSKY: You've already tried?

DR. SCHAAR: We've tried various things. We are certainly open to any suggestions that anyone has about how to really start working in that area and it's especially difficult at the elementary area which I think is critical. One of my comments back to the panel is that we would certainly be interested in any suggestions or any comments that came out of this work on what could be done with what we view as a critical elementary school challenge. The elementary teacher has so many different subjects that they're learning today and so to say we want to make them into a mathematics specialist by either doing research or special training gets very hard to do. Yet I think the payoff potentially is very, very high.

DR. STOTSKY: Can you give us any idea of the problems in trying to build into, say, a math methods course for a prospective elementary teacher some training on how to use calculators appropriately in teaching elementary math.

DR. SCHAAR: I almost would have to defer. Please. Thank you.

DR. STOTSKY: Skip.

DR. FENNELL: Having done this for 31 years, I think I can take a crack at this. I think actually there are avenues, Richard, that technology corporations could explore. There is a very large and active affiliate of NCTM called the Association of Mathematics Teacher Educators that is largely made up of those who provide pre-service teacher education background for teachers.

I think that pretty much any material that such folks would use would sort of get at some of what you're talking about. But one of the things I've observed is that pre-service candidates actually come to those classes with a much better understanding about the computer and how it could be used because they have essentially been raised on it than they do the calculator. So this sort of judicious use of this particular instructional tool and how it could impact and not pull away from important curricula is an issue. I think you're continuing cooperation, not just Texas Instruments, but essentially technology in general of helping pre-service and frankly in-service teachers deal with two issues. One issue is access to technology of the students such teachers face, all students, and also the sort of divide that I find particularly younger teachers facing. That is, the student teacher goes out and that student teacher is often providing the software and the computer background because the teacher who has been there for 20 years doesn't know how to turn on the computer. It's a pretty complex issue, but I think it's something that people are working toward.

MR. SCHNEIDERMAN: Just a couple brief comments on that question. One is there was a Federal program called "Preparing Tomorrow's Teachers to Use Technology" out of the U.S. Department of Education.

I think there is a lot of data, about a two or three year program, and then funding was cut out for it, but it was designed exactly to create partnerships between local schools and the pre-service programs.

The second comment is I think there is probably a generally perception or view that perhaps incoming teachers will be better able to use technology because they grew up with it. But in fact, as I think we're all pointing out, the opposite is generally true and not knowing how to turn on the computer problem aside, I think the veteran teachers who are more comfortable with their teaching tasks and with their content, etc. feel more comfortable experimenting with the technology. Oftentimes, that's the only way they can implement it in a school if there's not strong systemic leadership in the school for going in that way. But I completely agree that the pre-service training and teaching training in general is perhaps the key issue to more successful use of technology in our schools. Thanks.

CHAIR FAULKNER: I have Tom, then Wu, then Bob.

DR. LOVELESS: I have a question for Mr. Schneiderman first and then the others can comment if they want. It's a general question about the industry. I receive lots of studies from various corporations, and I have to admit that I am somewhat skeptical just from the get-go when I began reading about a study that has a positive effect. I rarely read about negative effects of products that various corporations are willing to disseminate. So I guess my question is one about the industry. Are there controls, codes, or do you have a set of standards within your industry. I'm thinking really of the drug companies and the tobacco companies when I think of companies that have conducted research and have not been honest about negative findings. Do you have a set of standards that regulates how the studies are done, how they are reported in terms of effect sizes, how control groups are created and then finally how results are disseminated?

MR. SCHNEIDERMAN: We did put together a guide for our members around conducting research on their products. It does not have strict protocols as that might suggest. I'm not sure those are in place or developed throughout education in general, because there are certainly lots of interventions and things that are going on in education besides technology to which those standards, I think, would broadly apply.

I think a second issue to deal with is the funding. Companies are investing in product development and evaluation research, but we need funding from other sources like government, foundation, etc., to supplement that. I think that will allow for perhaps those protocols and those models to develop more. Right now the companies are faced with doing that research on their own. A lot of times, as you've heard here today, when they are finding results that are not where they might want them to be, those results are going back into product development. I think that's a potential problem with releasing all results because the products are constantly being revised, especially web-based products. They can be more seamlessly changed. There's a tendency in education to label something, working or not working, and not go back and revisit that. So that's a challenge.

I completely hear what you're saying. There are a lot of, I think, challenges around that. I think as the industry matures those protocols will be more appropriate and more called for.

DR. LOVELESS: I guess the bottom line here is can you assure us that if there are negative findings that we'll hear about them.

MR. SCHNEIDERMAN: I would say probably not, but I don't know that that's any different than anyplace else in education.

CHAIR FAULKNER: Turn on your microphone.

DR. NEWMAN: Yes. Let me just add a couple things to that. One is that certainly the Institute of Educational Sciences has raised the bar and has set a number of standards very clearly as to the requirements for this kind of research in order to have proper causal impact. So the requirements are out there very clearly. There is nothing like the FDA that requires these things to be done prior to marketing. There's nothing preventing that in that sense of regulation.

I think that the overlooked factor in this is that it should be the schools, the school districts, or the states that are initiating the research. It's in their interest to purchase things that are effective. Their interest in reporting negative results just to understand the impact for them is quite natural.

Just one final point is that my company has quite a number of contracts with vendors. Generally our agreement is that we will publish anything unless the vendor declares it to be a formative state prior to our publication. However, to prevent them from then going out and finding another researcher to do a less rigorous study and publish it, we say if anything else is published on that version of the product, then we'll publish ours just so that the What-Works-Clearinghouse doesn't get overwhelmed with things. We will actually hold things off the market if the publisher is in the midst of improving the product. We don't want to put something out that is about a product that is no longer available because it's being fixed.

CHAIR FAULKNER: Wu?

DR. WU: I have a question I think for all the presenters here. It seems very clear to me that technology has to play a role in self-improved education but I think we're still groping for exactly what the boundary is. How much can it help? So from what I've heard and pretty much elsewhere too, the thing that seems most striking is in the feedback area. That is that you use it to test student's understanding so you ask for something and then they give you an answer of some sort. Then the computer decides whether it's right or wrong.

It seems to be the case that at this point assessment in this sense is limited to very simple skills and not much else. I don't know if you will correct me. For example, I have not seen any feedback, any assessment, of the type, for example, ask a student to explain why 1/8 is 0.125. Is that capable with current technology? Is it possible? Explain the reasoning why 0.125 is 1/8?

DR. RITTER: Yes. I guess to the first part of your question I do think that we can assess more complex skills. What we try and do, as I was talking about in our presentation, is give a larger task but each individual component of that task we can assess. So it's not like you're assessing a single answer. You're trying to assess each step in the process.

Now the specific example that you're giving of assessing an explanation is very hard. That's pushing the limit to the technology because of language. But to the extent that you can provide an interface that shows as much of the student's thinking of the process as possible, you can assess the individual component of the process. I do think that that's really crucial to effective instruction so that students know where they're going wrong.

DR. WU: That's very good. I mean that's very true that if you have the one single skill or several component skills and you can assess every one of them in succession. Now given something like a skill which is a complex skill and I wanted to assess whether someone knows how to decompose that complex skill into several single skills, is that within the capability of the present technology?

DR. RITTER: I think so. I mean I look at the ability to decompose a task to kind of plan and attack a complex problem. That itself is a complex set of skills. There is sort of an art of design here. You don't want to design a computer interface so that it gives it away. You want it to be open enough that the students are doing the work on their own. You're not over-scaffolding it, but on the other hand, you do have to have enough structure so that you can understand what the student is doing. So there are certainly particular cases like with language where it's very difficult to provide a blank sheet of paper and let the student go. But I think we're pretty close to that in a lot of cases and I don't think planning tasks in particular are outside of the realm of things that we can help connect them.

DR. WU: But you do see an upper envelope of what you can do, right?

DR. RITTER: Currently, yes.

DR. WU: Yes, currently.

DR. RITTER: And things are getting better. Even language understanding is perpetually ten years off.

DR. SCHAAR: We're certainly not there yet to the extent that you're talking about. Denis was talking about and I talked about in this Richardson's program where you can take a graphing calculator that is specially designed for pre-algebra and hook it into this wireless system. This gives you instantaneous feedback as to what a student is doing at each step along the way and so you can work assessments and very formative at that point. We're not where we need to be. That's part of what Denis is doing with us. He is helping us guide the process even within the context of what you're talking about. We're going in the right direction with regard to the development of future technologies in this area. But the idea of this kind of real time assessment I think is very, very important.

DR. PETERSON: May I make one comment, Dr. Wu?

DR. WU: Sure.

DR. PETERSON: What we find is that a student goes through one of our activity and they can master it. They can do very, very well and they can get even more challenging. You present problems that they've never seen before and they are able to solve them. But when you talk to them, very often it's clear that they have no idea mathematically what's going on behind this thing that they are able to do very well. We have yet to find any way through a computer to tell them that explanation or get across or even assess where they know the meaning behind it.

The meaning is very, very difficult to assess and very, very difficult to get across. We have not figured out a way for technology to do that and I would very much like to figure out a way to do. So far we rely on the teachers.

DR. WU: I wonder if all of you would consider this connection to be of great benefit to teachers across the nation to give them an idea of the intrinsic limitations of what technology can do for you. I think there are all kinds of fantasies out there about tomorrow something wonderful is going to take all the worries away. I think that teachers ought to be told the reality of the technology. I think you might want to think about it whether you think it's do-able. I myself think it's extremely helpful to have something like that.

MR. SCHNEIDERMAN: There was certainly a time, probably not long ago, when maybe the teacher profession saw the computer and software as a threat to their jobs. I don't think that's in any way the reality anymore. I do agree that there's always education that needs to happen. I would also not want to see on the flip side sort of our search for the perfect getaway. I think there are a lot of terrific technologies out there already that we're going to keep pushing. But there's a lot of work that needs to be done to adopt the effective products suggested here today and recognize them for what they can do at this point in time.

DR. WU: Yes.

CHAIR FAULKNER: We have to get three more questions in here. Okay.

DR. SIEGLER: Very promising technologies and very interesting effects as to mean differences for people using the technologies or not. There wasn't much emphasis, if any, on changes in variability among learners of different incoming knowledge or ability. You could imagine the best learners to zoom ahead and increase the distance between them and others just because they get more out of each unit of time. You could also imagine the variability decreasing because the poorest learners are going to be responding more actively and will spend more time actually interacting plus overcoming embarrassment. How does it actually work in the technologies that you're using?

DR. PETERSON: One thing that we see is the students that do the best in the program make the most mistakes. They try and try and they get things wrong more than the people that end up doing worst on the CST. So what's very amazing is that students that have seemingly the most variability are actually improving the most. We see that very often. It's not 100 percent that case, but when you just look at the data of where students are trying things out and getting things wrong, very often it's correlated with how well they do at the end. I think that's very interesting.

DR. NEWMAN: It's clearly also going to depend on the technology and the design of it. We are always using the pretest score as the co-variant in the analysis. We very often are finding interactions such that the lower scoring students initially are getting better advantage or the higher scored students are getting better advantage. I think that all studies need to take that and use it. It's quite a natural thing to do and I think that it's an excellent suggestion for research. We're almost always getting some kind of an interaction on that thing.

It's also I think that a couple of things came up about the teacher preparation and looking at where there are certain kinds of programs that we expect the teachers with more preparation are going to be able to use it more effectively. There are other programs where in fact we think that the program may supplement teachers who are coming in without a strong background. That has two different predictions and again those things need to be tested. But it can go either way.

CHAIR FAULKNER: Deborah. We're going to need to go quickly here. I'd like to ask everybody to be crisp.

DR. BALL: Is that what you said, crisp?

CHAIR FAULKNER: Crisp.

DR. BALL: Crisp. Okay. I'll try. I appreciated the fact that all of you emphasized that instruction is a critical element of the overall, I think Barbara described it as system, that produces what the students have the opportunity to learn and what they in fact learn. But I have two questions. One may not be answerable right now. One is, I was curious whether in any of your work or across any work that you're familiar, is there anything that specifies the kinds of mathematical knowledge that are particularly supportable with different technological tools and some that perhaps are not because you didn't talk at all about differences. You happened to be talking about different content but you didn't say whether the content you chose was particularly amenable to support your technology. I mean we're concerned with mathematics here and content didn't really show up except sort of by example.

My second question has to do with whether any of you have done any validation work about what students are, in fact, thinking and doing when they do this. I worried a lot in watching the fraction work having taught young children fractions and when you just said that those who make more errors in fact do better. It made me even more concerned frankly because there are many ways to work one straight through that and given the lack of the validity of many outcome assessments I just worry a great deal about what we might be looking at in these studies. So my question comes back to what sorts of validation work have been done about the nature of student's actual mathematical work while they're engaged with these tools in any case. What is their actual thinking, their mathematical thinking, in work?

DR. PETERSON: If I could make one clarification. There are more errors because they tried more times.

DR. BALL: Exactly, but one could go through that and never be thinking about fraction concepts correctly.

DR. PETERSON: That's true and that's a major problem. What I said is that these students, when we talked to them after they go through this, and you said "What were you doing? Why did this happen?" and they were able to go through and master this exercise. Seemingly they would understand the fraction content behind it, but when you asked them and you really probe them with some questions, you find that they are really lacking understanding. They'll give you some answer that's absurd, incorrect, and you go further with them and you show them why and then they start thinking about it. They make a lot of progress through the interaction with a real person talking to them about what they're doing. Without that, you're not going to get a deep understanding. You need that interaction with the teacher. I don't know if that answers your question.

DR. MEANS: I was just going to say that I know in the work, for example, we've done with SimCalc and the SimCalc assessment, in fact, do that kind of cognitive, think-aloud, probing of how the students interact with the items. There was a lot of that to make sure that the items on the assessment in fact were tapping the concepts and skills that they were designed to be tapping on the blueprint. Like any assessment when you design it, the first set of items often didn't. That kind of detailed work has been done at least in some cases.

DR. SCHAAR: Going back for a moment to try to answer your first question which is how specific technology to a particular curriculum area relates. We're dealing with one technology, of course, but fundamentally, we're a software supplier. We just do it in a box with a battery and so what we've done over time is to assign different specialists to different grade levels and different materials so that we can fine tune what the software in that box does to really attune within the curriculum within the instructional needs of that particular area. So you have to get down at that level to really understand what impact you can support and what impact you want to try to make.

CHAIR FAULKNER: I think we've gone all we can go. Dave has a question. Valerie has a question. Skip has a question. And you're going to get to ask them privately.

(Laughter.)

CHAIR FAULKNER: We're going to take a break here. I'd like to get everybody to come back at 15 minutes after the hour.

(Whereupon, at 3:04 p.m., the above-entitled matter recessed and reconvened at 3:16 p.m.)

CHAIR FAULKNER: On the record. All right. Let's go. I'm going to wait for a couple more panel members to show up. All right. People are coming back in. We're now going to go to the session on Research and Instructional Practices. Russell Gersten, Deborah Ball and Skip Fennell collaborated on planning this session. I want to acknowledge their work.

The presentations will consist of two 30-minute presentations and 30 minutes of Q&A. We have Thomas Good, Professor and Head of Educational Psychology at the University of Arizona and James Hiebert, Robert J. Barkley Professor of Education at the University of Delaware. I'm going to propose that we do this a little differently. We'll do a 30-minute presentation from Dr. Good. We'll take 15 minutes worth of questions. Then we'll go to the 30-minute presentation from Dr. Hiebert. The reason for that is Dr. Good has to depart for an airplane at 4:30 p.m. So let's go. Dr. Good.

DR. GOOD: Okay. Thank you. Thanks for the opportunity to be here to share a few ideas. I feel like I was in school today, and I've been here all day listening to all the sessions, listening to the presentations, some of it exciting, some of it less exciting. I recognize that this is just a small fraction of the amount of material that you'll be looking at and trying to integrate, and I wish you the best of luck on this important task.

The panel's work is necessarily ambitious. We have seen the less than expected outcomes of numerous reforms in American education over the past

50 years. Historically, reform efforts have been focused on such a small range of ideas that they mitigate against any meaningful reform. Some reform is focused on curriculum, but left untouched the professional development that might have helped teachers implement the intended curriculum.

Too often new curriculum units have been put forth without data to show that they would help students to understand content better than did the previous curriculum. Over time, such new adjustments quickly followed by yet again new adjustments have left many teachers with the perception that any proposed change will soon be gone. One wonders about the lack of enthusiasm for certain levels of in-service development if this is just another fad. Why become professionally committed?

I'm an educational psychologist who has spent many hours observing math teaching in K-12, especially in grades three through five. I've come to believe that good mathematics instruction varies in terms of curriculum goals, the pedagogical skills of teachers, and the mathematical knowledge of teachers and students. Different instructional formats can provide effective learning environments. Students can learn from other students as well as their teachers. There are no panaceas or preferred formats that transcend all learning context. The quality of the teaching, the quality of the teaching format, is vastly more important than the format per se.

My statement is not revolutionary, but it is supported by considerable research evidence. Whole class teaching or learner-centered instruction can be dreadful or wonderful. Yet reformers often insist upon the superiority of one single format. Despite no argument that good math teaching takes many forms, the history of reform suggests that at different points in time only certain approaches to curriculum or teaching have been defined as good teaching practice by policy makers, educators or even foundations.

Let me just take a few. Many of us will know these things. It may be less central in mind to others of us, but I've been through a few reform movements in this country. In fact, among other things, I gave testimony to the report that yielded *A Nation at Risk,* and I've noticed that every commission that has looked at reform has become identified with a particular format, shibboleth or a slogan that you can use to characterize the work of the panel. I hope that this will not be another silver bullet that is suggested but rather a coordinated set of recommendations that affect instruction, evaluation, technology, learning and various issues.

I do think it's useful to go through a few reforms quickly, not to be cynical or to be less than optimistic, but just to say that many of us have faced these decisions in the past and the history of reform including math reform in this country is not spectacular. I review but just a few of these movements.

Recall the Sputnik crisis. Many in the country assumed that this demonstrated that American classrooms were so weak in math and science that it left us at military peril. The policy responses to this threat were to radically reform the mathematics curriculum and to introduce abstract set theory, new math, to whole classes of students as a solution to our scientific problems. Set theory was quite different than the mathematics of the day, and it is arguable that we won the space war largely with scientists and mathematicians who were trained in the 1940s and who had not studied new math.

Some have felt very strongly about the movement at faddism in education. I cite just one person who commented. There are many of these that I've included in an appendix. This happened to be a physicist who was reacting to new math. "In many ways, the new math movement has the character of the children's crusade of the Middle Ages. It was recognized as such as many responsible educators but is difficult to stop because of the very large and tightly-net web of vested interest preying on the mathematical unsophistication of the press, the public, and the foundations themselves." It goes on to ask for "evidence and research in terms of the use of reform." Not a bad idea, I think.

Reform in the 1960s became interested in more individualized instruction. Students learned at different rates. We should recognize this. We should build it into schools and curriculums. This sounds pretty good too. Technologies were identified, emerging technologies, to do this. However within a few years, less than a decade, educators' interests in individualized education had moved from individualized education to humanistic, open education so that students would not be isolated learners but they would be part of a community. Also the open school movement, there was a notion that students should be given incredible amounts of choice so that they could become committed to their learning and then in time to become more integrative, creative and more powerful learners. Need I say that the open classroom movement came and disappeared fairly quickly.

This came to *A Nation at Risk* following the shopping mall high school, which showed that surprisingly high school students when given many choices sometimes made bad choices. So what did *A Nation at Risk* do? Well, we called for more adult control, more structure, more content. In 1983, *A Nation at Risk* sounded the alarm that American was in economic peril because our students' education was inferior to that in Germany, Japan and elsewhere. This reform movement called for more, more, more. It called for more instruction in core academic subjects, longer school days, longer school years, more homework and so forth. The economic war was soon won by businessmen and women who had not received the educational value of the more curriculum.

Again, my point here in just quickly going through these and, as you know, I could go through many more movements. It is not to be cynical but just to suggest that there really are complex issues and that the reform can only take place through coordinated and, I believe, small steps. It can only happen through a series of coordinated changes in the curriculum rather than revolutionary changes that take away some of the best of the curriculum as we add more and more.

Why have these reform efforts failed? First, these reform efforts have largely focused on discrete concerns, curriculum or teaching format, technology or no technology, the quality of teachers' characteristics or their practices, student motivation or volition, earlier induced through choice now through accountability and fear, teacher-centered instruction or student-centered instruction. Second and again, as I noted at the beginning, I applaud the committee and its ambitious agenda that is moving beyond these either or things and trying to deal with a lot of things.

It's hard to keep in mind because we get so committed to single variables, but I think the hardest thing to recognize, deal with and stay with is that no single variable or any set of variables have any independent effect on student learning. None. Absolutely none. Maybe time, but even that's problematic.

Teacher characteristics are mediated by teaching practices, which are mediated by student characteristics which in turn are mediated by those opportunities that students have to apply content, concepts, and so forth. The usefulness of the variable depends upon both the quality and how it fits into a learning system.

If, for example, we talk about multiple choice, research shows that homework has what effect on learners? (A) It lowers student attitudes. (B) It improves students' achievement. (C) It lowers student achievement. (D) It improves student attitudes. (E) All of the above. The answer is (E), all of the above. Research has shown that under certain conditions, depending upon the quality and how homework is used or not used as part of the system, it can have all of these effects. So the research is for what is the quality. How does it fit into a learning system? It's not a single variable, but variables in combination have impact on students' learning. Single variables are popular among reformers. I hope that doesn't happen with this panel.

Let me just give you another example. This one is sort of playful, but I think it helps to make the point. Another variable that recently garnered much media attention is fun. Should math be fun? Should it be personally relevant? The effects of fun on learning were recently examined in an international study.

But I ask another question. I mean we can look at all of these variables if we want to, but why should math be fun? Is there any theory or research to suggest that enjoyment and math proficiency are highly correlated? I enjoy singing and listening to music, but I do not sing well. Would you want me to sing to you now simply because I like singing?

Probably not, if you're wise. Did I enjoy preparing this paper? I did not. Does homework need to be fun to facilitate learning? Apparently, educators suggest the need for fun have not studied the whole class movement that I referred to earlier, refining personal relevancy we're defining characteristics of the reform. I could continue to examine the futility of single variable reforms, but my point has been made. Single variables, although potentially useful, have meaning only as part of an instructional system.

Now I'll make a few comments about improving mathematics instruction coupled with of course better curriculum, better technology, better testing and so forth. I comment upon only a few instructional issues and opportunities in grades three and five mathematics classes. First its scope may seem limited, but personally it's the scope that I've taken. I would also argue that we're seeing again and again that mathematics students that are lost in grades three and five, and we lose a lot in grades three and four, will not take advantages of the reforms that come later. This is not to take away from those needed important reforms that will occur later, but just to say that the focus of my thinking in this presentation is for students in three to five.

The most important predictor of learning or opportunity to learn is time needed to learn. Given this important principle, it is critical to ask that we allocate enough time for mathematics instruction in grades three to five. The answer is a resounding no, although many fear that the effects of NCLB would be to reduce the elementary school curriculum to only the study of reading and math. These predictions were only 50 percent correct.

There is striking and recent evidence to suggest the elementary school curriculum has become a literacy curriculum. In one national study, nice sample, one national study, one large state study, it was found that time spent on mathematics instruction in grades three, four and five was less than the time spent in transition between subjects. Robert Pianta and his colleagues National Institute of Child Health and Development (NICHD) 2004 described what took place in a single day in 780 third grade classrooms sampled from about 250 school districts. He found that over half the time available was spent on literacy instruction. The ratio of time committed to other activities were mathematics 0.29, transitions 0.24, science 0.06, technology 0.03 and free time, students choosing actual tasks of their own, 0.008. Hard to think when you don't have time to think or to make decisions.

In a study of grade three in one state, 145 teachers were visited 447 times. Overall 2,736 ten-minute intervals of observational data were collected. Of these, since it's a good math group you can do the math, 2,736 ten-minute intervals of observation data were collected. Of these, 587 were devoted to math, 1,642 to literacy, not arguing at this time that literacy is not needed, but we're looking at 3:1 ratios and our literacy scores are going down. We might wonder about some of the use of that time. But in all seriousness, if we're going to improve mathematics instruction, I think we have to understand its role in the curriculum, how much time is being allocated and what is normative practice in order to think about how we might improve normative practice. It seems important to understand it to begin with.

The amount of time allocated for math instruction is further reduced by the fact that time spent during the math period is not always spent on math instruction. Research for a long time has shown that teachers vary enormously in their use of time. In some cases as much as 50 percent of the available instructional time is spent on such things as announcements, housekeeping, and so forth. Also we have time spread across content area, and I think this is an important topic. No advocacy here. Just description.

Time issues have intensified for grades three to five teachers because in the last 20 years more ambitious math content has been recommended for inclusion. For example, topics and activities like estimation, measurement, problem solving, statistics, calculator usage, and computer usage have been added to the curriculum. However, nothing has been taken away from the curriculum. We're still doing division with remainders. We're doing multiplication, operations, number facts and so forth. So the last 20 years we've added a lot to the curriculum but nothing has been removed.

Thus, teachers today spend less time on computational activities and instructions than they did 20 years ago. This is because the breadth of the curriculum has expanded and time has remained constant. It is not surprising that elementary school students' computational proficiency has dropped in important ways in recent studies. This is not an argument against teaching more content. It is an argument for increasing the amount of allocated time for math and instruction. If time cannot be increased, then the curriculum must be reduced. Spreading the same amount of instructional time over more and more content guarantees that teachers cannot touch, let alone teach, content included in the math curriculum. Increasing the time of mathematics instruction by even 15 minutes a day is an easy, straightforward and inexpensive policy action that might have policy impact.

Studying the normative curriculum. In addition to time, what happens in instruction? What are we doing? So if we had more time for instruction, how would we use that time and I think one way to answer it is to look at how time is being used at present. Data from the National Institute of Child Health and Development (NICHD) study 2005 of third grade classes, as well as an earlier study from that same group of a national sample of first grade classrooms in 2003, reveal that the focus of instruction in most classes was basic skill instruction. The ratio of basic skill instruction to analysis and inference opportunities was roughly 11 to 1.

McKaslin, et al., in another study, a state study found that the focus in grades three to five was on basic skill instruction. In mathematics in a separate study of how the time was being used, students were virtually never asked to engage in tasks that involved higher order thinking and reasoning.

Rather students were three times more likely to engage basic facts and skills in relationship to tasks that also included basic facts and related thinking. Not so much that the focus is on basic facts, it's just that it's in the present tense. There's not a forward looking integration of how this is being used. It's almost being taught as separate topics in and of themselves.

Furthermore, McKaslin, et al., found that students did not make observable decisions in classrooms largely because they did not have the opportunity to do so. In our research, we found that in only four percent of observations were students allowed to make any choice, and choices, when allowed, were in procedural areas rather than in opportunities for autonomy. Importantly, students typically earned opportunities for choice in over 50 percent of the occasions coded. Choice was contingent upon successful completion of something else. When you finish your problem solving activities, you can do X. If time allows, I'll come back to this issue later and discuss the potential value of increasing students’ contingent choice and argue that earned contingent choice differs markedly from the do-as-you-please choice opportunities associated with the open classroom movement of the 1970s.

So the review of the normative curriculum shows that most instruction is focused in the present on skill and how we could make this activity more meaningful. Well, in this group, I would probably only have to mention Brownell, 1947 and earlier work and all sorts of strategies would come to mind. I'm not revolutionary. That's not a new idea, but it's a solid, sound idea. Anything that we can do to make mathematics meaningful is important.

Doug Grouse and I addressed this issue some in the 1970s in terms of how to make mathematics more meaningful so as to increase student learning. As I told you, I've been around and seen a few of these reforms come and go. This research supported by the National Institute of Education became known in time as the Missouri Math Project, MMP. The conception of the research methods and findings can be readily obtained elsewhere.

Doug and I addressed two goals in this project. First, we wanted to assess the degree of teacher effects on student learning. After establishing a strong correlational link between teaching practices and student achievement, we then pursued a second goal. Can these practices and beliefs be taught to other teachers in ways that improve students' achievement in comparison to students in matched control groups? We found in experimental work that the treatment had an important impact on student achievement.

Building the treatment, we drew upon our correlational work that described how teachers who obtained high student achievement scores taught differently than did teachers who obtained lower achievement scores from similar students under similar circumstances. Importantly, and a lot of people don't recognize this about the program, we also drew upon a small consistent set of findings in mathematics that show that the ratio of time spent on developing the meaning of the content should be greater than time spent on practice. These studies vary, but typically the studies would show that if you do 60 or 70 percent on meaning development you had much more powerful results than if you reverse it. You spent 20 percent on development and 80 percent on practice.

Although this literature that meaningful orientation allows for practice to be more coherent and the learning to be more powerful, practice at that time, and I might say extant practice still today, would show that most of the time was spent in practice. The kids were basically working on practice. Our goal was to see if we could increase the time that teachers and students spent discussing the meaning of the math they studied so that application would be more powerful in the seatwork. In general, there were a lot of aspects of the treatment and they are detailed elsewhere. Teachers would implement the treatment trying to change normality practice. The development, the meaning portion of the lesson was more problematic in the extent to which we could get all teachers to do it and to do it well. They made some improvement.

Clearly then, we would conclude that more work on the variable of how to develop mathematical meaning whether coming from teachers, students or both was needed. But we had at least made a dent in the problem. Others have implemented the Millennium Math Project (MMP) and have reported positive impact on student achievement in other experimental studies and some have adjusted the treatment for successful application in other settings.

Publication of our findings was met with enthusiasm in many quarters. Others rejected our findings out of hand and criticized our conception of practice as too narrow. Some of these concerns were legitimate but many were political. The notion of active teaching was no longer on the preferred how to teach menu that teacher educators served. Although teachers and policy makers were markedly favorable to our findings, teacher educators as a group were generally dismissive.

Teacher educators' view of what normative practice should look like differed from our findings. There is no reason to relive the mid `80s and the `90s, but I do want to say that our basic claim was that MMP project was a good way, not the only way, to teach math concepts as opposed to problem solving and other types of mathematics. Further, by using two different ways to classify students and one analytical way to measure teacher characteristics and beliefs, we found that differences in teachers and student preferences mediated treatment effects. Although largely ignored by critics, those published data showed that MMP treatment was mediated by teacher and student beliefs. Those findings invited basic research on how and why the MMP treatment could be modified to benefit more students.

I mention this because one criticism of MMP was that it was insensitive to teacher and students' beliefs. My goal here is not to pull MMP off the shelf, but I do want to argue that many teacher educators have woefully underutilized the role of explicit teaching. As important as it is however, explicit teaching is not enough. I do want to argue that whole class teaching under certain circumstances is extremely powerful. To echo again that for whatever reason I suspect that many teachers leave teacher educator programs without being able to conduct whole class meaningful instructions as well as I believe they should be able to do so.

Again, I'm not trying to argue that explicit teachers and the teachers make a difference. Clearly, there are a lot of variables that have to be associated with that. With Jerry Brofey and others we've outlined a series of things that have to supplement explicit teaching. Take but one and it's been mentioned here several times is the appropriate view that teachers hold for expectations for student learning. We know in a number of situations that students of different ethnicity, gender at least at one point, and other student characteristics are denied opportunity for meaningful mathematics opportunity and are given a steady diet of drill and practice. There's clear evidence to show that under appropriate conditions that active teaching including active conceptualizations of students learning and their potential can have a powerful impact on the type of mathematics that students practice, they get, and they have the opportunity to learn.

CHAIR FAULKNER: You're a minute away from your time.

DR. GOOD: Okay. What constitutes quality teaching remains under debate. I point out that the ecological complexity of the classroom shows that there's many opportunities for teachers to use formats that involve students in student-to-student learning, interactions, project work that extends over weeks and there are many ways to characterize mathematics at a meaningful level. I think one thing that's largely out of the debate now in terms of thinking about students and effective instruction, and it came up in some of the international studies to date where we were talking about the culture of teaching, the linkage that the variation within countries was less than across countries and that part of good teaching had a cultural sense and identification.

I think one of the things that we've been missing in the last decade is an understanding of students as social beings, and that's quite different than understanding them as learners. And let me just give you one quick example, and if someone asks a question I'll be happy to come back to it because it's a major theme that I hope you'll pay some attention to in the paper that you have. I was consulting with a major, very well-known group last week, a very prestigious group. They were talking about problems of getting control group teachers and getting teachers to implement treatments. They were also talking about students and what sorts of things to involve students.

I said what incentives are you giving to students, and I was looked at like why in the world. This makes no sense at all. What are you talking about? I tried to give the equally stupefied look back like you don't know, and they said we're going to give sweatshirts, and I said what kind of sweatshirts. Sweatshirts. Anybody knows that, you should know if you have a knowledge of students as social beings, that whether that sweatshirt has a hood or not, whether it has an attractive logo, whether that logo is easily available or not makes all sorts of sense to whether the kid is going to like it or whether it's going to be an insulting thing to them.

I'm using this example and I am summarizing just to say that if in fact we're going to design mathematics that includes graphing in relational understanding of things that are important to kids, we have to understand them as social beings. Students are social beings and some of the things that they think about can be more powerfully accessed through their social experiences as through abstract, intellectual experiences. Thank you. Sorry I went over my time.

CHAIR FAULKNER: Thank you, Dr. Good.

Questions? We'll take questions and comments on this presentation before we go to the next. Are there any questions? Russell, then Bob.

DR. GERSTEN: Tom, I have two questions and they're kind of related and one you've sort of answered but it will be good to deal with it for a few more seconds. You're right that the findings for the various studies were admired by many people but also not by generally the teacher math education establishment at that time. Right now, some may question, this is no longer relevant. This was approximately 30 years ago. As I recall from the study, all the teachers in the correlational study were intentionally using the same curricula so that you could look at variations in practice with a constant curricula, constant exam, district policy, etc. Some may say that it's not relevant. So I guess one question is do you see a lot of the work that you did as still being relevant for what we as a panel have to address?

DR. GOOD: I think if you take into context the student as a social learner I would really change the treatment program in a lot of ways to take advantage of that knowledge. But a couple things to point out, one, we know that the normative curriculum is still teachers teaching whole classes of students.

We may read in all sorts of journals about the exciting things that are taking place, but the figures I gave you a moment ago, technology is used in 0.03. Whole class instruction is the mode that teachers use. So I think that relevancy from research on how to make that method more meaningful and more powerful has implications for today.

But just to echo again, I'm really not trying to pull the Millennium Math Project (MMP) off the shelf. I really mean that. But I am trying to say that teacher educators as a group have undervalued for the last 25 years the role of large group directed teaching that is very explicit, and almost all the research that we have now on teachers make a difference we now know that.

In 1970, it was still debatable. We talked about home, heredity. People were saying schooling didn't make a difference. Teachers didn't make a difference. Most of the research showing that teachers make a difference is involved in teachers using large group formats in their instructional mode. So I mean this is where this data is coming from. So if you move to other areas, the role of the teacher as coach, facilitator, although arguably and theoretically important, is not demonstrated empirically. All the data that we have on teachers making a difference and how powerful it is comes from studies of teachers who differ in how they teach large groups of teachers. I shouldn't say all, virtually all of them.

DR. GERSTEN: Could I follow up?

CHAIR FAULKNER: Sure.

DR. GERSTEN: Another thing and this does really relate to the social aspects of teaching. As I recall, one key finding was development, teachers who spent time developing and discussing meaning definitely had higher achievement. It was very difficult through training to get some teachers to do that for a variety of reasons that we know more about now maybe.

But another part was that teachers who asked a lot of questions that had clear right/wrong answers, what you then called product questions, but who then gave kids feedback that asked them to think or reminded them or asked them probing questions, which tended to be an effective pattern of interaction if my memory is correct. just wanted to check that that is and why you think that might be especially because it then relates to the study that Jim and Diana Worren did years later.

DR. GOOD: Right. I think that in terms of the proficiency of the teachers to use the development lesson, we could have tapped that in other ways. That was a correlational finding, but I don't think its explanatory part is that powerful. I've heard a lot about the immediacy of feedback and the importance of feedback, and for a lot of learning that's important. But if you're going to get into thinking and reasoning with mathematics you ought to make some mistakes, too, and you have to be able to learn from your mistakes. And remember that we were talking in that program about learning academic concepts probably more important to be successful there. But if I were advocating the teaching of problem solving, I certainly would want broader questions to be asked, more opportunities for students to frame questions, reframe them and for them to have more choice. I don't know if that's helpful or not.

DR. GERSTEN: Very, very helpful. Thank you very much.

CHAIR FAULKNER: Bob.

DR. SIEGLER: I would like to ask you a question about it sounds like just a language matter but I think it's probably deeper than that.

DR. GOOD: Right.

DR. SIEGLER: So there's a rhetorical device that I hear a lot when people in education are talking that no one factor matters.

DR. GOOD: Right.

DR. SIEGLER: And yet the research that you talked about and that other people talk about show that individual factors do matter, and, indeed, if science is going to make a difference in education, you have no choice but to identify individual factors that matter as main effects and then go on to identify interactions. Time on task you were talking about is one factor that matters. Emphasis on meaning is another factor that matters.

I wonder if this kind of rhetorical style that this is a very complex system so no one factor matters, is what's really meant that no one factor is the silver bullet or is there more to the rhetoric than that? Is it really saying what it sounds like it means?

DR. GOOD: I think there's a lot more to the rhetoric that I think just as you change one variable your whole dialogue changes. If I'm talking about teaching basic skills versus teaching problem solving, the range of variables that I would look at remarkably change in terms of what might be important. Time would be one that would stay the same.

But give me an example, it might be helpful if I could take one of these things that we know that you know and that we could then talk about it because I think that the pattern of variables are just incredibly important. Now if I'm in a fourth grade classroom teaching a particular topic, can I tell you what the independent variable is? You bet.

I'm talking about a college methods course. I don't know. The treatment might be quite different. So I don't know what level of generality you're trying to get me to make. So if I'm talking about teaching as teaching, I think there are a lot of things that are important. But the caveat that I would want to keep saying is that again it's the quality of the format. I've seen small group instruction that's wonderful. I've seen it as horrible. So within the small group instruction, you can talk about six or seven variables that at the third grade level make small group instruction better or worse in a particular context.

DR. SIEGLER: To follow that up, there are certainly variables like small group instruction where it's going to be tremendously interactive and depend entirely on the quality of implementation. But if science is going to contribute, we have to produce generalizations that people cannot totally contextualize. I mean we'll never be able to say given these 500 contextual variables this is what should be done because there will never be enough research funding to proceed to that, and it seems that the kind of variables you were talking about like time on task, like meaningful connections among, say, procedures and concepts, that these are the kind of generalizations whereby science can influence education.

DR. GOOD: I would agree at that level. Again, the rhetoric I was using was mainly large group teaching, explicit teaching, active teaching, has got a bad name. So I was arguing that you could do a fourth grade lesson on division with remainders whether you have a student lesson, whether you have a teacher lesson, whether you have technology or you don't.

But I agree with the point that you're making now, and it was a point I was trying to make before in being a little cynical that the new math came and left without evidence. I was suggesting that Missouri math left with evidence. If we wanted to have a science, here was a program that was having some impact and it had a main effect. We can talk about that independent variable, but it also had interactive effects with different types of students, which is just a wonderful research opportunity. What could we do the next time to make it more powerful? So I agree with you completely. I wish that we could bring the talk of research in because we move from one thing to another without that research.

CHAIR FAULKNER: I think we're going to need to move on. So let me thank you, Dr. Good, for your contributions, and we'll move down to Dr. Hiebert.

DR. GOOD: My pleasure. Thanks for the opportunity to be here.

CHAIR FAULKNER: Thank you.

DR. HIEBERT: I would like to thank you as well for the opportunity to participate in this important process. Even at the end of a long day, I appreciate the opportunity to make a few comments.

CHAIR FAULKNER: There's more after you.

DR. HIEBERT: Wow. I would like to make just two simple points, but I hope to make them in a way that sort of underscores what I think is their importance and with some sense of urgency that we attend to these. The first is primarily just to underscore what could be the theme for the day and that is that teaching matters in terms of providing learning opportunities for students. I'd like to make a few particular comments about that. And then the second point is that how teaching matters depends at least in part on the kind of learning goals we choose. If we focus for a little time on a goal, we can all agree on which is helping students make sense of mathematics, helping students understand what they do, then there are a few key features that we can identify.

I might say that I agree with many of the comments that Tom has just made, and I think you'll see some intersection of those, some similarities between the comments that I make and those that he just made. With regard to the second point, what I'm trying to do here is sort of balance the trick of agreeing that although there is no single thing that I think is going to fix the system, I also think there are some features that are more important than others. If we want a place to look, I think we have some research basis for guiding our search.

Okay. So first of all, the point that teaching matters, one way of saying this, and it's already been said today is that all educational innovations whether it's curriculum, professional development or whatever, actually reach students through teaching. And by teaching I mean here the details of the ways that teachers and students interact about the content during classroom lessons. Unless this kind of interaction in the classroom changes, students aren't going to know the difference. We can do a lot of stuff outside the classroom, and the learning opportunities for students will remain essentially the same.

I would also like to add a caution here about the fact that teaching is not the same as teachers. Many people conflate these two ideas, and I'm guessing that it's going to be tempting for the panel to address the issue of instructional practices at least in part by describing desirable qualifications of teachers. The problem is that these qualifications don't determine the way teachers teach.

We've been teaching mathematics in much the same way in this country for as long as we have documentation. During the same time period, let's say over the last 75 to 100 years, the qualifications of teachers have changed substantially. However, the way we've been interacting about mathematics in the classroom has remained surprisingly stable. If we want to address instructional practices in the classroom, I think we need to find ways to address them directly, not indirectly.

So if we would want to do that, if we would want to look at teaching practice and think about what makes teaching effective, what would we do? First of all, I want to say that the question of what makes teaching effective is much more difficult to answer empirically than simply verifying that teaching makes a difference. What about it makes the difference? It's extremely difficult to isolate particular features that play the most important roles.

One thing we know, and I think we can safely say at this point, is that at least in the near future we won't find a single way of teaching that is the most effective. There are a lot of reasons for this, but one of them is that it appears that different features are more effective for some learning goals than for others. Now if we for a minute focus on this goal of helping students make sense of mathematics then I think we can identify a few features. I'm going to identify two that seem to be especially critical, and coincidentally Tom Good mentioned his colleague, Doug Rouse, on the Missouri project. I'm going to mention Doug's name as well because the two features I'm going to identify here are two features that emerged from a recent review of the literature that Doug Rouse and I completed.

So let's look at the two features that I think are especially important in helping students make sense of mathematics. The first one is that in some way students need to attend explicitly to mathematical relationships, to the way in which facts and procedures and representations and ideas are connected mathematically. There are a lot of ways that one could describe how this plays out in the classroom. I'm simply going to identify two.

One way to describe it is to identify particular topics, particular ideas, and particular representations that can be related in a meaningful way in the classroom. One example is to have students examine the similarities among patterns with constant rates of change, linear functions expressed in symbolic form, let's say, and straight lines on a graph. As students develop connections between those representations, they deepen their understanding of all of them. So that's one way to describe how students might attend explicitly to mathematical relationships.

Another way to describe this is to look at common pedagogical structures in the classroom. So students do mathematics often by solving problems. As students see relationships between the problems they solve in the classroom, their sense-making improves. So one example would be at the primary grade level. Someone earlier mentioned multi-digit subtraction, let's say. So students are working on problems involving subtracting numbers with more than one digit and near the end of the lesson, they come across a problem where the minuend, the top number, has a zero in it. That's a special case of the kind of problems they've been working on up that point. It's not a new problem that requires a new set of procedures. But it's not always treated that way. Different kind of problems are many times treated as unique problems that require a separate set of rules or procedures to solve them.

The second feature that I think is critical is to allow students to do some of the important mathematical work. This often takes the form in the classroom of teachers presenting students with challenging problems, appropriately challenging problems, problems that are just beyond the level of familiarity of students. They're not totally foreign to students. Students can use things they know to solve them, but it's not immediately apparent what the answer is.

One of the major threats to this kind of teaching in the classroom is a teacher's feeling uncomfortable when students are wrestling with something that they don't quite understand and jumping in too quickly to provide the solution. It's not that teachers are trying to shortchange students learning and short circuit the learning process. But I think it's often the case that students believe that this sort of struggle is similar to confusion and confusion isn't good. So my job as a teacher is to clear this up as quickly as I can.

One of the things I would like to say about these two features that I've just described, and this comes out of the work that Doug Rouse and I did, is that these seem to be robust enough that their effects are found in many different styles of teaching. This isn't a matter of proposing a particular style like teacher-centered instruction or student centered instruction, the kind of different labels that Tom Good was describing. These features are implementable in different styles, and they seem to have effects regardless of the style.

What I'd like to do now is to elaborate a little on these two features by returning to the context that we started out with early this morning and share with you one finding from the TIMSS video study that addresses the way in which these two features operate in math classrooms internationally. So just as a quick reminder, what I'm using here is the TIMSS 1999 video study, which examined about 100 8th grade mathematics lessons in seven countries, six of them higher achieving than the United States.

One of the early findings in the study is that students in all countries spend their time in mathematics class solving math problems. Over 80 percent of the time on average in these classes was spent with students solving problems, not necessarily in an ambitious sort of authentic problem solving way, but in completing mathematical problems. So how teachers work on these problems with students, what kind of problems are they, and how teachers work on them would provide some good insight into the kind of learning opportunities that were available to students.

We looked at the kind of problems students do in each of these countries, and we could reliably classify all the problems that students worked on into three very general categories. The first was called stating concepts with the emphasis on "stating" because this was essentially asking students to recall information that they had learned previously and apply it in a pretty straightforward way. An example would be what are two important properties of an equilateral triangle or could you please plot the point 3,2 on the Cartesian coordinate system.

The second kind of problem, and the kind of problem that's most common in most countries, we called using procedures. This involves students practicing procedures that they were supposed to have learned either by the teacher demonstrating, by having discussed them previously in an earlier lesson, but in some way students being familiar with the procedures.

And then the third kind of problem, which is called making connections, is a problem that has an apparent intent based on the statement of the problem for students to connect or construct relationships between ideas, facts and procedures. So obviously this is a problem that's going to play a little role here in laying out how these findings related to the two points I was just making.

What I'd like to do is to focus especially on using procedures and making connections because those are most relevant here. But before showing you the findings, I would like to elaborate a little bit on the making connections problems because of their importance. Here are two examples from two lessons in the video study. In the first problem, teachers asked students to solve these two equations and describe what is different about their solutions. What turns this into a making connections problem is the phrase "describe what is different about their solutions." So it asks students to look back and forward, look at similarities and differences between the problems, and make some connection between them. A second problem says find a pattern for the sum of the inter-angles of polygons with varying numbers of sides. "Finding the pattern" is what qualifies this as a making connections problem.

What kind of problems do countries present in an average 8th grade math problem? Here are the countries with abbreviations, Australia, Czech Republic, Hong Kong, Japan, the Netherlands, and the United States. Switzerland wasn't included in this analysis, and I'd be glad to talk about why later. If you look at these six countries, there are two things I want to point out. On the tan bar, by the way for those of you in the back that can't read, it is using procedures problems. The blue bar is the making connections problems, and this shows the percentage in an average lesson.

Two points here, Hong Kong and Japan were at the opposite ends of the spectrum in the percentage of types of problems that were presented. These were the two highest achieving countries in the sample, and they've chosen very different kinds of emphases in their classrooms in terms of percentage of problems worked. The second thing I'd like to point out is that in terms of problems presented based on their apparent intent, the U.S. is not substantially different from other high achieving countries.

When we watch the videotapes, it's clear that not the same thing is going on in these countries, that teachers are using these problems in different ways. So we went back, coded all these problems again a second time based on how they were worked on during the lesson.

This by the way is where teaching makes a difference because teachers can transform problems. How do they transform problems? Here's an example. So take the problem that was presented earlier on finding a pattern for the sum of the interior angles of a polygon. A common way that teachers could implement this problem if they wanted to retain the making connections potential of this problem would be to do something like asking students to measure the sum of the angles for a three-sided polygon, a triangle, a quadrilateral, a five-sided polygon using a protractor, add up the angles and then say look at those three results. What do you think might happen in a six-sided polygon? A ten-sided polygon? A N-sided polygon? Students can work on this in many cases depending on their level and what they've had before. Students can work out a general relationship between the number of sides in a polygon and the sum of the interior angles.

Alternatively, teachers can say what I'd like to do is give you a procedure for finding the sum of the interior angles of a polygon and you'll notice that if you subtract two from the sides and multiply by 180 you get the sum. Now go ahead and check this out on three-side, four-sided, five-sided, and so on. These are obviously very different ways to implement the problem. But the important thing is that students are doing different kinds of mathematics. They are reasoning differently and in particular in the first implementation, they have an opportunity to engage in the two features I identified earlier that is to make connections, find relationships and to do some of the mathematical work. In the second implementation, they have an opportunity to do arithmetic but that's essentially all and it takes away the mathematical work from the students.

So how do countries implement these kinds of problems? Here again is the slide showing the percentage of problems as they were presented. What I would like to do is to look at just the making connections problems to follow those into the classroom and see how they were implemented.

Again, there are two points I would like to make from this graph. One is that in the United States and that's sort of start finding that happens so often that it rounds to zero. Essentially teachers transform all of these problems into something else, and I'll fill out this graph in just a minute.

The second thing I would like to point out is that before Hong Kong and Japan looked very different. Here they look identical and they look very similar to the other high achieving countries in this sample. In other words, although the other high achieving countries teach in very different ways and have different emphases when they present these kinds of problems to students, they agree about how to implement them.

Just for completeness, let me show the next graph. If we add back in the stating concepts category and if we add a fourth category, which was required in order to classify all of the problems once you look at how they're implemented and the category was "just give the student the answer," then you get this graph. Again, the U.S. is an outlier. The higher achieving countries, the Czech Republic, Hong Kong, Japan and the Netherlands have very similar profiles.

So what does this mean? Let me just repeat that although high achieving countries displayed different styles of teaching they shared a relative emphasis on implementing making connections problems as implementing making connections. This includes attending explicitly to key relationships and allowing students to do important mathematical work. These are exactly the two features that disappear from

U.S. mathematics teaching. One of the points to add is that although good curricula, I think are absolutely essential, they're not enough because teachers transform curricula, because students experience the way teachers teach, not the way the curricula was intended.

So one might ask why are these features absent from U.S. math teaching. First of all, this is not a new finding. As I mentioned before, we've been teaching very much the same way for years and all of the earlier reports describe teaching much the same as we saw on the videotape. I think one of the reasons that it hasn't changed, one of the reasons, is that in fact teaching is deeply embedded in our culture. Most teachers learn how to teach by being students in classrooms and watching their teachers so that the ways we teach get handed down from generation to generation.

I'd like to also mention another finding from the video study that's relevant here and that is that teachers filled out a questionnaire about their backgrounds, their qualifications and so on. There was great variety of teachers of 8th grade. A number of 8th grade teachers indicated qualifications that most people would agree would put them in a highly qualified category. They taught just the way their peers did. So although again, I think academic qualifications are critical, the better teachers we can recruit the better, that's not enough. Teachers are inclined to teach the way they were taught and we need to figure out a way to break this cycle.

So let me conclude by suggesting just a few thoughts about changing teaching and how this might happen. First of all, I think we have to be realistic and say that it happens gradually. Any deeply embedded cultural practice happens slowly. Changes in that practice happens slowly. For one thing, I think if we're serious about this, we need to develop a consensus about the key learning goals for students and we need to keep them in place for a long enough time that we can learn how to teach effectively in order to help reach them. So we need to have a stable set of goals.

Secondly, I think we need to continue contributing to the knowledge base about what effective teaching toward that goal looks like. I think we're somewhere on the way but we certainly can refine the kind of description I was giving today. We need to find levers for helping both teachers and students respond positively to changes in teaching practices. In other words, we need to get their buy-in, not just from teachers but from students as well.

Teachers often say that if they come into the classroom and teach differently students don't like it. That's absolutely true. So we need to get buy-in from both teachers and students.

And finally, in the end, it's teachers that need to do this work. Teachers teach. That's what they do. If we're going to change teaching, teachers are the ones that have to do it. No one can do it for them. But it's really hard work. So they're going to need a lot of support and assistance in changing their practice. Thank you very much.

CHAIR FAULKNER: Thank you, Dr. Hiebert. Let's go to questions and answers. Tom.

DR. LOVELESS: I have a couple of questions about this idea attacking a problem as a procedural issue as opposed to making connections and especially in regards to the TIMSS video study. The first point, I know that in the video studies no achievement data were collected.

DR. HIEBERT: That's correct. Not on the particular classrooms that were included in the video study.

DR. LOVELESS: Right. So the data that were collected were observations of teachers teaching and students doing the work that teachers had them do but no achievement data were collected. Therefore, I have some doubt about making any causal claims that one particular way of teaching is more productive than another way of teaching. Am I safe to say that?

DR. HIEBERT: I would say. Yes -- go ahead.

DR. LOVELESS: What we can say is that in the high achieving countries we found a certain way of teaching that was dominant. In the lower achieving countries we found another way of teaching that was particularly dominant. But what we can't say is that their high achievement was due to that particular way of teaching.

DR. HIEBERT: No, but could I even problematize the comment you made earlier that was just made in high achieving countries we found a dominant way of teaching. I think we only found a few features that were shared widely among high achieving countries. If you look at the videotapes, the styles of teaching are really quite different.

DR. LOVELESS: Okay. I'll be more specific then. In the bar graphs that you showed, what reassurance do we have that it's that particular instructional approach that's leading to those countries being high achievers?

DR. HIEBERT: Right. We have no data to make causal effect claims about the data that you saw internationally and the achievement internationally. I think what raises their salients is the fact that if you look at research from a variety over a fairly long period of time both in this country and elsewhere, it's those same two features come bubbling to the top as candidates for features that are playing an especially important role.

DR. LOVELESS: But the data themselves don't tell us which of those two teaching styles is necessarily going to lead to higher achievement.

DR. HIEBERT: No, absolutely not. Right. Internationally.

DR. LOVELESS: In the videotape.

DR. HIEBERT: Yes.

DR. LOVELESS: Then the second question I have deals with the example that you gave of measuring the sum of interior angles of a polygon. The second example, the procedural approach. If a teacher just presented the formula, explained the connections to students, have them practice, perhaps even question the students through Socratic methods, how would that work out in comparison to the other approach? Would you code that as procedural when you're doing your video studies? Would that be coded as procedural or would it be coded as making connections?

DR. HIEBERT: In order to qualify for a

problem being implemented as making connections, there needed to be some explicit time in the lesson where students or teachers or both made clear what the important connections were and it could be done in a lecture style format. It could be done in an inquiry-based approach. So I think in your description that would have counted as implementing the problem as making connections.

DR. LOVELESS: Okay. So the students don't have to discover for instance in this.

DR. HIEBERT: No. It didn't really have to do with discovery. Right.

DR. LOVELESS: Thanks.

CHAIR FAULKNER: We're going to Bob, then Sandra, then Valerie.

DR. SIEGLER: I think that this interior angles of a polygons problem is a really fascinating case for getting at a rather general point and that is the sort of grain size that's needed to connect observational data with teaching implementations. When I thought about this example, which sounds incredibly familiar with what I remember from school at this level, there are at least four different reasons that you might get the difference between teaching in the U.S. and teaching in the high achieving countries that would have drastically different implications for what the remedy would be. So one of these is that depending how many math courses teachers' transcripts say they've taken, they may not know the relevant math. So one thing that might be done would be to actually give these problems to teachers and see how many of them could solve them. My reading of the Praxis' results is probably not such a high percentage. So if that were the problem or one problem, you would want to beef up their understanding of this kind of procedure so that they can make the connections.

Another possibility is that teachers do have the relevant understanding but they don't think that students do and maybe students really don't. So those are actually two different possibilities. One is that the teachers could teach that way but the students wouldn't benefit. Another possibility is that the teachers could teach that way and the students would benefit but the teachers have a misperception about whether the students would benefit. Then another possibility is just that the teachers have never imagined teaching in this way because they weren't taught that way. If you said to them you might try teaching in a way where you make the connections between the concepts and the procedures and you explain what that means, maybe they could say that's what I ought to do.

So do we have any idea which one or more than one of these examples is actually responsible for the phenomenon that differentiates the U.S. teaching from the high achieving countries on this kind of making connections?

DR. HIEBERT: We certainly don't have data. I can't give you a percentage breakdown that would fit into each of your four categories, but I can comment on them because we can infer a few things. One is, first of all I would suggest that all of those might be in play for different teachers under different conditions. So I would guess that all four might be candidates for further investigation. But with regard to your first, I don't remember all the four but I can address it.

With regard to the first one about whether the teachers might not have the content knowledge to be able to do this, it's clear in the video study that some teachers certainly should have had the content knowledge based on their academic preparation to do this. We didn't test their knowledge directly on the sum of the interior angles of a polygon. But based on their academic preparation, one would have expected them to do this.

The fact that a percentage of teachers

seem to be well qualified to teach 8th grade mathematics, but didn't play out, not necessarily this particular problem but any of those making connections problems, in that way, I would suggest says that it's not the whole problem. It may be the problem for some teachers. It's not the problem for others.

I think it's likely that for some teachers it's the last one you mentioned. They simply don't know. They don't have a model of what teaching this kind of a problem might look like, what the alternatives are. So I think that although sometimes we would like to explain the problems teachers have in a classroom it's just that they're incapable of doing it, I think it's equally likely that they simply haven't learned how to teach in another way or that some teachers might believe that the other way is not the way to teach.

One thing that was apparent from watching teachers in the video study is that teachers in the U.S. get very uncomfortable with student confusion, if there is any question. One simple heuristic or rule of thumb that I noticed was most American teachers can stand two questions on the same problem, but not three. So if they're walking around when students are doing seat work and the first student asks about question 23 and then the second student asks about question 23, the teacher becomes visibly uncomfortable that two students have now asked about the same one and as soon as a third student asks about it, they go to the board and say, "Sorry but there's been a lot of confusion about number 23. So let me go through that one a little bit more." So I think it's a belief about the way mathematics gets done most efficiently that also plays into it.

CHAIR FAULKNER: Okay. Let's go to Sandra.

DR. STOTSKY: My question is one of clarification. I have one of the pages handed out this morning from the talk. I think this was from Dr. Stigler and it talked about teacher time spent lecturing in these different countries at grade eight and it ranges from 18 percent in the U.S. to 42 percent in Chinese. Then I'm looking at your finding here at 80 percent of lesson time in every country is spent working on math problems which was apparently with the students. I'm trying to put those two together and I'm not sure if we're talking about the same classrooms.

DR. HIEBERT: We aren't talking about the same classrooms. In fact, I think the first percentage as you mentioned came from the questionnaires that the larger TIMSS sample of teachers filled out, not the video studies.

DR. STOTSKY: Right. These are teacher reports. No, these are teacher reports of how they spend their time.

DR. HIEBERT: Right.

DR. STOTSKY: And then here are videos. So we're getting enormous discrepancy there.

DR. HIEBERT: I'm not sure that it's enormous discrepancy because I'm not sure how teachers respond to the questionnaires about their teaching style. But for example, a very common way of teaching that we see and this is true across countries, is what could be called a lecture but it could also be called recitation. It could be called demonstration. So when a teacher is in front of a classroom demonstrating how to solve a problem they often will ask students a short answer and what should I do here and what should I do here. But it's the teacher doing most of the talking. Some teachers may describe that as a lecture. We would have coded that as the students were working on a problem at that time if they were asked to do a piece of the problem. So it may get coded both ways depending on the particular style that it's delivered in.

CHAIR FAULKNER: Vern.

MR. WILLIAMS: It's been awhile since the interior angle problem was on the screen, but I'll remember as much of it as I can. I don't think it's a great example of making connections the very first way that it was done. Basically what happens is you put kids in groups, you pass our protractors, they measure angles, maybe they'll measure the angles of the triangle, then quadrilateral, pentagon, etc. and they find this pattern. And I wonder if they would understand why the pattern is going to continue or that they just found the pattern. Whereas if you use the formula and try to have them justify the formula, perhaps you should start at a point and create as many triangles as you can or diagonals as you can, if they of course know that there's 180 degrees in the sum of the angles of the triangle which can also be justified. Once they establish the pattern there, they can prove it, justify it.

So I think more quality teaching or presentation of the problem happens with the second version than with the first version. But when it's presented, it seems like the connections are made in the first way, but not in the second.

DR. HIEBERT: You know my initial reaction to this is this is exactly the kind of discussion we should be having about what makes good teaching because there are a lot of interesting questions that you raise and it's to me, the point I was trying to make with that example. There are common ways in which teachers might work on that problem that would have been classified in our coding scheme as making connections.

There are also common ways that would have been classified as using procedures and those were illustrations of those. Whether you could take either of those and make it meaningful to students, I think absolutely you could. If you took the second one and did what you were describing, it would have been classified differently in our system.

But the question that's most interesting to me is suppose you would start at either end of that. What could you do with students in the way you interact with them about mathematics that might present them with interesting learning opportunities? If we could begin having that kind of discussion, I think we would be well on our way to attending to teaching in the way it deserves. I think we often don't get to that level of detail.

MR. WILLIAMS: The only reason I brought that up is that it seems as though lately most people or many people in the education community believe that students can't make connections unless they are cutting out something, measuring something, coloring something or doing something physical and I just totally disagree with that premise. I think they can make connections abstractly through examples at the board without having to physically engage in stuff.

DR. HIEBERT: Yes. I absolutely agree.

CHAIR FAULKNER: Wu.

DR. WU: Thanks, Jim, for the presentation. I am not going to ask a question but I hope I'm allowed to make a comment. I've been quite uncomfortable throughout this whole discussion about interior angles of a polygon and I finally decided that maybe something should be said in honor of the subject.

I am somewhat surprised. I don't quite know the right word to say without being impolite. What happens here is a case of partial understanding of mathematics, partial presentation of mathematics, perpetuated in a particular culture. This is now taken to be the norm so that the minimal, very, very minimal, basic minimum amount of mathematical information is being taught. You have to explain to students, you have to let them understand why that formula is correct which of course now you call it making connections, whatever it is. That knowledge is supposed to be retrieved from that international study.

The mathematical committee would say you don't have to consult anyone. If you want to teach mathematics, you have to teach the minimal amount of correct information and that minimal amount of correct information includes in particular when you present a formula like that you say why it is true. Until you've done that you are not finished teaching. How you teach it doesn't matter. It could be a takeoff from what Vern said, but I might slightly disagree with him. If I were the teacher and if time allowed, I would give them a pentagon, a quadrilateral and then draw the diagonals and then say a quadrilateral has two triangles, what we call a triangulation in technical language. A pentagon has three triangles and so on. A hexagon has four and so you add up all the angles and then when you add up those angles, it would turn up to be the angles of the interior angles. Well, you'd better start with the convex problem and make it understandable.

Yes, it could be discovered. You provide all the hints and then the students make a minimum amount and make them feel good. That's great. They have to feel good. But my point is that if there were close collaboration between mathematicians, competent mathematicians anyway, worth educating community on these problems, they would not solve the problems of mathematics education but we could have started at a much higher level. These things wouldn’t be taken for granted and we go on from there.

But now we seem to be reinventing the wheel and saying these are great things. In fact, these are the absolute rock bottom minimum. That's all.

DR. HIEBERT: I'm not sure how I should respond except to say --

DR. WU: (Off the microphone.) It is not a comment for you. I'm just stating the state of mathematics education. The fact that we are now at the stage where the minimum amount of knowledge, it has to be rediscovered whether it is in fact if there has been constant communication between the two communities, this should have been the starting point rather than to be one of the high points of a recent discovery.

DR. HIEBERT: The discovery I think is that this kind of teaching in 8th grade simply doesn't happen in the United States.

DR. WU: That's what I mean. That is exactly my point.

DR. HIEBERT: And that if we're going to change it we need to address it directly not somehow through the back door indirectly by either upgrading the curriculum, changing the qualifications of teachers. I think that isn't going to change how they work on a problem like that with their students.

DR. WU: I'm sorry. I'll take just one more minute, Larry. Perhaps I didn't make myself clear. What I'm saying is this should have been the starting point of our discussion because this is a no-brainer for mathematicians, well fairly competent mathematicians anyway. So our efforts should be saying our teachers should be learning this. If they don't, our in-service professional development is in grave trouble. Let's reform it. Let's do something better. But it seems to have taken a Trends in Mathematics and Science Study (TIMSS) to uncover this fact, no not this particular fact, but the general idea that whenever you present you need an explanation. You need support. You need reasons for it. That to us is the basic rock bottom minimum and why should this be discovered through an international study.

So this is not a comment about your presentation, not at all. I'm just saying that we're at this stage where something totally obvious would have had both communities in communication, and now we always seem to be striving to reach the place that should have been the starting point for the discussion.

CHAIR FAULKNER: Do you have any further comments on that?

DR. HIEBERT: No. I think it's a serious problem that we all need to work on together. Absolutely.

CHAIR FAULKNER: Okay. Deborah is in line here and we actually need to finish with Deborah, but we can take two more questions. Go ahead, Deborah.

DR. BALL: Okay. I want to say that I would like to echo your last comment, Jim, and you used what Wu was talking about as a jumping off point because on one hand, he's making a broader set of comments that aren't related particularly to what you just said. One thing that both of you are talking about that's critical for our work is the interplay of mathematical content in particular, particular ways of teaching and I would add in your case particular ways of studying it. I think yours is the first presentation we've had that demonstrated incredible care with attempts to code actual instructional practice and Tom questioned you a bit about how you code it.

There could be disagreements about how you code it. I know from having talked with you how much difficulty it was in developing this, but how careful that team was. I'm wondering about whether you might give us advice about the fact that most of instructional data that we're going to have available is extremely indirect, either self-report or less than that, observers, impressions or feelings about things. How might you, given what you just urged us, how might we try to make some headway on what this group might say that's in the spirit of sensible attention to content and instructional practice that moves beyond these debates? This is what we've been hearing all day. I think it's perfect that you're last. Do you have advice for us about where we might look to inform our work in such a way that we could make reasoned and analytic comments about mathematical content and instructional work?

DR. HIEBERT: Maybe we should have ended before this question?

(Laughter.)

DR. BALL: And if this is, if y u can advise us not necessarily in this moment that would o be fine. This is what we most need.

DR. HIEBERT: Can you repeat the phrase about content and instruction?

DR. BALL: Specific content. You made an attempt to talk about the very specific aspects of mathematical work. Now we can disagree. People got into disagreements of what the teacher should do. That's not my question.

DR. HIEBERT: Okay.

DR. BALL: My question is detailed research that puts together specificity about the content with specific detail about instruction. Like all day we've been hearing about lecture, but then hearing from you and we all know this lecture can mean a thousand things. I wanted to ask Tom what he meant by "explicit." Explicit about what? I mean how can we make some headway and if this is too large a question. I want to invite you to send us advice about this because there is a posity of this and we're becoming in flooded with lots of comments about how to improve math education but yours is one of the few presentations we've heard that led us to specifics about content instruction. That's not to speak to whether anyone agrees with the problem that you were just describing, but research that could help us on this point because I think you're right, in the sense that we have to work on that.

CHAIR FAULKNER: Answer briefly.

DR. HIEBERT: Okay. I would like to take your invitation to think about it and send you comments later.

CHAIR FAULKNER: That's a good answer.

(Laughter.)

CHAIR FAULKNER: We're going to take two more questions. Liping and Russell.

DR. MA: (Off the microphone.) I just called --

CHAIR FAULKNER: Turn on your microphone, Liping. Microphone Liping.

DR. MA: Maybe I talked myself after sometime.

CHAIR FAULKNER: No, that's okay. Go ahead. You haven't asked a question.

DR. MA: Yes. I just want to pick up from Vern's comment about that problem of polygon. I feel that these two examples may cause some misleading. I would suggest to you to add something at the second example by only giving the formula without discussion because I totally agree with Vern's comments and I also noticed that your work is very influential and very important. So by making that case more specific will cause less misleading.

DR. HIEBERT: Thank you. That's a good suggestion and let me just repeat that the last thing I wanted to do was to raise the debate between discovery learning and direct instruction. The reason those were up there as examples is that they came from the video studies. But in general, I absolutely agree with our discussion about what makes for productive learning in one case and not in the other.

CHAIR FAULKNER: Okay, Russell. You get the last question.

DR. GERSTEN: Yes, and this is really just a comment and it's not going to be hard because. I think what was very interesting about your exchange with my friend and colleague, Wu, is there was agreement on a lot. One of my hopes with this panel is that we advance the field a little bit, that we use different terms. Some of Tom Good's terms come from a different era, but that we all agree the way of teaching, just putting this formula on the board and saying guys, do these dozen problems, is not mathematics. There's not a reason for doing it. There's no principle. It's terrible and something else is better. So you presented an example from the actual videos that seemed better than that. Wu is providing guidance of something.

That teacher at least was immersing kids in it so that they would have a sense what this formula meant whether they discovered or the teacher intervened after awhile. They were thinking about this issue. Wu came up with something which I think has been raised more like guided discovery, but it again was basically turning this into a mathematical lesson which is what Tom was getting at by this loosely defined development explicit that somebody is in there helping kids make meaning.

So I think we're all going to make mistakes and get each other agitated. But I saw the beginnings of some good faith here because we can't rewrite history and so I feel good about the exchange in the long haul.

DR. HIEBERT: People try to rewrite history all the time.

(Laughter.)

DR. GERSTEN: They try it.

CHAIR FAULKNER: Do you have any closing comments, Dr. Hiebert?

DR. HIEBERT: No. Thank you very much.

(Laughter and applause.)

CHAIR FAULKNER: Thank you for your comments. That closes this session. Now we have our task group reporting session yet to go, but I think people have been sitting for a long time. I'm going to allow you to stand up for five minutes and then you can come back. Off the record.

(Whereupon, at 4:54 p.m., the above-entitled matter recessed and reconvened at 5:00 p.m.)

CHAIR FAULKNER: On the record. Let's go ahead and start getting back into place.

(Off the record comments.)

CHAIR FAULKNER: All right. Let's go ahead and get ready. We're in the home stretch here. Let me ask you to get back in your places please. We're about ready to start. We are in our closing session for the afternoon here and the purpose of this is actually for the task groups to report. For the benefit of the public audience, much of the work of this panel is going on in subdivided groups that are devoted to different topics and we will come back periodically and have those task groups report in open session and that's what we're about to do.

I want to thank the panel members for their help in organizing the sessions we have just gone through. I think they have been productive sessions of testimony. We probably had all we can handle for one day, but we have had a productive period. I also want to thank all the presenters. Many are already gone, but I can express our thanks anyway.

We are going through progress reports on task groups. We'll do four of them. There are staff members who are supporting those task groups and I want to thank them for their work. Let's begin with the Task Group on Conceptual Knowledge and Skills which is Skip Fennell's task group and he will report if he turns on his microphone.

DR. FENNELL: Thank you. Our work dealing with Conceptual Knowledge and Skills leading to algebra has been driven at least lately by some work by the Science and Technology Policy Institute where we asked them to conduct essentially five different layers of analysis based on some of our questions. That work was provided through funding by the Office of Science and Technology Policy (OSTP) and the project leaders are Pam Flattau and Nyema Mitchell. I think they may have left by now and there are five areas.

The first one dealt with algebra and we did an analysis of content topics from a sample of algebra textbooks and also looked back historically at algebra, in fact the year 1913 to the present. We conducted a content analysis of state-based curriculum frameworks specifically within algebra in the 22 states in this country that have specific frameworks. We also analyzed algebra as it's pulled out of the Singapore curriculum, teased out of an integrated curriculum.

Some of our findings in that work, the content of commercial textbooks in algebra has frankly changed very little in 50 years with the exception of what I sort of personally refer to as the Tom Loveless phrase of "bloating." That is a lot of pages that are color and photo and activities and the like but also and importantly additional information on probability, statistics, reasoning and proof, which some would argue are not necessarily algebra.

We certainly saw dramatic differences in depth and content of algebra across the 22 states and across those states, 16 of the states had seven common topics. And for Singapore, there were eight major topics. Of course, in Singapore, there is no distinction between Algebra I or Algebra II and there were three topics of commonality between the seven states where we saw common topics in this country. So we're continuing to work with that algebra analysis from those sources.

Our second question dealt with the notion of an integrated curriculum, which is now going on in different ways in eight different states in this country. A case study was conducted using the state of North Carolina as the for-instances case and in the state of North Carolina where they have an integrated curriculum, we noted that seven of the eight content expectations for geometry were covered in the integrated curriculum. Virtually all of the content expectations for Algebra I were covered in the integrated curriculum but only nine of the fifteen of the content expectations were covered in Algebra II. And we'll probably look more at that information, but it does at least raise the flag of if a state would have an integrated curriculum and would try to account for specific expectations, you would have to do a very careful job of flagging those across such an integrated curriculum. Again that was a case study. We were interested in that as a particular case.

Our third question dealt with pre K through 8 essential knowledge and skills and we reviewed course expectations pre K through 8 in nine states that we had identified. We're also looking at particular expectations in a case study at the fourth grade level. We continued to be influenced by the curriculum focal points presented by the National Council of Teachers of Mathematics at our last meeting.

Our fourth area of study looked specifically at some of the work that we heard about earlier today and that's the International Math and Science study and NAEP in terms of the actual content looking at similarities and differences there. We identified states whose students appear to be proficient in mathematics using state-based assessments and note the gap as we compared such states to how those also do in NAEP assessments looking at two different ways to account for such gaps. And that information we find to be interesting and frankly regardless of how we frame it, it still calls for, in my opinion only, a need for a national report card however we build the table of specifications for that measure.

Our final question dealt with the issue of college readiness. We want to look at the important mathematics for kids prior to algebra. We want to look at what algebra is, but then once people do that, what does that mean with regard to college readiness. The comments that I'm going to make do some continuation of the ACT presentation we heard yesterday afternoon about this time, but also a little bit different.

The ACT studies on student preparation for college level mathematics and state standards and assessments alone do not accurately reflect college readiness. We do see some modest improvements in recent years in terms of ACT test takers, but we also note that many are not ready for college level mathematics. While we saw that data yesterday, I think it's safe to conclude that Algebra I and II are recommended in the core curriculum that ACT recommends as being necessary for college as well as entry level jobs. But I would also maintain again based on the report yesterday that it probably needs more than that. But clearly, the importance of algebra is justified in that work. We probably won't be doing much more with that particular report because it satisfies our needs in terms of the importance of algebra. But that's pretty much where we are at this point.

(Off the record comments.)

MS. FLAWN: The research question.

DR. FENNELL: I'm trying to figure out what the answer is.

MS. FLAWN: It's at the top.

DR. FENNELL: Yes. The ACT research question. Is there any reason why I have to go first at all these by the way because all these other people have time to kind of get ready? I'm the only one that's embarrassed.

(Laughter.)

DR. LOVELESS: Just mention the focal points.

(Laughter.)

DR. FENNELL: That's why I sit next to Loveless. The research question that we're having ACT help us with is the aspects of mathematical understanding that relate to success in algebra. We're trying to get a feel for sort of the notion of for instances does success with rational number relate to success in algebra. To what extent do we know that? Does success with, say, whole number operations relate to success with algebra and so forth? So we're looking some correlational work that they are providing for us in that area. Thank you.

CHAIR FAULKNER: Thank you, Skip. Is there any discussion or are there questions from the rest of the panel?

(No response.)

CHAIR FAULKNER: Okay. If not, then we'll go onto Dave Geary. Dave is chairing the Task Group on Learning Processes.

DR. GEARY: Thanks Larry. As many of you know we're looking at the concepts, procedures and declarative knowledge that compose mathematical competencies in a number of core mathematical domains related to algebra and leading up to mastery of algebra and these will be domains that we're working out with Skip's group.

We worked with Abt. Associates on refining the search criteria for identifying high quality research related to questions of learning in these domains and so we hope to have the 1,000 or so identified articles reduced at least somewhat between now and January or sooner than that. In any case, by

January, we hope to in the interim report have an preliminary discussion and report on what children bring to school to include the types of competencies that children enter kindergarten and first grade with and how these may relate to the ability to acquire other competencies.

We hope to have a section on basic mechanisms of memory and learning to include the general principles of learning that are true across domains that are relevant to many of the discussions in the content areas that will follow this section. We will also include information on social/emotional mechanisms that may influence motivation to learn, engagement in classroom activities and so forth and of course, diversity issues.

We hope to have the first section pretty much completed, aspects of the second section completed by January and then of course we will do review in particular content domains looking at children's conceptual learning, procedural skill development and declarative knowledge in these domains. We hope to have all or part of a draft of whole number arithmetic from simple addition through long division algorithms drafted for the interim report or at least a large part of that done.

For the final report, we will also include fractions which will be an important aspect of this and then aspects of geometry and algebra that Skip's group identifies as emerging as key in their group. We also hope to have a shorter section on future directions and this may include a number of topics as comes up and as seems necessary as we progress with this.

For January, we will probably have a brief statement regarding the usefulness and limitations of research and cognitive neurosciences and the brain sciences as related to learning and the domains that we will cover and in general and this is certainly an area of promise, but also an area in which that promise has yet to be realized and we want to make some statement regarding the research in that particular area. And I think that will pretty much round out our goals for January.

CHAIR FAULKNER: Thank you, Dave. Are there questions or comments from panel members for Dave?

(No response.)

CHAIR FAULKNER: Okay. I think we're worn out. Russell. Russell Gersten is the chair of Instructional Practices.

DR. GERSTEN: We have about eight or so topics that keep coming up as topics of interest. We were told that we should pick two research questions for Abt. Associates and after extensive group discussion, it seemed that we wanted to start with this critical question which is going to take us at least a year to really ponder and pour through. This is essentially what does the research say and/or other evidence about effective instructional practices in teaching math K-8. So it's very broad. It doesn't include everything, but we thought it was better to do that than to try to micromanage or come out with a report on visual representations only or on technology. So we started to raise some sub-questions and tomorrow morning we're going to spend an hour with Abt., making sure the key words are in sync and beginning really a process of communication.

We will include things like the role of the teacher, selecting what to teach and how that intersects with practice, which we heard some comments about this afternoon, use of representations, how that might come up in what we know from the studies. We're also going to begin with, let's call it, the kind of research Valerie and her group has talked about, causal research, high quality experimental, quasi-experimental research that has good proof of equivalence of groups. We will begin there, see what we find, see not only tickle off the studies in terms of technical quality but also in terms of meaning. Is it is three-day study that looked at acquiring one theory of varied concrete skills? What is the meaning? What is the relevance of this kind of thing?

So that is really where we're going to begin and for the first report, we will basically do an interim report. We will write out this question and sub-questions after iterations and I think getting feedback at least from the chairs of the other committees and any members they want to kind of help really raise questions.

The second question we raised and we will share it with Abt., but it isn't nearly as much of a priority is real world or authentic problem solving and then what other insights one might gather from more qualitative case study work into this including how that fits into the sequence of teaching. This is one of about five or six topics that some members are incredibly interested in and some are profoundly indifferent to. I think that's true with all our second tier questions.

But number one will keep us occupied. If it breaks into three natural sub-questions that we really can focus more on, we'll take it from there. So that's where we're going to start, but we're definitely going to look at the other literature and we'll need to work with Abt. and Valerie’s committee so we start having some rules of evidence or start with assertions.

Something that we'll begin to play with is the idea Russ Whitehurst suggested in Chapel Hill which is start with an assertion, a belief, or a hypothesis that many members believe and then look for evidence on it. Then we will talk about causal evidence on it, contradictory case study evidence on it, no evidence on it, or whatever is the case. So we will kind of work this methodology over time. What I hope to do is write out and share with the members, Tom, Vern, Camilla and Diane, what and why we're doing it, and get feedback from others. That's our plan.

CHAIR FAULKNER: Tom.

DR. LOVELESS: If I could just clarify one thing, Russ, in terms of the way you described it. The way I understand question one, the way we discussed it is really getting at this question that if we look at a continuum of direct instruction/ teacher-led instruction, on one end, student-centered/student-led instruction on the other end with differing roles of teachers and students which of those -- what do we know about the evidence and effectiveness of those and of all the variations in between and the mixes?

DR. GERSTEN: Yes, that's it. In between, yes.

DR. LOVELESS: And that that's question one, not just effective practice, but really looking at specifically this question of the teacher's role and the student's role and these two different ideas of teaching.

DR. GERSTEN: Yes, that is a way to cut it and it's one that many members want. That is the way to look at it and so that is definitely one of the dimensions we will look at and start to sort things. We’ve also agreed that about 98 percent will fit neither pole. So we have to sort out the other 98 percent of approaches to teaching. So Tom is totally correct. That is definitely going to be one of the themes or hypotheses or questions.

CHAIR FAULKNER: Sandra.

DR. STOTSKY: Just a quick question also about the role of the textbooks and the teacher's manual, the kind of materials that the teacher is expected to use on instructional practice.

DR. GERSTEN: Okay, but remember I said the other topic some of us are extraordinarily interested in and some are profoundly indifferent. So that falls into that category that some members of our group think it's of critical importance. Others are pretty indifferent to it. So right now, it's on the back burner though definitely any interface with a given curriculum be it Tom Good's study where everybody had exactly the same teacher's manual and textbooks and he looked at natural variation. I mean we'll definitely use that as context here but that's not where we're going to start and again it is a group decision.

CHAIR FAULKNER: Bob.

DR. SIEGLER: I worry a little bit that, if there's nothing about textbooks for example and curriculum or just some cursory introductory comments, the general public is going to say what are these guys doing.

DR. GERSTEN: Okay. So the other thing is this is Abt. said no more than two questions for now and we're not going to stop in January.

DR. LOVELESS: And, Bob, that's really the hardest thing that we've had to do and we spend all of our meetings on is that we thought of 20 questions like that that are extremely important but we're told to narrow to two. So the two that we thought were the meatiest and the most important and really where the research begs some kind of analysis was the direct instruction. Let's call it, let's simplify it, to direct instruction versus student-centered and then also the question of real world problems.

CHAIR FAULKNER: I don't think the intent to be narrowed to two for the entire duration.

DR. LOVELESS: No. I'm not saying that.

CHAIR FAULKNER: It's because we have a short-term horizon where we have to report.

DR. GERSTEN: And, Bob, that is another issue that to go charging and to have our first two questions be so broad and so diffuse and also overlapping did not seem a good way to go. We're going to keep going and at the very least, we will link what we say to what is in the What-Works Clearinghouse and whatever ever Promising Practices Initiative has because it seems we need that kind of integration. I mean we can even disagree with the summaries but we want some linkage to what we're disseminating to the public and there are curricula studies that are being posted.

DR. SIEGLER: Yes. My comment was based on a misunderstanding.

DR. GERSTEN: Yes, those were our top two.

DR. SIEGLER: A year from now where you'd be rather than two months from now.

DR. GERSTEN: No, this is just right now.

CHAIR FAULKNER: Skip.

DR. FENNELL: It seemed to me that one of the reasons we very specifically went after Tom Good and Jim Hiebert for this meeting was to help frame not only for your subcommittee but for all of us to think about not so much the model as you were saying, direct versus student-centered or whatever, but the similarities between what we talk about relative to instruction. Call it explicit. Call it direct. Call it student-centered. Call it whatever. To me it makes sense to take the work that we have received today from Tom Good and from Jim to help frame the kinds of questions you're doing. I suspect that somewhere along the line the issue of curriculum, textbook or otherwise, will be dealt with.

DR. GERSTEN: Thanks for your support for the view I've taken.

CHAIR FAULKNER: Thank you. Let me turn now to Deborah Ball who's on the Task Group on Teachers.

DR. BALL: I'm going to report the side that we're taking initially and what's on our docket for the longer term. We made some progress at this meeting in trying to articulate two major questions that we want Abt. to help us first. We're still discussing the order of these. So this doesn't necessarily represent the whole group's decision about how to order them, but there are two essential questions that are at the forefront of our work right now.

The first has to do with reviewing the evidence on the relationship between teachers' mathematical knowledge and students' achievement gains. We have a number of sub-questions as follows: 1) are there effects and, if so, how large, 2) how has mathematical knowledge been conceptualized and measured across the studies that do exist, 3) how has student achievement been conceptualized and measured, 4) are there differences by student populations or levels or content or other student or context variables, 5) are there differences by levels of the teachers, that is elementary, middle or high school, or years of experience or professional or content training or other teacher variables and the like. So there are a number sub-questions that may help us to push into the literature to understand what kinds of evidence there are about something that many people hold to be common sense but clearly hasn't been something that has been easy to either measure. This may be our first question, but the two are highly related, as you'll see.

The second question in which we're deeply interested has to do with what sorts of programs or conceivably other kinds of interventions for pre-service, teacher education and in-service teacher education that help teachers to develop the necessary mathematical knowledge that they need for teaching. Of those that have had effects on teachers' mathematical knowledge, which of these programs has done so in ways that demonstrably affect their instructional effectiveness and their students' achievement? So we’ll be looking for evidence that looks at programs, their relationship to teachers learning, but those teachers' ability then what their instructional practices look like and what their students' achievements look like.

And again then we have predictable sub-questions to that. We're trying to find out what is known about how pre-service or in-service programs can effectively increase teachers' knowledge in ways that provide levers for them to have effectiveness in the way that they both teach. So we're interested in things like what sorts of designs have been shown to make a difference for teachers' mathematical knowledge. We’re interested in all the usual questions about how that's been measured and conceptualized. This includes things like mathematics course work or requirements, math education course work or requirements, clinical work such as field experience, student teaching and the like. This also includes licensure tests, other sorts of things at the pre-service level and separate from that what sorts of similarly designs or uses of those in in-service teacher education and professional development have made a difference for teachers' mathematical knowledge. We are interested in whether experienced teacher’s engagement in mathematical study has had effects on their learning or other instruction or their students' achievement, study of kids' mathematical work, study of school like K-8 curriculum materials, different kinds of experiences that could be provided in in-service and how those in turn do or don't affect teachers' mathematical knowledge and in turn, their instruction and their students' achievement.

So those are two big categories deeply related to each other that start our group out in looking at an area where we know there has been research. We don't know how it will meet the different kinds of evident material that we've been working on but we're prepared to survey the range of literature that we can uncover about this.

Later after January, we have other things on our list in which we're interested in including specialization of teachers at the elementary level in mathematics, what models exist, instructional effectiveness, school improvement, kids' achievement and the like, but we're putting that after and you can see the relationship between these first couple of questions in that. We also suspect there's been little research on that. So we wanted to first understand better the basic elements about teachers' preparation and knowledge and skill and the relationship to instruction.

We're also very interested in evidence related to the recruitment and retention of mathematics teachers and factors that have been shown to effectively both recruitment and retention of highly qualified teachers. You can again see why that's something that we will do better at exploring once we've laid the groundwork with the questions I've just discussed. So we're hoping that we will be able to review the articles that we can uncover about this and be able to make at least some progress report on these two initial questions about mathematical knowledge and interventions or programs at the both pre-service and in-service teacher education level.

So we are hoping to make some headway on this by January, at least a report on where we are with those two questions. Anyone in my group want to add to this?

CHAIR FAULKNER: Don't be too voluble.

Stanford needs us out of this room at 5:30 p.m. and it's past 5:30 p.m. right now. So if there's something essential that has to be said then fine, but otherwise we need to wrap this up. Okay.

Let me wrap it up then. First of all, let me thank the public for attending. There are very soldiers out here. We appreciate your being with us.

(Applause.)

Let me also announce that the National Panel will have its next meeting in New Orleans on January 10 and 11, 2007. Most of that meeting will not be in open testimony. Most of it will be in task group work because, as you probably can perceive from the comments that have just been made the focus, the panel for the near term has to be on getting our interim report prepared and that has to be made available to a peer review process just after the New Orleans. So the New Orleans meeting will be largely dedicated to task group work aimed at getting our interim report done.

We will return to receiving public testimony on topics that may be of interest to you and the public after the New Orleans meeting. There will be a short time set aside for public comment at the New Orleans meeting, but as I said the primary focus will be on drafting the first report.

With that, I will declare this session adjourned. (Whereupon, at 5:33 p.m., the above-entitled matter was concluded.)