Research Findings in Teacher Education:
New Approaches → Transformative Possibilities?

2009 Math and Science Partnership Learning Network Conference

January 25-26, 2009 • Washington, DC

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NATIONAL SCIENCE FOUNDATION

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Participant comments have been paraphrased; they are not exact quotes. The contents of this document do not necessarily reflect the views of TERC, the National Science Foundation, or the organizations of any participants.

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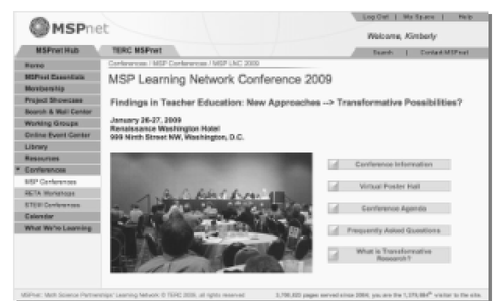
About This Summary

This overview of the 2009 Math and Science Partnership Learning Network Conference offers brief summaries of the plenary presentations and panel discussions that took place during the conference. The intent is to provide a sense of the overall conference themes and highlights.

Readers interested in pursuing any of the plenary session presentations summarized here are encouraged to access MSPnet. Full video recordings of the presentations as well as all PowerPoint presentations used during the conference are available on MSPnet. All abstracts submitted for the conference are available in the MSPnet Virtual Poster Hall.

Visit the MSP LNC 2009 Virtual Poster Hall

For all conference abstracts, as well as post-conference commentary and dialogues concerning the abstracts.



Visit MSPnet.org and click on Conferences or go to:

http://hub.mspnet.org/entry.cfm/msp_conf_2009_abstracts

OPENING REMARKS

Daniel P. Maki
Program Officer
Division of Undergraduate Education
National Science Foundation
Math and Science Partnership

Maki notes that the Learning Network Conference (LNC) provides a yearly opportunity for cross-sections of MSP project teams to gather and exchange information. The LNC enables NSF to learn from what the projects are doing, allows projects to learn from each other, and assists newer projects by bringing them into contact with veteran projects.

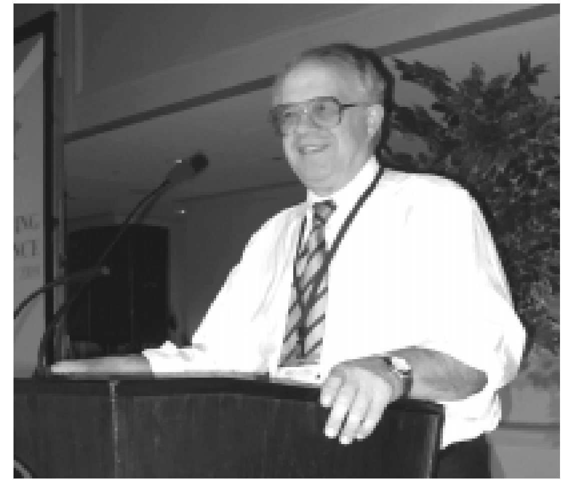
The MSP is advancing from a youthful phase to vigorous young adulthood, Maki observes, and has experienced a productive year. A full solicitation has funded Targeted, Institute, and RETA projects as well as two new branches: Phase II awardees will look deeper and more rigorously at aspects of Phase I projects to add to the knowledge base; and MSP STARTs provide planning grants to projects requiring the time and resources to form robust partnerships and full proposals. There is a new full solicitation deadline in February and another for Targeted proposals this summer, Maki reports, and the intent is to enable all five categories of MSP projects to move forward.

Kathleen B. Bergin
Program Director
Division of Undergraduate Education
National Science Foundation
Math and Science Partnership

Bergin begins her remarks by stressing that the conference theme of teacher education is the heart of this work, engaging teachers as the professionals that they are. She cites President Barack Obama's book, *The Audacity of Hope*, which identifies education as the number one factor affecting our nation's competitiveness, with science and math ranking second and energy third. Bergin notes that we are educating the next generation that is going to solve our energy problems via the teachers of students of that generation.

The stimulus package now before Congress includes money for science and math teaching. However, Bergin observes, from the beginning a key element of MSP work is that it must be evidence-based, and the President stressed the need for accountability in his inaugural address. "The nation will be looking to us in terms of what has been learned from this investment that can be shared with others in order to transform how we are educating our students," Bergin states.

The title of this conference references the research findings that will be shared over these two days, she continues, but also includes the phrase "transformative possibilities?" with a



Daniel P. Maki

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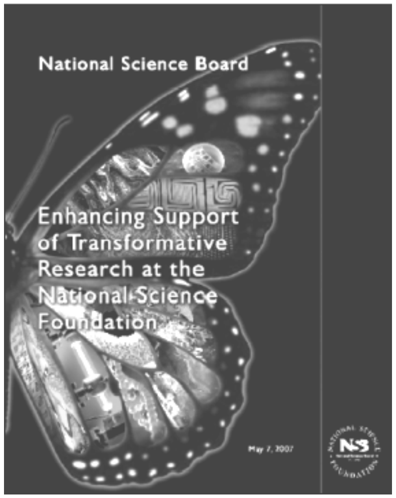


Enhancing Support of Transformative Research at the National Science Foundation (NSB 07-32)
http://www.nsf.gov/nsb/documents/2007/tr_report.pdf

Transformative Research - Notice No. 130

Endeavors which have the potential to change the way we address challenges in science, engineering, and innovation.

Those endeavors which promise extraordinary outcomes, such as: revolutionizing entire disciplines; creating entirely new fields; or disrupting accepted theories and perspectives.

Director Arden Bement, Notice No. 130, September 24, 2007, Important Notice To Presidents of Universities and Colleges and Heads Of Other National Science Foundation Awardee Organizations
http://www.nsf.gov/pubs/2007/in130/in130.jsp

question mark. This is something that NSF is intensely interested in, in terms of both education and the bench research that it funds. Bergin directs participants' attention to the concept of revolutionary versus evolutionary change in the quote below.

Science progresses in two fundamental and equally valuable ways. The **vast majority of scientific understanding advances incrementally**, with new projects building upon the results of previous studies or testing long-standing hypotheses and theories. **This progress is evolutionary**—it extends or shifts prevailing paradigms over time. The vast majority of research conducted in scientific laboratories around the world fuels this form of innovative scientific progress. **Less frequently, scientific understanding advances dramatically**, through the application of radically different approaches or interpretations that result in the creation of new paradigms or new scientific fields. **This progress is revolutionary, for it transforms science by overthrowing entrenched paradigms and generating new ones.**

"While most of the work done in education and in bench science is evolutionary, conducted step by step," Bergin says, "there are moments in time when keen minds come together and create something revolutionary." She urges participants to look at their own and others' projects over the next two days and think about what might be an investment in revolutionary work. This charge is not just being made to those engaged in MSP projects, Bergin notes. It also went out to the presidents of all the universities in the United States from Arden Bement, Director of NSF, over a year ago.

NSF is putting money into this effort via EArly-concept Grants for Exploratory Research (EAGER) both within the bench sciences as well as education.

EArly-concept Grants for Exploratory Research (EAGER)

- Replaces part of the Small Grants for Exploratory Research (SGER) program
- Supports high-risk, exploratory and potentially transformative research
- Requests may be for up to $300K and of up to two years duration
- Further guidelines in Grant Proposal Guide (NSF 09-1, January 2009), Chapter II, Section D (Special Guidelines), Subsection 2

Bergin concludes with the statement, "If someone comes up with a revolutionary idea that is truly going to transform the discipline of education, then NSF is very interested in funding that idea."

KEYNOTE ADDRESS: HOW DO WE ATTAIN BETTER QUALITY MATH AND SCIENCE TEACHERS?

Arthur Levine
President
Woodrow Wilson Foundation

Levine opens his remarks by relating that over the past few months he has spoken to governors, legislators, chief school officers and higher education executive officers on the topic of this keynote address and the importance of math and science to America's future in terms of economics, civics, defense, and international competitiveness. Those conversations focused on the acute shortage of math and science teachers in America, the quality of math and science instruction in our schools (particularly urban schools), the need to improve teacher preparation and professional development, and the difficulty of recruiting and retaining math and science teachers. "I told them action in these areas is imperative," Levine states, "but you know all of this. You are at the vanguard."

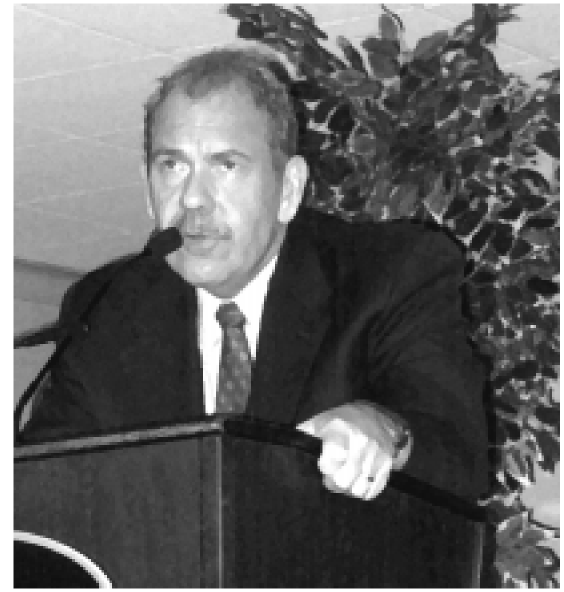
In his keynote address, Levine focuses on key realities we face and the implications in terms of obtaining the math and science teachers this nation needs.

Capitalizing on the Current Priority on Math and Science

In a quarter-century of school improvement, a cornucopia of issues have been proposed for the top of the priority list in the search for a silver bullet, from class size to early childhood education. "You all know there are no silver bullets," Levine states, "but when a topic becomes a priority it's like hitting the jackpot on a slot machine." What follows is funding, media coverage, and political attention. Practitioners move into action, scholars devote attention, and the business community embraces it.

"The fact is we have witnessed a cascade of efforts from each of these sectors, and in each of these priority areas they have been short term and have only lasted as long as the funding," Levine observes, "but this is our moment, this is our time."

This is the time to improve math and science teaching and the recruitment and retention of math and science teachers, Levine stresses, adding that past work has taught him that systemic change requires going through four stages. First, if your report gets enough media coverage, people start voting on it. Second, you get invited to talk to audiences of policy makers, practitioners and scholars. Third, pieces of your report serendipitously get adopted in various places, from universities and school districts to states. Fourth, you need to build a coalition of power brokers and mobilize the actors involved, including policy makers,



Arthur Levine

"Not since Sputnik have the times been better for improving science and math teaching. The leadership for this effort is sitting in this room. There can't be a better sponsor than NSF and its status, its experience, its staff, and its commitment."

- Arthur Levine

> We need to tie the importance of quality math and science teachers to health care, to energy, to the economy, to defense, not simply educational improvement.
>
> \- Arthur Levine

Conference participants

practitioners, scholars, business people and professional organizations. Then, Levine adds, "We need a very clear agenda of what it means to get good math and science teachers and how we're going to go about it."

Linking Improvement in Math and Science Education to Current Concerns

Time is short, Levine cautions. Education is declining as a national priority in public opinion polls, giving way to concerns over economics, war, terrorism, health care, and energy, even though each of those concerns is associated with math and science education. What this means, Levine explains, is that if we want success in this area, we need to tie improvement in math and science to the issues that are currently American priorities. "We need to tie the importance of quality math and science teachers to health care, to energy, to the economy, to defense, not simply educational improvement."

Eliciting Support from the Priority Areas and Agencies that Have Money

In a time of declining resources and economic crisis, Levine observes, federal resources are going to the bailout, to stimulus packages, to the war, and to mitigating tax declines. The federal government will delegate the education agenda to the states, which won't have any money themselves due to burdens of social services, health care, unemployment, and declining taxes. As one of the biggest items in state budgets, education will be cut. At the same time, universities are experiencing their own economic difficulties. "What I think we are going to see in the next few years," Levine predicts, "is a lot of finger pointing. I think it is a time when we are going to be asked to be more accountable, we're going to see more regulation, and we're going to see fewer resources."

Support will have to come from areas beyond education, he advises. "We are going to have to look for those agencies and those organizations that have money, and they are going to be government agencies, such as defense, labor, health, energy, economic development and retraining. We need to tie the importance of math and science teachers to those areas."

The Importance of Evidence

Education reform often has much more to do with competing ideologies than with the needs of children, Levine observes, emphasizing that our efforts have to rely on evidence. Political issues will come into play if ideologies dominate, he cautions. "Teaching is equally divided. We don't agree about how we prepare people to teach. We don't agree about professional development." One of the sharpest divisions in this country with regard to teaching, Levine notes, is whether teaching is a craft like journalism, learned largely on the job, or a profession like medicine or law, requiring a great deal of education prior to engaging in work, and we are seeing states moving in both directions. We also disagree about where teacher education should happen, whether in universities or through alternative routes. Publishers are seeking to corner the market on teacher professional development, offering education online and via satellite, using professors as content providers and gaining state authorization to give credits and award degrees. This can also spring up in the public as well as the private sector, Levine observes, noting that the largest provider of professional development for teachers in science is PBS.

"We don't know what the most effective means of teacher preparation or professional development is in terms of student learning," Levine states. "We don't know what instructional strategies and pedagogies are most effective in providing math and science education with what populations. We don't know and we don't agree on what students need to know and be able to do in math and science."

If we're going to combat the ideological wars, Levine advises, we need to be noncombatants. "Our commitment has to be to what works, with outcome-based evidence that goes beyond anecdotes and the satisfaction surveys that characterize the research in this area. We need to document our findings, we need to document our recommendations in ways that are compelling and stand up. We need for our data to stand up as well as any data can if we are to succeed."

Scaling Up on Statewide Levels

School reform initiatives are ephemeral and few in the past quarter-century have succeeded in scaling up, Levine observes, adding that in twenty-five years we still haven't succeeded in turning one urban school district around. To implement and adopt the findings of MSP, he advises, we need to seek leverage and target for maximum impact.

The venue Levine proposes is working with whole states and building coalitions within states, a strategy that has been employed with teaching fellows at the Woodrow Wilson Foundation. Small numbers can make a significant difference at the state level, Levine observes. It is also possible, using small numbers, to fill significant openings and build critical masses. While the Woodrow Wilson Foundation is turning out eighty teaching fellows a year in Indiana, that will increase the number of certified math and science teachers by twenty percent a year.

Take advantage of the opportunity for statewide action, Levine suggests. If you're going to advertise for math and science teachers, why not do it for a whole state? States provide common venues in which these types of efforts can operate coherently. If you're going to change teacher preparation, why not identify a handful of the major teacher preparers in the state and provide them with the incentives to change?

What states also permit, Levine observes, is vertical strategies for change, from recruitment

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> "The lesson for us, if we are going to reform math and science teaching and we are going to be revolutionaries, is don't choose. Use both the traditional and laboratory sectors. It is the only way we can develop and implement ideas for improving science education. We need to figure out which sector is best for the nature of the program we want to endorse."
>
> - Arthur Levine

to preparation, to placement, to retention, to professional development, to assessment. As an added plus, he notes, states provide opportunities for regional funding, which is likely to remain even in hard times.

Integrating Traditional and Reformist Approaches to School Improvement

There is also, Levine observes, the question of where we implement these efforts, whether in traditional settings, existing school systems, or through alternative reformers. Traditionalists are those who want to improve existing schools. Reformers are those who want to make more substantial changes in public education, favoring initiatives such as charter schools, pay for performance, non-university-based teacher preparation, and dismissal of failing tenured teachers.

Levine identifies the new Secretary of Education, Arne Duncan, as one of those rare individuals who has straddled both camps. In fact, the traditional and more radical approaches to school reform are more alike than different, Levine points out. Both are in the business of trying to sustain the existing school system. The traditionalists, playing prominent roles in school systems, universities, and government, attempt to produce change from within. The reformers, mostly a generation younger, attempt to work from without, creating laboratories for major redesign of specific practices in the nation's schools. Examples include Teach for America and New Leaders for a New Era.

In recent years, Levine recounts, we have seen integrators such as Arne Duncan and others bringing the lessons they learned in the reform sector to the larger public school systems. "The lesson for us, if we are going to reform math and science teaching and we are going to be revolutionaries, is don't choose," Levine advises. "Use both the traditional and laboratory sectors. It is the only way we can develop and implement ideas for improving science education. We need to figure out which sector is best for the nature of the program we want to endorse."

In Closing

Levine concludes his remarks by affirming his belief that we have the capacity in the years ahead to obtain the math and science teachers America needs and to dramatically increase the quality and quantity of those teachers. What is required is that those involved in MSP go the next step by taking advantage of the times, building coalitions of key actors, developing a specific agenda for action, tying that agenda to national priorities, providing compelling evidence to support the agenda, making use of labs and existing school systems to try out ideas, and targeting for maximum impact.

"Not since Sputnik," Levine states, "have the times been better for improving science and math teaching. The leadership for this effort is sitting in this room. There can't be a better sponsor than NSF and its status, its experience, its staff, and its commitment."

Question and Answer Session

Pool of Prospective Math and Science Teachers

- In Massachusetts they asked seniors taking the SAT what they want to study, and out of roughly 48,000 students, 62 mentioned science teaching. How do we change that mindset in this society? • Christos Zahopoulos, Boston Science Partnership

- For our work in Indiana we did a national study looking at who would be willing to become teachers in what circumstances, and our work focused on math and science. It's not only the question of whether high school students want to be teachers. There are many points along the continuum from which we ought to be recruiting. We have college seniors—those with no previous interest in teaching and those who realize they don't want to be bench scientists. We have the recent graduate who may have tried something else and is ready to come back and be a teacher. There are those who have raised families and are ready to come back into the labor market. We also have veterans. In current economic times, we have a much larger pool of career changers. There are also baby boomers who may want to try one more career. And there are mathematicians and scientist who may be looking for jobs.

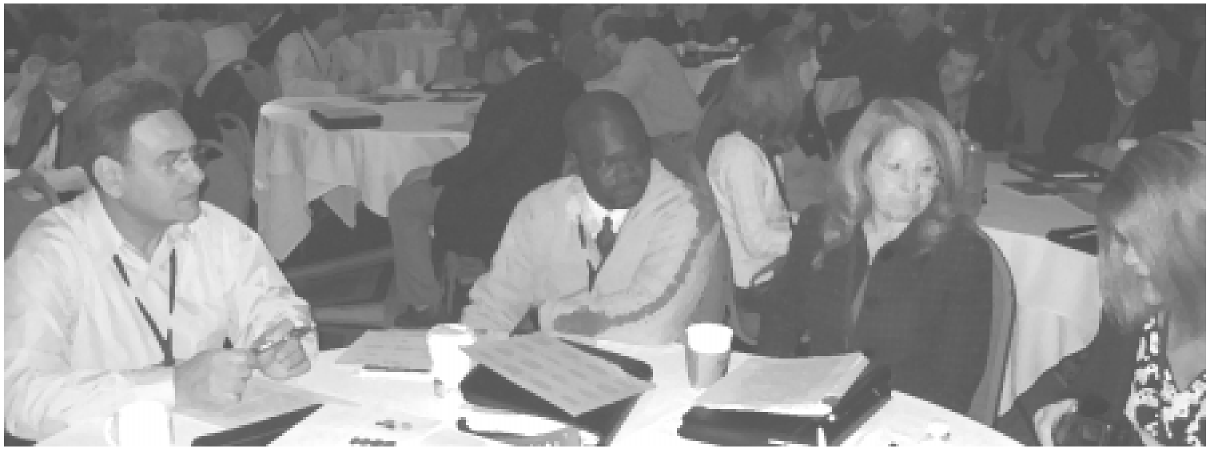
  We contracted for a survey of adults ages 25 to 60. Forty-two percent said they would consider changing from their current job to a teaching career. Clearly 42% aren't doing it, and we're now attempting to identify the trigger. But we can do a lot better in terms of looking at the pool of people who may become math and science teachers than the SAT survey shows. • Arthur Levine

Pool of Prospective Math and Science Teachers

- I have a question related to generational differences. Evidence is showing that people of the next generation aren't interested in being in the same job for thirty years, whether it's teaching or anything else. That would seem to require rethinking the whole process of teaching as a career. The retention issue may not get better if there is this generational change. • Danielle Susskind, CASHE Project/VIP K-16

- Moving towards that time in which we have teachers moving out every two to three years will do harm because the places they're leaving most frequently are inner cities or rural areas. This means students who desperately need the best teachers are getting green recruits. We asked Northwest Evaluation Association to do a research study for us that included the issue of teacher longevity and student achievement. We found major differences between student achievement in classes in which teachers had taught for seven years or more compared to those who had taught for three years. We can't settle. The reason people are leaving is because the jobs aren't attractive enough, the pay levels are too low, working conditions are poor, and the status is low. If we're serious about math and science teachers being excellent we need to deal with those issues. In the interim we will recruit those who can afford to teach and those who are idealistic enough to want to teach. That's nice, but it isn't enough. • Arthur Levine

Conference participants



THE MSP PROGRAM AT THE USDE: WHAT DO THE PROJECTS LOOK LIKE AND WHAT ARE WE LEARNING?

Visit
www.mspnet.org
for a video recording of this panel as well as full PowerPoint presentations from all U.S.D.E. panel participants

For more information and full text of this report go to the USDE Web site
www.ed.gov/about/reports/annual/index.html
or contact
patricia.johnson@ed.gov

Overview of USDE MSP

Patricia O'Connell Johnson
Team Leader, MSP Program
Office of Elementary and Secondary Education
U.S. Department of Education

O'Connell Johnson's overview focuses on a summary of the third annual report of the USDE Math and Science Partnerships from fiscal year 2006. The Department of Education MSP program operates under Title II, Part B of No Child Left Behind and is a professional development program charged with developing partnerships of high-need school districts and STEM faculty in institutions of higher education. Other school districts, IHE faculty and nonprofit organizations may participate as well—almost half of the projects have education faculty and work with other school districts. The intent is to provide intensive professional development that will lead to improvement in classroom instruction, and in turn to student achievement gains in math and science.

Funds for the program are appropriated through Congress and allocated on a formula basis to the states, the District of Columbia, and Puerto Rico. The states distribute

Left to right: Patricia O'Connell Johnson, Meera Chandrasekhar, Keith Murray

USDE MSPs at a Glance

- Over 3,000 Institutions of Higher Education (IHE) faculty participated in ED MSP projects.
- Approximately 3,800 organizations partnered to form 501 projects across the country.
- Over 49,000 hours of professional development was provided to more than 56,000 teachers.
- Enhanced the quality of classroom instruction for over 2 million students.

MSP Funding FY 2006

- $181 million dollars to provide professional development to K-12 educators through a formula to the states.
- States received awards ranging from $906,246 to over $25 million dollars.
- Projects received awards ranging from $24,000 to 3.6 million.
- The average MSP grant was $337,015, and the median was $200,000.

Characteristics of Project Participants

- An average of 6 IHE faculty participated per project.
- More than 56,000 elementary, middle, and high school teachers participated.
- The majority (84%) of teachers who participated in MSP projects were elementary and middle school teachers.

funds on a competitive basis to the partnerships of IHE STEM faculty and high-need school districts.

O'Connell Johnson reviews the process used to collect and analyze project evaluation results. Excerpts from the summary and evaluation results are offered here.

Professional Development Projects

- The typical project provided professional development to 113 teachers, and the median number of teachers that participated in professional development per project was 44. The number of teachers that participated in individual MSP projects ranged from 5 to 1,549 teachers.
- MSP projects reported using one of two main models for providing professional development (PD) for teachers:
  - The individual teacher model (83%) – when teachers from a set of school or school districts participate as individuals in order to improve their own content knowledge and teaching skills.
  - The teacher leader model (17%) – when teachers are trained to become mathematics or science leaders in their schools/ districts.
- Of the projects: 43% of projects focused on mathematics; 25% of projects focused on science; 30% of projects focused on mathematics and science.
- 65% of projects provided summer institutes, with almost all of these projects providing follow-up throughout the school year.
- Of the projects that provided summer institutes with follow-up, teachers were provided an average of 125 hours of professional development; 66 hours during the summer and 59 hours during the school year.
- 34% of the projects used other professional development models, besides summer institutes, and provided an average of 83 hours of professional development over a 12-month period.

Teacher Gains

- In mathematics, among the 11,693 teachers who were pre/post tested on their content knowledge, 71% made statistically significant gains in content knowledge.
- In science, among the 6,689 teachers who were pre/post tested in their content knowledge, 80% made statistically significant gains in content knowledge.

Student Gains

- In mathematics, among the projects that reported on the percentage of students scoring as proficient before their teachers benefited from professional development as compared with how their students performed after participation—overall there was a 6% increase in students scoring as proficient. This can be compared with the 3.5 % increase in the national average across all of the states.
- In science, there was a 7% gain in proficiency from one year to the next in participating teachers' classrooms. There are no comparable national data in science.

Evaluation Design (Projects that Reported Results)

Experimental = 6
Quasi-Experimental = 173
Other = 290
Did Not Report =24

Data Quality Rubric Applied

After rigorous screening: 29 projects identified as having a quasi-experimental design with a matched comparison group. Of those 29, 8 were classified as having a strong quasi-experimental design in one or more categories: content knowledge; teacher classroom practice; student achievement.

Regression Analysis

Project characteristics significantly associated with gains in teacher content knowledge:

Characteristic	Math	Science
Individual Teacher Model	positive	n.s.
"Other" Program Lead *	positive	positive
# of Participating Teachers	negative	n.s.

* Other than LEA or IHE

Left to right:
Carolyn Siebers, Frederica Frost, Roger Verhey

A Look at Two USDE MSPs

Patricia O'Connell Johnson introduces two of the USDE MSPs, the first from Michigan, the second from Missouri.

Project:
Making Mathematics Matter (PM3)
A Model for Effective PD

PD Philosophy

- Long term, sustained, collaborative, school-based, linked to curricula, focused on student learning
- Whole district, mandatory participation with LEA partner support

Districts

90%+ socio-economically disadvantaged student body

District A
- 3 elementary schools
- 1 middle school
- 1 high school
- 62% English language learners

District B
- 3 elementary schools
- 1 middle school (closed)
- 1 high school
- 1 career/alternative high school
- 99% African American

Professional Development in Challenged Environments

Carolyn Siebers
Mathematics Consultant
Wayne County Regional Educational Service Agency

Frederica Frost
Program Evaluation and Research
Wayne County Regional Educational Service Agency

Roger Verhey
Emeritus Professor, University of Michigan-Dearborn
Director, Center for Mathematics Education

This team presentation demonstrates that professional development in mathematics can be successful in low socioeconomic, highly unstable environments. The PD model used required mandatory participation of all teachers within the two participating districts who work in math and science in grades four through eight.

Challenges Faced

Challenges over the past four years resulting from the unstable environment of the two participating school districts include school closures, district reorganization and layoffs, high use of substitute teachers; and high turnover of principals, superintendents and curriculum directors. These challenges continue in year five, with one district in total reorganization and implementing massive layoffs.

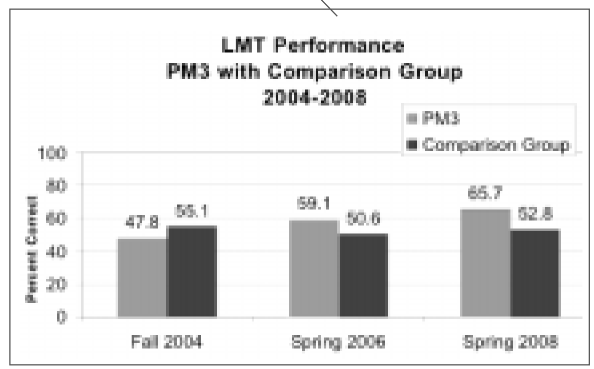
Evaluation and Results

The evaluation involved pre-post, quasi-experimental, matched comparison group design. Kirkpatrick's four-level design was modified to five levels, using a mix of qualitative and quantitative methods and multiple measures.

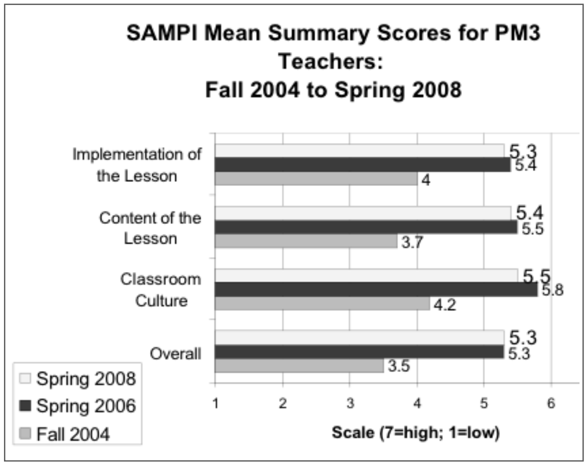
Kirkpatrick's Model Amended

Level of Evaluation	Measures
Response to the program	Individual session evaluations
Acquisition of knowledge & skills	Mathematics content assessments
Opportunity to implement	Focus groups, coaches, observations
Implementation	Multiple measures
Impact on students	State mathematics assessment

Learning Mathematics for Teaching results are below, showing steady increases across the three data points, with comparison group results on the right.



To evaluate implementation, one of the measures used was the Science and Math Program Improvement (SAMPI) Scale, used in Michigan math and science centers for the last fifteen years. It measures implementation, classroom content and classroom culture.



Effect Size 2004 - 2006

Culture 0.80	Content 1.95
Implementation 1.62	Overall 1.79

Professional Development Model

At the core of this collaborative model is the Wayne RESA Center at UMD, serving as the hub for MSP District A, MSP District B, and services to schools, districts and teachers. The focal points of the professional development model are institute courses and coaching.

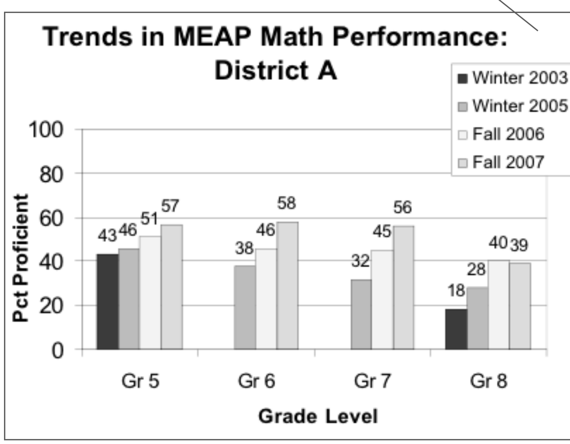
Purposes of Institute Courses

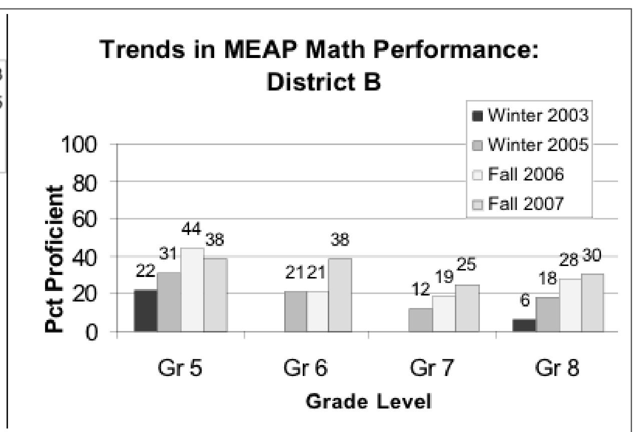
- To deepen teachers' mathematical content knowledge for teaching with an emphasis on the mathematics in the grade band they teach
- To model best practices in teaching mathematics to diverse learners (focus on student learning by focusing on teacher learning)
- To gain a profound understanding of fundamental mathematics

Importance of Coaching

- Work with teachers in institute courses and then return with them to classrooms
- Nurture collaboration through grade level meetings
- Establish district curriculum for institute grade levels

Results on student performance from state proficiency tests in mathematics show desired gains and steady increases by grade level. Note that while District B suffered a period of "high pain and misery," students in grade eight moved from the sixth percentile to the 30th percentile.





Courses for Teachers

- Number, Operations, & Proportional Reasoning (2)
- Algebra (2)
- Geometry and Measurement
- Data Analysis & Probability
- Improving Instruction in Rational Numbers & Proportionality
- Improving Instruction in Algebra
- Improving Instruction in Geometry & Measurement

More About Institutes

- 50-60 teachers from grades 4 - 8
- Courses are flexible and customized
- Follow LEA rather than university calendar
- PM3 leadership team participates
- 30 contact hours over 5 school days per semester
- Summer institute
- Option of earning graduate credit

Summary: Essential Elements

- District-wide
- Long term and sustained
- Collaborative at all levels (leadership, in courses, coaching and building)
- Administrative support
- Content-focused coaching
- Institute courses
- Focus on implementation and accountability

Academy for Teachers using Inquiry and Modeling Experiences for Physics First

www.physicsfirstmo.org

Project Overview

- Math-Science Partnership Grant (2005-2008)
  - Design and implement professional development curriculum
  - Physics content & pedagogy to teach a year-long 9th grade course
  - 3 years of summer academies and academic year support
  - 70 teachers from 25 Missouri school districts
- Partners:
  - Columbia Public Schools (lead) and 12 original partner districts
  - University of Missouri and Missouri State University
  - Central Missouri Astronomical Association, Columbia Water & Light
- External evaluator: M.A. Henry Consulting

A Time for Physics First

Meera Chandrasekhar
Department of Physics and Astronomy
University of Missouri

Keith Murray
M.A. Henry Consulting, LLC
Wayne County Regional Educational Service Agency

Why Physics First?

Introduction to this Missouri-based professional development project involving 25 school districts begins with the rationale for reshuffling the traditional high school science curriculum, placing physics first in the ninth grade. Biology has changed in the last fifty years, and today biology molecular genetics has taken center stage. This change from a concrete observational science to an abstract experimental science has implications for the science curriculum.

	19th Century HS Science Course Sequence	21st Century HS Science Course Sequence
11th grade	Physics	Biology
10th grade	Chemistry	Chemistry
9th grade	Biology	Physics

There are a number of advantages to offering physics in the ninth grade. Conceptual physics provides the foundation for the subsequent science content of chemistry and then biology. Physics First schools report large increases in upper science level course enrollment. Students enter college with basic knowledge of physics, a gatekeeper course for college-level science and engineering majors. These factors will increase the number of science and engineering majors.

Highlights of the PD effort are outlined below.

Commitments and Benefits

Commitments
- Participate all 3 years
- Attend 3-week summer and academic year sessions
- Implement a yearlong 9th grade physics course
- Administer pre/post tests and provides scores for evaluation
- Provide support for implementation

Benefits:
- State-wide professional development
- Stipends, travel, room and board
- 12 hours of graduate credit
- Curriculum & assessment materials
- Equipment
- Access to equipment on loan
- Support from PLT, Coach-Mentor and project staff
- Access to log-in on website

Professional Development Structure

Summer:
- Three week academy focused on physics content for science teachers
- Math teachers attend for 1 week, administrators for 2 days

Academic Year:
- Return for 4 Saturday meetings
- Coach-Mentors visit mentees once a month
- Support for Teacher Professional Learning Teams (building- or district-level)
- Teach Physics in 9th grade classrooms
- Conduct pre- and post tests for students, provide results for evaluation

Curriculum

- 12 units over 3 summers
- Based on Modeling and Inquiry
- Sequenced using 5E learning cycle model
- Hands-on labs, analysis and discussion
- Readings
- Practice exercises—lots!
- Homework
- Aligned with Missouri State Standards (GLEs)

1. Uniform Motion
2. Accelerated Motion
3. Intro to Forces
4. Newton's Laws
5. Free Fall, 2D Motion
6. Energy
7. Momentum
8. Planetary Motion
9. Electricity
10. Electromagnetism
11. Waves
12. Heat & Applications

Teacher Content Gain
(All Gains Are Statistically Significant)

Summer	Units	Mean Pretest	Mean Posttest	Mean Gain	t	Sig. (2-tailed)
1	1-2	37.67	70.56	32.89	21.7	0.001*
2	3/4	74.16	80.49	6.33	3.74	0.001*
2	5-9	55.63	82.36	26.73	17.29	0.001*
3	10-12	55.69	82.38	26.7	17.64	0.001*

Significant teacher content gains are seen in all project years, with larger gains seen on project-constructed tests.

Student Content Gain
(All Units Show Statistically Significant Gains)

Units	Mean Pretest	Mean Posttest	Mean Gain	Sig. (2-tailed)	Effect Size
1	21.44	67.80	46.36	0.001*	2.305
2	15.56	63.72	48.16	0.001*	2.033
3/4	46.78	71.07	24.09	0.001*	1.280
5	26.69	65.99	39.30	0.001*	1.801
6	14.44	61.04	46.60	0.001*	2.111
7	13.90	55.42	41.52	0.001*	1.889
8	15.09	58.18	43.09	0.001*	1.531
9	9.70	60.33	50.63	0.001*	2.373

Average n = 911

All units showed statistically significant content gains. Project-developed tests had greater gains than units 3/4. Number of total students was 2000; maximum number on any one test was 1390 on unit 1.

Evaluation and Results

Highlights from the evaluation results are offered here.

This depicts entering status of the Physics First Year 1 group. Only 3 had physics content at the beginning of summer 2006. All remaining teachers who complete the final year of the university course will obtain highly qualified status.

Increase in Highly Qualified Teachers

Teachers' Initial Degrees – Original Cohort

Secondary Education		Content Majors		Other Degrees	
Secondary Science (area not specified)	15	Biology	6	Elementary Education	4
Physics/ Astronomy	2	Chemistry	2	Education	1
Biology	1	Physics	1	Physical Ed.	4
Sec/MS Science	2	Geology	2	Home Ec.	1
MS Science/Math	1	Agriculture	1		
MS Science	2	Animal Science	2		
		Wildlife Cons. Mgmt.	1		

Teacher Observation Outcomes by Domain

Category		Mean pre	Mean post	Sig.
Design	Y1 pre-Y1 post	3.38	3.38	1.000
Design	Y1 pre-Y2 post	3.38	3.66	0.095
Implementation	Y1 pre-Y1 post	3.25	3.41	0.344
Implementation	Y1 pre-Y2 post	3.28	3.47	0.338
Content	Y1 pre-Y1 post	3.31	3.63	0.023*
Content	Y1 pre-Y2 post	3.35	3.90	0.003*
Culture	Y1 pre-Y1 post	3.28	3.41	0.474
Culture	Y1 pre-Y2 post	3.34	3.47	0.564

*Significant gains in Content at p<.05 level; no other domain showed significant gains
Observations by coach mentors using Horizon, Inc.'s *Inside the Classroom Observation Protocol*

The ratings in these categories is on a scale of 1-5. Classroom observation scores showed significant gains in content delivery. No significant gains are seen in other classroom domains (design, culture, implementation). "Y1pre" is the first observation ever done on the teacher; "Y1post" is the second observation in that year. Observation by coach mentors utilized Horizon Inc.'s *Inside the Classroom Observation Protocol*.

REMARKS ON NSF & USDE MSP PROGRAM COORDINATION, BUDGETS AND PRIORITIES

NSF and USDE MSP Program Collaboration

• There are three basic ways we see collaborations taking place. One is that many NSF-funded projects have applied for state grants and received them either to enlarge the numbers served or continue after NSF funding. Another, as we have seen here, is that many of the projects are using the tools, resources and ideas developed in the NSF MSP programs and applying them to these more discrete projects. Third, in some cases the NSF MSPs have been asked by the states to help convene and coordinate what is being learned in both the NSF projects and the USDE projects. So there are a number of ways that our programs are working together at the state level. **• Patricia O'Connell Johnson, Team Leader, MSP Program, USDE**

• I want to reemphasize this mode of cooperation between the two programs. In some way, all of you see this as two funding streams, but this is one community of students and teachers that we are all trying to reach. Certainly our funders—Congress and the executive branch— see both sets of tools as very important ways to reach the nation. In the stimulus package before Congress at this moment there is very specific language that talks about these MSP programs as a major source of competitiveness for the future of this country. This work and learning that involves all of us is critical, so continue the dialogue. **• Jim Hamos, Program Director, MSP Program, NSF**

National Science Foundation MSP

Daniel P. Maki
Program Officer, Division of Undergraduate Education, National Science Foundation, Math and Science Partnership

In response to questions about the status of the NSF budget, Maki notes that there are actually three budgets currently operating in parallel. The first is the 2009 budget, which is under consideration, moving forward, and will hopefully be resolved soon. Fiscal year 2009 started in October and like much of the government, NSF is currently operating under continuing resolution. The second is the 2010 budget, which has been under construction for about a year, is about to be rolled out, and will then proceed through Congress. The third is the stimulus budget, which at this stage includes money for math and science education. In regard to the stimulus budget, Maki advises projects to assume a state of readiness.

Maki observes that while this conference showcases NSF MSPs, the number of schools involved in MSP versus the number in the nation means that NSF is unlikely to impact the entire nation unless they work with other groups such as USDE. Maki urges participants to identify, contact, and share with the USDE MSPs in their states, noting that many have already done so, and states that cooperative efforts between the programs will continue.

U.S. Department of Education MSP

Patricia O'Connell Johnson
Team Leader, MSP Program, Office of Elementary and Secondary Education, U.S. Department of Education

O'Connell Johnson recounts highlights of a recent meeting of the career staff at USDE with the new Secretary of Education, Arne Duncan. The President is serious about early learning, including numeracy and early mathematics as well as early reading, and a major initiative is under way to work with existing programs. Another priority is support of those both entering and already in the teaching profession to retain high quality teachers over the long term. While Duncan and the President agree with the basic premise of benchmarks for progress and raising achievement of all children, they will be studying NCLB carefully prior to reauthorization.

Duncan also talked about the stimulus package, which includes significantly increased Title I funds and IDEA funding, significant amounts for technology support and school construction including science labs, and funding for early childhood. While passage depends on Congress, the question is how this money can be absorbed quickly and have maximum impact. The point, O'Connell Johnson emphasizes, is that those in MSP should be contributing to the dialogue, ready to share their ideas, and prepared for emerging opportunities.

DETERMINING WHAT WE KNOW AND HOW WELL WE KNOW IT: THE PROMISES AND PERILS OF KNOWLEDGE MANAGEMENT

Iris Weiss
President, Horizon Research
Co-PI, MSP Knowledge Management Dissemination Project

Barbara Miller
Education Development Center
Co-PI, MSP Knowledge Management Dissemination Project

The Basis for Decision-Making

Iris Weiss opens the presentation with a participatory exercise.

**Opening Exercise:
Deepening Teacher Content Knowledge**

- A fact sheet includes a description of the background and context of an MSP as well as two alternative plans for deepening teacher content knowledge in order to improve their mathematics and science instruction.
- Participants are instructed to read the sheet and discuss with others at their table which plan they would recommend and why.
- Participants are then asked to indicate which of the following best characterized the discussion at their table regarding the basis for their recommendation: a) primarily on research findings; b) primarily on people's prior experience; c) about equally on research and experience. The majority indicated b.

Weiss observes that while there have increasingly been calls for basing practice on empirical evidence, for multiple reasons practice tends to be based on a wide variety of sources. Those sources include: research findings about particular strategies, your own experiences, the experiences of people you respect, beliefs about what is important, and the particular context.

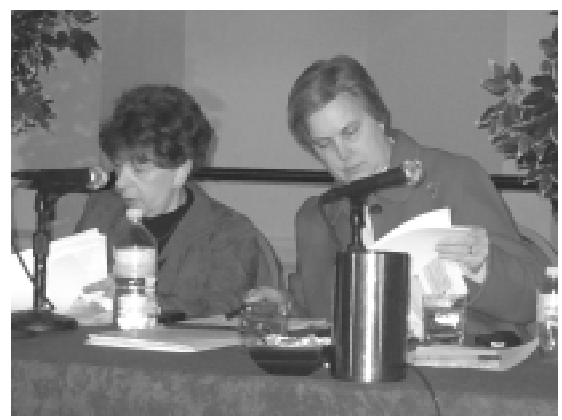
Differences in beliefs about what is important have played out in the work the Knowledge Management Dissemination (KMD) Project is doing, Weiss notes. For example, there are those who say you can't teach what you don't know, so you have to start by helping teachers understand content at a deep level. They can then begin to think about applications for their classroom practice. An equal number say that by their very nature, teachers are practitioners. You have to start from their practice as a way to draw them in to have them recognize the need for deepening their content knowledge. In fact, Weiss submits, the empirical research does not provide much guidance about which plan would be more effective in the context of the participatory exercise or in any other.

"We are never going to have sufficient empirical evidence to guide all of our decisions," Weiss states, noting that contexts differ and there are trade-offs to consider in each situa-

Visit
www.mspnet.org
for a video recording of this presentation as well as full PowerPoint presentation

A copy of this PowerPoint presentation, as well as details about the MSP Knowledge Management Dissemination Project methodology and results can be found at their Web site:
www.mspkmd.net

Iris Weiss and Barbara Miller



Areas for Exploration: Focus on K-12 Education

- Teacher Content Knowledge (TCK)
- Teachers as Intellectual Leaders (TL)
- Teacher Induction (TI)

Knowledge Management Framework

- KMD is acquiring two types of knowledge:
  - empirical research findings, including MSP research
  - practice-based insights, including from MSP community

Empirical Research

- Identified and screened studies, from research literature databases, to ensure that each includes an empirical investigation of the topic of interest
- Summarized research questions and framework, research methods, findings, conclusions, and implications
- Developed and applied standards of evidence to fairly assess contributions and limitations of research studies using different methodologies, building on earlier work by the NRC and others
- Provided a rating and narrative for each of six domains:
  1. Adequate documentation of activities
  2. Internal validity
  3. Analytic precision
  4. Generalizability/external validity
  5. Overall fit
  6. Warrants for claims

tion. "Nevertheless, we are all expected to draw on what is known, the accumulated knowledge of the field, while we continue to forge knew knowledge." This is the purpose of the Knowledge Management and Dissemination Project, to help future MSPs and other R&D efforts ground their strategies, including evaluation/research designs, in what is already known.

Overview of the KMD Project

Barbara Miller introduces the goal of the KMD Project: to synthesize knowledge generated through the Math and Science Partnerships and integrate it into the broader knowledge base for education reform. She then reviews the three areas of focus for KMD, noting that the focus of today's presentation is on teacher content knowledge and teacher leadership.

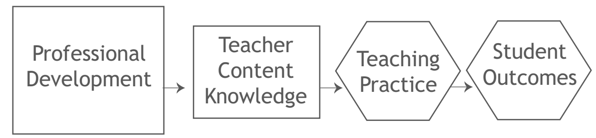
Explaining that KMD is acquiring two types of knowledge, both empirical research findings and practice-based insights, Miller provides detail on each.

Practice-based Insights

- Developed and applied process of collecting and vetting practitioner knowledge from various sources:
  - MSP leader interviews
  - On-line discussion boards (MSPnet) and focus group reflections
  - On-line collection of insights, evidence, and examples (modified Delphi Panel) from panels of experienced practitioners, researchers and evaluators

What We've Learned About Deepening Teacher Content Knowledge

Iris Weiss provides a sampler of some of the things the KMD Project has learned about deepening teacher content knowledge, presenting a diagram of the logic model.



Professional development is offered with the intent of deepening teacher content knowledge, including pedagogical content knowledge and understanding of student thinking as well as disciplinary content knowledge. The point is to get results in the classroom that will lead to improved student outcomes.

One of the things the KMD Project looked at was the link in the literature between teacher content knowledge and teaching practice: Does teacher content knowledge matter? They found that it mattered in a number of ways.

Teacher content knowledge matters for teaching practice:

- Selecting content to emphasize
- Selecting instructional strategies and sequences
- Selecting assessment tasks
- Implementing curriculum materials
- Engaging in teacher professional communities

21 studies in mathematics, 7 studies in science

Weiss notes that while, in this case, there were 21 studies in math and 7 in science, in other reviews that is reversed and there doesn't seem to be any reason for the number of studies from either discipline.

The bottom line, she continues, is whether teacher content knowledge matters for student outcomes. In this area they found two studies in mathematics and two in science. For their literature review they only included studies that had measures of teacher content knowledge (actual assessments rather than self-reports), which screened out many studies. Weiss then points to the following study.

Teacher content knowledge matters for student outcomes

For example, Magnusson and colleagues (1992) found that when teachers held an incorrect idea about heat energy and temperature, their students were more likely to develop the same incorrect idea than if the teacher correctly understood the concept.

While the literature is lean, Weiss concludes, there is support to say that teacher content knowledge matters. She adds that in the literature there are incentives to report positive findings, and the studies in the literature are more likely to have positive findings than studies that never got submitted or accepted.

The next question to be addressed is, what do we know about efforts to deepen teacher content knowledge, typically through professional development? In this case, 13 studies were found in mathematics and 26 studies in science. Weiss notes again that this is a sampler and that more detail may be found on their Web site. She then reviews findings regarding strategies for designing programs and for implementing programs to deepen teacher content knowledge.

The first two pieces of advice deal with designing programs. The advice in these and following summaries is culled from the KMD Project's work with MSPs.

Designing Programs: Understanding Teacher Needs

Advice

Expect the nature and extent of teacher content-related needs to be different for different topics.

MSP Example

- An MSP's summer institute for secondary teachers focused on two strands of mathematics content: algebra and geometry.
- The MSP found that teachers view algebra very procedurally, so they decided to focus on getting teachers to see the concepts behind the procedures.
- In contrast, said the PI, "The big issue with geometry is that when kids come in to high school geometry courses, teachers think that they are ready to do deductive work. In almost every case, kids come in with a very, very poor structural understanding of the geometric figures that they are having to face."
- As a result, the MSP's focus in geometry was on teacher pedagogical content knowledge, in particular teachers' understanding of students' developmental stages in geometry learning.

Designing Programs: Content-based Investigations

Advice

Developing deep mathematics/ science conceptual understanding takes time; teachers need multiple opportunities to explore new ideas.

Research on Content-based Investigations

- Content-based investigations are a fairly common PD strategy.
- The KMD literature search found:
  - 7 studies in mathematics
  - 20 studies in science

Example from the Literature

- Puttick & Roseberry's (1998) case study of an elementary teacher involved in multiple content-based investigations over 2 years found, in relation to specific investigations, that the teacher:
- *"…began to work with basic ideas underlying equilibrium (e.g., the role of weight as a downward force, the notion of a system in balance)," and*
- *"…acquired a grounded understanding of acceleration and of Galileo's theory of accelerating bodies in particular."*

MSP Example

- An MSP engages secondary mathematics teachers in extended investigations of advanced, challenging problems. The PD focuses on:
  - what it means to do the work of mathematics,
  - key ideas in the high school curriculum that relate to these challenging problems.
- This MSP is conducting case study research to connect teachers' experiences in the PD with their developing knowledge of what it means to do mathematics, and how that knowledge plays out in their practice.

Switching to implementing programs, Weiss says, "We hear loud and clear from the MSP community that it's really important that you be true to these disciplines."

Barbara Miller steps in to share some of what the KMD Project knows about using teacher leaders, from teacher leader practice to preparing and deploying teacher leaders. The term "teacher leaders" refers to current or former classroom teachers working with other teachers and educators within the school and district. Many of the other terms used, such as coach or teacher on special assignment, would fall under this heading.

Miller reviews a sampling of what has been culled from literature and practice, beginning with the impact of teacher leader practice on teachers' classroom practice. Regarding ways in which teacher leaders improve teachers' classroom practice, she notes the importance of both content knowledge and classroom experience working in conjunction. Miller continues

Implementing Programs

Advice

Be true to the discipline — Professional development should model mathematics/science "habits of mind."

Example from the Literature

- Hill and Ball (2004) analyzed natural variations in implementation among 15 teacher summer institutes focused on number and operations. Institutes implemented with a focus on mathematical analysis, reasoning, and communication had larger impacts on teachers' mathematics content knowledge.

Teacher Leader Practice:

Impacts teachers' classroom practice

- Providing instructional support to teachers
  - Inside the classroom (e.g., modeling lessons)
  - Outside the classroom (e.g., leading professional development)

8 studies

Is related to student outcomes

- Positive impact on student outcomes in classrooms taught by teacher leaders These are TLs conducting classroom teaching. (The implication is that TLs can help other teachers do what the TLs do in their own classrooms, which requires a leap of faith and poses a good question.)
- Positive impact on student outcomes from school-level effects, including teacher leader practice (Note that teacher leader practice is just one part of a mix.)

7 studies

Improving Teachers' Classroom Practice: Teacher Leader Modeling

Advice

Demonstration lessons and other modeling experiences should be structured to engage teachers in reflecting on their classroom practice.

MSP Example

An MSP's teacher leaders provided model lessons for teachers with these features:

- The teacher leader and teacher agreed beforehand on the explicit learning goals of the lesson.
- The teacher's observation of the modeled lesson was framed by a specific question, e.g., how students were engaged in sense-making of key ideas.

Improving Teachers' Classroom Practice: Teacher Leader-Led PD

Advice

Whenever possible, choose teacher leaders who have strong content knowledge as well as classroom experience.

Example from MSP Research

Manno and Firestone (2006) found that teacher leaders identified as content experts (minimum of an undergraduate major in the teacher leader's content area and teaching certification in that area) were more likely to:

- provide support in curriculum implementation, including leading professional development and
- establish greater trust between themselves and the teachers with whom they worked

MSP Example

- Teacher leaders in one project co-designed and presented grade-level professional development sessions on individual *Investigations* units prior to teachers being asked to teach the units.
- Because these teacher leaders had piloted the program in their own classrooms, they were confident about how the program worked with students. Because of their experience, they were able to share their genuine enthusiasm for the units and the program and also able to answer specific questions that teachers had.

Working with Principals

Advice

Recognize that it's a two-way street. Teacher leaders need the active support of principals, and principals benefit from the knowledge of teacher leaders.

Research on Working with Principals

Collaboration between teacher leaders and principals gives principals access to the specialized knowledge of teacher leaders (content and pedagogy) to inform leadership decisions.

4 studies

MSP Example

- MSP leaders and others note that principal support for teacher leader efforts is critical, including providing time, materials, and public encouragement.
- "Some progress can be made with a passive principal or a hands-off principal, but sooner or later, if the principal is not supporting the work, a plateau will be reached and it is unlikely that a system (school) will be impacted over the long haul."

with teacher leader modeling, work with principals, and ways in which teacher leaders' knowledge and skills are developed.

Miller concludes this portion of her remarks by stating that looking across what we know from empirical research and practice-based insights, this is what we see. The second point here is consistent with participant response to the opening exercise of this presentation and what the KMD Project has been seeing around these topics.

Comparing Empirical Research and Practice-based Insights

- Empirical findings tend to be larger grain size; practice-based insights tend to be more contextualized and nuanced.
- We were surprised at how little guidance the available research provides and how much guidance expert practice provides, although without the backing that empirical research would provide.

Research on Developing TL Knowledge and Skills

- Teacher leaders generally carried out the work for which they had been prepared. 6 studies
- Wallace et al. (1999) and Miller et al. (1999) found that teacher leaders tended to reproduce in their practice the model of preparation they had received. The proportion of time in the preparation programs devoted to subject area content, pedagogy, and leadership corresponded with the time that teacher leaders spent in these areas in their work with teachers.

Developing Teacher Leaders' Knowledge and Skills

Advice

- Teacher leaders need more than preparation in content and pedagogy; they need to have opportunities to develop the role-specific knowledge and skills they will use in their work in schools and districts.
- "Too often, assumptions are made that good teachers will be good teacher leaders. While it is important to have the personal qualities necessary to lead, teacher leadership also requires a new set of skills and knowledge that prepare teacher leaders for new roles and responsibilities."

MSP Example

An MSP used a variety of strategies to prepare teacher leaders to provide in-class support to teachers.

- Teacher leaders attended 2-3 professional development sessions before they began their work in the classroom, dedicated to providing them with the basic knowledge they would need to carry out their leadership roles.
- After teacher leaders began their work with teachers, preparation staff conducted on-site visits to observe teacher leaders' work in the field. Based on their observations, staff worked one-on-one with individual teacher leaders to improve their skills in areas of need.

Why Don't We Know More?

- For TCK, systematic keyword searches identified nearly 2000 relevant items published since 1990. However, approximately 90% of the studies were screened out because:
  - They were advocacy or opinion pieces, not research, and/or
  - They were studies of pre-service teachers only, and/or
  - They did not include a measure (quantitative or qualitative) of teacher content knowledge.
- The 174 TCK studies that passed "eligibility" screening were reviewed using MSP-KMD's standards of evidence to identify their contributions to the knowledge base.
- Similarly, only 58 of the nearly 800 studies identified in the TL literature review passed through the screen and had standards of evidence applied.
- In applying standards of evidence, we often found vague or incomplete documentation of programs or interventions. Consequently, we know something worked, but we don't know a lot about what "it" was.
- Studies tended to be more like program evaluations rather than research on particular strategies. Consequently, we know the overall experience worked, but we don't know how much particular interventions contributed to the gains.
- We often found serious limitations with study research designs, including:
  - Selection bias in samples and contexts
  - Lack of comparison groups or criteria
  - Idiosyncratic instrumentation, without evidence of validity/reliability/credibility

Why Don't We Know More from the Empirical Research?

Iris Weiss addresses the question of why more knowledge has not been gleaned from the empirical research and offers findings from the KMD Project's forays into the literature. She notes parallels in the problems encountered with many studies in the literature and aspects of MSP research.

Why Don't We Know More?

- There are too few studies of any one phenomenon to be able to have confidence in the robustness of the findings in any case.
- High quality research is expensive, which may explain why so many in-depth studies in the literature involved fewer than 5 teachers.
- There is a tension between design for change and design for learning. From a system change perspective, if you plan on having two cohorts, it makes sense to start with the schools that are "ready." But doing so makes research on program effectiveness problematic; it will not be possible to disentangle the effects of differences in readiness from the impact of the interventions.

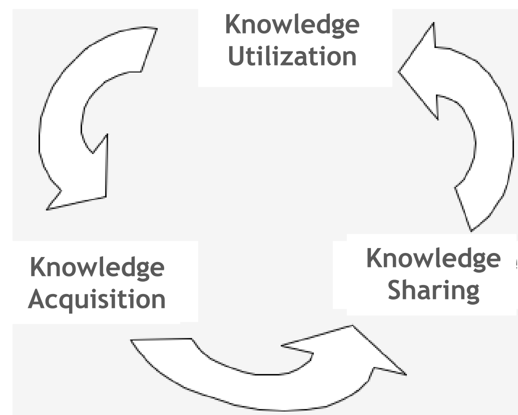
From an MSP abstract:
"Further, these results suggest benefits of designing MSP project implementation in ways that facilitate most valid assessments of impact. For example, random assignment of eligible teachers to participate in [project] would provide greater confidence that observed effects are not associated with teacher self-selection or with administrator support for the most qualified applicants."

- Even when individual studies are well-designed and well-implemented, it is difficult to look across them and figure out the extent to which the findings might generalize.

How Can We Learn More?

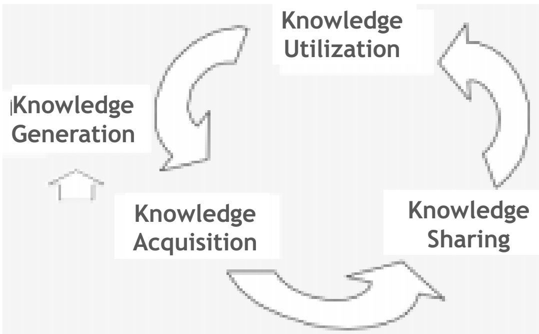
There is a second question that is even more important, Weiss states: How can we learn more? She relates that the KMD Projecthas been using a fairly simple knowledge management framework dealing with iterative stages of acquiring knowledge, sharing the knowledge, watching and seeing how the knowledge is used, and acquiring more knowledge in a cyclical process.

Knowledge Management Framework



"The more we toiled in the fields of teacher content knowledge, teacher leadership and teacher induction, the more we realized that really learning much required another box," Weiss observes. "We really need to be thinking more about how to accelerate the systematic generation of knowledge.

Adapted Knowledge Management Framework



In framing a research agenda, how do we think about the priorities and about improving the system so that we can learn from it? The fact that in research, one question leads to another is a good thing, Weiss observes. What is not a good thing is that there are few incentives for replicating or following up on others' work.

Framing a Research Agenda

- Research→Research
  - In research, answering one question leads to many others.
  - However, there are few incentives for replicating studies in different contexts, or otherwise following up on others' work.
- Practice→Research
  - Focusing research on problems of practice helps to bridge the research to practice divide.
  - Practice-based insights can be considered hypotheses for research – to be systematically studied with different populations in a variety of contexts.

In addition to focusing practise more on research and empirical findings, she adds, there are increasing calls for research to focus more on important problems of practice. Further, practice-based insights can serve as hypotheses for research.

Weiss then details the ways in which we can learn more from MSP projects.

How Can We Learn More?

- Many MSPs have evidence that their interventions are effective, and those findings should be shared.
- In addition to the quantitative analyses, case study descriptions of interventions, target audience, and context, and discussions of lessons learned about sustainability, would be extremely helpful to the broader field.
- Individual MSPs would add even more to the knowledge base if they systematically studied their treatments under different conditions – with more and less experienced PD providers, teachers with stronger and weaker content backgrounds, etc.
- Similarly, MSP projects would add more to the knowledge base and increase the likelihood of going to scale if they studied different configurations of their interventions:
  - How much drop-off in impact is there with a reduced level of treatment?
  - Would providing fewer hours of PD to a larger proportion of teachers in a school have a greater impact on teaching and learning?
- The fact that MSPs have similar goals and similar interventions provides an opportunity for more transformative research, accelerating the generation of knowledge about what works, for whom, and under what conditions.
- Setting up cross-site studies has the potential to add considerably to the knowledge base, providing information about the effectiveness of particular interventions in different contexts.
- Among the advantages of cross-site research:
  - STEM disciplinary faculty who are new to social science research will likely appreciate the guidance that the research design and protocols provide.
  - Projects that are too small to get project-representative results can still contribute to the knowledge base.

Knowledge Sharing

Miller notes that much of what Iris Weiss shared is basedon what the KMD Project has learned and on the potential that exists for knowledge generation in the MSP community. A number of venues have been utilized for sharing knowl-

Knowledge Sharing

- Knowledge Reviews
- Presentations at professional meetings
- Articles submitted to journals
- MSP cases focused on sustainability
- TCK Instrument Database

Knowledge Reviews

- Approximately 20 posted to-date
- Reporting empirical research and practice-based insights
- Opportunities for MSPs to provide additional input

www.mspkmd.net

TCK Instrument Database

- A total of 168 instruments surfaced in the TCK research review
- RETAs have developed measures of TCK
- Partnerships have developed measures of TCK
- Only instruments that provide a way that others can come up with "scores" are included in the database
- Instruments can be searched by:
  - Subject
  - Type of knowledge (disciplinary, pedagogical content, ways of knowing)
  - Nature of assessment items (selected response, constructed response, other)
  - Grade levels of teachers studied
- Database includes:
  - Descriptions of instruments (but not the instruments themselves)
  - Scoring information
  - Validity and reliability information, when available
- 62 instruments included to-date

edge, particularly on the topics of deepening teacher content knowledge and teacher leadership. Miller provides additional detail regarding Knowledge Reviews and the Teacher Content Knowledge Instrument Database and encourages participants to visit the KMD Web site to take advantage of both of these resources.

Miller concludes by outlining the next steps for KMD, and notes that MSP projects will shortly be receiving a request for their recent research regarding deepening teacher content knowledge and teacher leadership, for materials developed or used by MSPs for teacher content knowledge and teacher leadership, and for instruments developed or used for teacher content knowledge work.

Next Steps

- Developing Knowledge Reviews on STEM Disciplinary Faculty Involvement
- Updating existing Knowledge Reviews, including adding recent MSP research
- Developing a TCK/TL materials monograph

Coming Soon…

A request, with encouragement from your Program Officer:

- Recent research by MSPs on TCK/TL
- Materials developed/used by MSPs for TCK/TL work
- Instruments developed/used by MSPs for TCK work

Question and Answer Session

Leadership Databases from Other Fields

- It seems to me you could summarize what you've said about teacher leaders by saying that teacher leaders need to know how to lead and need to know something about leadership. There is a large body of leadership literature from other sectors such as business, politics, the military, and higher education. Has anyone searched those databases to see what we might learn about what might make better teacher leaders? • Donald Langenberg, Chancellor Emeritus, Professor of Engineering, University System of Maryland
- We haven't done a systematic search of that literature compared to what we've looked at in education, particularly in mathematics and science leadership. What we do know about leadership in other fields is that it works with very different constructs about what constitutes leadership, even within those fields. If you look at what constitutes leadership within the military, for example, there are many different models and approaches and the same is true for business and other areas. Certainly, as eductors, we can learn from how other fields conceptualize and think about leadership, but the empirical research base in those fields is no more clear or definitive or directive about practice than what we have in education. But from a conceptual point of view, there are some interesting, compelling models which can inform our understanding,

whether it's in research or in practice.
• Barbara Miller

Coaching and Technical Assistance for Framing Research Studies

• A question I've been dealing with for decades is the tension between the need to rush in and help needy districts versus approaching them from a research perspective. Certainly districts would like research-based practices, but they are not interested in being research subjects.

Another issue is that when one writes NSF grants, often there is no opportunity to receive counsel on a long-term basis involving cross-site or regional labs that could help synthesize the research and counsel individual presenters about what the literature says, the current state of knowledge, and to frame their project in ways that would help fill existing gaps. In that regard I'm not clear on the USDE regional labs and whether they could fill that role or not. • F. Joseph Merlino, Director and PI, MSP of Greater Philadelphia

• I don't know much about the USDE centers, but I believe more of the focus is on applying what we know to practice rather than helping researchers shape their research. I think what you might be talking about is this middle ground of people who are doing implementation, who are open to the notion of research but might not have the expertise so that some sort of technical assistance is needed. I think that would be useful, but the closest I know came from NSF during the first round of RETAs. After the panels met, NSF put a second panel together to look at the methodological adequacy. They put together a dynamite group of people to coach us on how to make our studies better. That could, perhaps, be incorporated into the review system or some coaching of new projects; not just making their research better but looking for opportunities across projects. • Iris Weiss

Research on Combined Math and Science Projects

• I'm interested that you divided up the math and science projects. I saw few to none that were math *and* science, and this is a math science partnership. I'm curious why the math and science people don't work together more. • Catherine Skoken, Associate Professor, Colorado School of Mines

• Some of the empirical studies we saw on teacher leadership did draw from programs that had both math and science. We continue to be curious about the empirical research, and even some of the practice-based insights in teacher leadership, where the content discipline, whether mathematics or science, was not the most robust feature. I don't know if that's a comment on math-science partnerships, or if it's about the nature of teacher leadership, that it doesn't distinguish. In work we've seen where the studies are done in a math or a science context, it leaves it up to the reader to ask whether the findings in one

Providing Research Support and Synthesis

• In the Division of Research on Learning, NSF has established a network center for each of our major programs to try to synthesize our findings and make then public. We recognize the need to look across the projects to provide support for our researchers and synthesis to the field. We're not quite sure how to provide support to people submitting proposals to us, but we are thinking about it. • Elizabeth VanderPutten, MSP Program Officer, NSF

USDE Regional Labs' Research Synthesis

• I can answer the question regarding the role of the USDE regional laboratories in synthesizing research. Much of the synthesis of the research literature that we can do is very much limited to randomized control trials, what passes at the What Works Clearinghouse. That work under the current regional educational laboratory contract has been an interesting one, especially from a research practitioner perspective. • Edith Gummer, Program Director, Research and Evaluation, Northwest Regional Educational Laboratory

Helping Shape Forthcoming PD Funding

• It's my observation that there are going to be a lot of "shovel ready" projects to do professional development of teachers with state and federal legislatures rushing in. I'm wondering how we can help channel that effort in ways that would be productive in terms of both programs and research. • F. Joseph Merlino, Director and PI, MSP of Greater Philadelphia

Asking More Nuanced Questions

• I'm interested in your thoughts about doing research on teacher leadership within a context of a volunteer program, where you'll find teachers within schools who are resistant to working with a teacher leader. How would you go about doing this? • Sabra M. Lee, Lesley University, Focus on Mathematics MSP

• There are any number of research questions that we could be asking. I think part of it is, of those, which ones do we want to pursue? That leads very much to the design issue. If teacher leaders are working in a situation with resistant and nonresistant teachers, are the results similar? Then there is the selection of teacher leaders. How prominent do you want the resistance of teachers to be in the work that you're doing? The research that we saw in teacher leadership tended to be at a very broad brush level, not making apparent those more specific questions. I think a contribution to the field would be any research that starts to ask more nuanced questions about the work of teacher leaders: With whom? Under what context? • Barbara Miller

• So for me the question would be: How do you go about working with resistant teachers and what strategies are effective? • Sabra M. Lee, Lesley University, Focus on Mathematics MSP

discipline fold over into others. • Barbara Miller

• I hadn't thought about this, but there are those of you who report results for both mathematics and science. We've been divvying them up, putting the math results with math and the science with science, but it's an opportunity for a comparison test. The notion of looking at whether the same intervention within an MSP would work equally well with math or science provides an opportunity to do comparisons. Again, what works for whom and under what conditions? • Iris Weiss

Standards of Research Documentation

• Iris mentioned that we have a sort of conventional wisdom about what counts as quality professional development. Those interested in doing systematic research, looking across projects in terms of examining those characteristics, are running into the issue that the framework of criteria is not an evidence-based framework. So again, under the current context of what counts as research, that sort of analysis is not appropriate. Could you comment on that? • Edith Gummer, Program Director, Research and Evaluation, Northwest Regional Educational Laboratory

• I personally think the restrictions on randomized field trials are overly limiting. We need a variety of studies. Randomized field trials are good, but they are not always the full picture. Most of us will try to do the best, most valid research design we can, and if that's a randomized field trial, great. But that may not always be possible, and it won't answer all of the questions. I think in addition to the "what works" factors not being well researched, we need standards of documentation so that when we see a study, we know what the intervention was. Right now, if you were to go by many studies in education, you would think that the size of the city and the region of the country are the most important variables, and there's usually something about student demographics. Those might not be the most important variables. Rarely do I see anything about teacher background or teacher experience. If we have a set of standards of documentation that we all agreed on when we report studies, then people could do meta-analyses and syntheses more readily. • Iris Weiss

KEYNOTE:
IMPROVING THE TEACHING OF SCIENCE THROUGH DISCIPLINE-BASED EDUCATION RESEARCH: AN EXAMPLE FROM PHYSICS

Lillian McDermott
Professor of Physics and Director,
Physics Education Group, University of Washington

Discipline-Based Research on Learning and Teaching

Lillian McDermott opens her remarks by introducing the work of the Physics Education Group at the University of Washington, which conducts a coordinated program of research, curriculum development and instruction, supported in part by grants from NSF. The Physics Education Group is engaged in discipline-based research on learning and teaching. The work is not hypothesis-driven and differs from traditional education research in which the emphasis is on educational theory and methodology. "The focus is on student understanding of the science content," McDermott elaborates, "which we believe is an important field of inquiry by science faculty and science departments. We believe it is effective not only for K-12 education but for K-20+." The farther you advance in science education, the farther away you get from introductory ideas, McDermott observes, and that is crucial because most of the faculty who are teaching this subject are very far away from what it is like to learn these concepts for the first time.

McDermott enumerates four reasons why this belongs in a science department as opposed to a college of education.

Why a Science Department?

- The incentive to improve learning is likely to be strongest there.
- The depth of knowledge that is necessary is there.
- The students studying science are there.
- Other science faculty are likely to be more influenced by a scientist in their discipline.

The overall goal of the Physics Education Group is outlined below. The constraints, McDermott notes, are those consistent with the culture of a traditional research-oriented physics department, and while the context is physics,

Overall goal of the Physics Education Group:
to understand *what* makes physics difficult for students and *how* to promote student learning

Expand research base on learning and teaching
- in learning specific content
- design and assess instructional strategies
- develop research-based and research-validated curriculum

→

Contribute to cumulative improvement in effectiveness of instruction
- disseminate our instructional materials
- apply results of research and curriculum development in undergraduate education and professional development of K-12 teachers & future faculty
- report findings in journals and at professional meetings

Lillian McDermott and Joyce Evans

Visit
www.mspnet.org
for a video recording of this presentation as well as full PowerPoint presentation and research articles by Lillian McDermott related to this presentation.

Constraint:

consistent with the culture of a traditional research-oriented physics department

It is necessary to:

- participate in life of the Department and identify with it
- build a group in which faculty have same status as others in the Department, not dependent on one person
- report results in meetings that physicists attend, publish in refereed journals that are readily accessible to them, and in language that they can understand (avoid frequent use of terms like constructivism, scaffolding, zone of proximal development, etc.)
- note that "intellectual merit" is likely to be more highly valued than "broader (social) impact"

Context:

physics but analogies can readily be made to other disciplines

Physics Education Group

Perspective:
Teaching is a science (as well as an art).

Procedures:

- conduct systematic investigations
- apply results (*e.g.*, develop instructional strategies)
- assess effectiveness (*e.g.*, through pretesting and post-testing)
- document methods and results so that they can be replicated
- report results at meetings and in papers

These are characteristics of an empirical applied science.

analogies can readily be made to other disciplines. From the perspective of the Physics Education Group, teaching is a science (as well as an art), and McDermott describe how the group works from this perspective, detailing the procedures used by the group (lower left) and the results (below).

Results

indicate:
- many students encounter same conceptual and reasoning difficulties
- same instructional strategies are effective for many students

are:
- generalizable beyond a particular course, instructor or institution
- reproducible

become:
- publicly shared knowledge that provides a basis for acquisition of new knowledge and for cumulative improvement of instruction

∴constitute:
- a rich resource for improving instruction

The focus of the group's research is on learning by students.

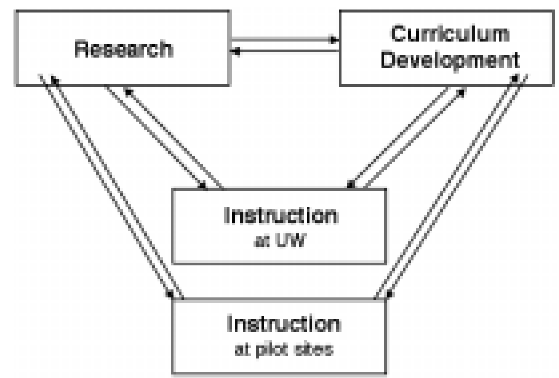
Focus of research is on learning by students

- identifying what students *can* and *cannot* do
- designing instruction to develop functional understanding*
- assessing effect on student learning

** ability to do the reasoning necessary to construct and apply conceptual models to the interpretation of physical phenomena*

"What we do is research on the learning and teaching of physics," McDermott explains. "We apply that to the development of curriculum, and then try to do it in the classroom. We do that over and over until we have reproducible results." They then work with pilot sites all over the country in physics departments at other universities see if the methods are generalizable.

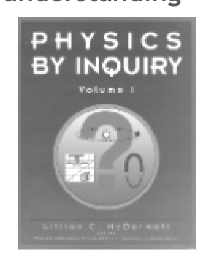
Application of research to development of curriculum



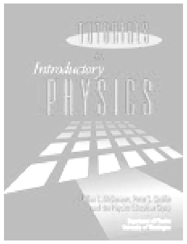
This process has resulted in two sets of curricula the group has been developing for over thirty years.

Investigations of student understanding

Physics by Inquiry
To prepare precollege teachers to teach physics and physical science (also suitable for other students)
- *self-contained curriculum that is coherent and laboratory-based with no lectures*



Investigations of student understanding



Tutorials in Introductory Physics
To improve undergraduate physics instruction
• *supplementary curriculum that supports standard instruction by lecture, textbook, and laboratory*

The Physics Education Group has worked with the following populations at U.W. and pilot sites.

Context: student populations
(at UW and at pilot sites)

- Introductory students (physics, engineering, other sciences)
- Underprepared students
- K-12 teachers
- Engineering students
- Advanced undergraduates and graduate students

McDermott proceeds to briefly sketch the professional development programs for current and future faculty and for K-12 teachers. The continuation course for K-12 teachers, which involves those who have participated previously in inservice training and takes place once a week during the academic year, helps to build a community and plays an important role, McDermott notes.

While all aspects of PD are important, McDermott acknowledges, her focus here is on

PD Program for Current and Future Faculty

Physics Education Group
Ph.D. Program

↑ ↓

Physics Department
Graduate Teaching Seminar
Weekly TA Preparation for Tutorials

↑ ↓

Short Workshops national meetings & universities 1/2 - 1 day	NSF New Faculty Workshops (semiannual)	Graduate Internships (short & long-term)	Faculty Visits (short & long-term)

PD Program for Current and Future Faculty

Courses for Preservice K-12 Teachers

Elementary & Middle School Teachers Academic Year	Middle & High School Teachers Academic Year

Courses for Inservice K-12 Teachers

NSF Summer Institute
for K-12 Teachers

↓ ↑

Continuation Course
for K-12 Teachers
Academic Year

↓ ↑

Resource for various local
NSF and WA programs

Professional development of K-12 teachers can focus on many different aspects, all of which are important:

- practical classroom skills
- instructional methodology
- personal motivation (of teachers and students)
- social issues
- political issues
- developmental psychology (of students)
- learning theories
- epistemology
- discipline-specific knowledge (concepts, reasoning skills, representations)

Emphasis here is on research that physicists can do to promote the intellectual development that teachers need to teach physics effectively.

Investigation of student understanding of geometrical optics

F. M. Goldberg and L.C. McDermott, "An investigation of student understanding of the real image formed by a converging lens or concave mirror," *Am. J. Phys.* **55** (1987).

K. Wosilait, P.R.L. Heron, P.S. Shaffer, and L.C. McDermott, "Development and assessment of a research-based tutorial on light and shadow," *Am. J. Phys.* **66** (1998).

P.R.L. Heron and L.C. McDermott, "Bridging the gap between teaching and learning in geometrical optics: The role of research," *Opt. & Phot.* News **9** (1998).

See above sources for fuller explanation of the research discussed in this presentation.

Systematic investigations of student learning
(at the beginning, during, and after instruction)

- **individual demonstration interviews**
  - for probing student understanding in depth
- **written questions** (***pretests*** and ***post-tests***)
  - for ascertaining prevalence of specific difficulties
  - for assessing effectiveness of instruction
- **descriptive studies during instruction**
  - for providing insights to guide curriculum development

the disciplinary specific knowledge—the concepts, reasoning skills and representation—and on research that physicists and other scientists can do to promote the intellectual development that teachers need to teach science effectively.

Example from Physics of Discipline-Based Research as a Resource for Improving PD and Student Learning

McDermott provides a detailed example that illustrates the kind of research conducted by the Physics Education Group. Even this relatively simple example involving geometrical optics, she notes, is one that isn't that simple and takes weeks in the teachers' course. Like everything the Physics Education Group does, this is based on research. McDermott describes that research and summarizes the results.

Research involves the steps outlined at left. In this example involving student understanding of geometrical optics, what students were able to do after standard instruction is illustrated below.

What students *could* do
(after standard instruction):

Solve problems algebraically and with ray diagrams

Example:

An arrow, 2 cm long, is 25 cm in front of a lens whose focal length is 17.3 cm.

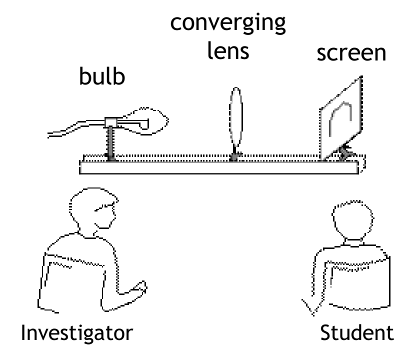
Predict where the image would be located.

$$\frac{1}{S} + \frac{1}{S^1} = \frac{1}{F}$$

A colleague, Fred Goldberg, joined the Physics Education Group on sabbatical, switching from atomic physics to this educational research. While he wanted to start with physical optics, McDermott suggested he begin with the simpler subject of geometrical optics. Two years later the focus remained geometrical optics, reinforcing the point that these concepts are not as easy as one would think.

Students were asked to predict the effect on a screen in the following scenarios.

What students could *not* do:



Predict effect on screen	*Correct*
1. if the lens is removed	50%
2. if the top half of the lens is covered	35%
3. if the screen is moved toward the lens	40%

Individual Demonstration Interviews: before/after instruction

The problem, McDermott relates, is that it didn't matter if students had taken the course in high school, if they had just had it in university, or if they had worked through the experiments in the labs.

Working with different populations yielded similar results and led to several practical generalizations.

Extension of research on many topics to several different populations

(e.g., undergraduates, K-12 teachers, graduate students)

1. Yielded similar results
2. Varied within about 5% for a given large population, regardless of many variables (instructor, academic quarter, time of day, etc.)

   ↓

   and thus eliminated need for a control group (which is often difficult to arrange)
3. Led to several practical generalizations

These generalizations on learning and teaching are evidence-based, not hypothesis-driven, and were inferred and validated by research and development of *Physics by Inquiry* and *Tutorials in Introductory Physics*. Two of those practical generalizations are offered below and are illustrated by the previous example.

The central concepts from the previous example that students failed to recognize are outlined below. The fundamental difficulty is that the basic ray model for light is just a memorized lesson for many people, but one that has no meaning.

Students did not recognize that:

- Principal rays locate image but are not necessary to form it.
- Area of lens affects only brightness, not extent, of image.
- For every point on an object, there is a corresponding point on the image.

but there was a much more fundamental difficulty

↓

Lack of a functional understanding of a basic ray model for light

- Light travels in a straight line.
- Every point on an object is the source of an infinite number of rays emitted in all directions.

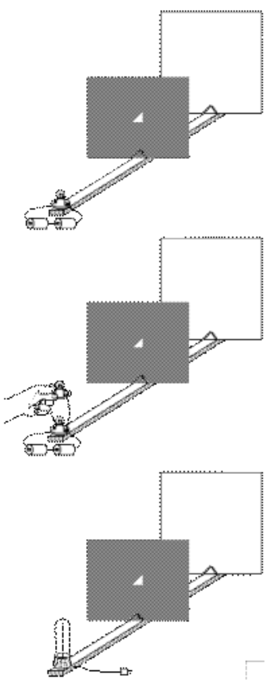
Working on the idea that the lens might be complicating matters, they tried eliminating the lens. The exercise at right is one of a number of exams administered to several thousand students as well as inservice and preservice teachers.

What happens if there is no lens?

What students *could not* do: Administered before or after standard instruction in calculus-based physics to several thousand students and to inservice and preservice teachers

Sketch what you would see on the screen.

Explain your reasoning.



Generalizations

- Facility in solving standard quantitative problems is not an adequate criterion for functional understanding.

  Questions that require qualitative reasoning and verbal explanations are essential for assessing student learning *and are an effective strategy for helping students learn.*

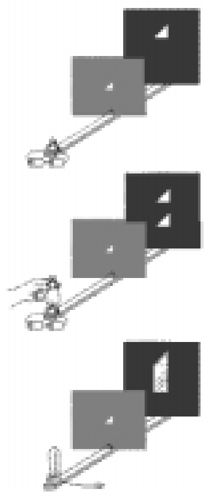
- Connections among concepts, formal representations (algebraic, diagrammatic, graphical, etc.) and the real world are often lacking after traditional instruction.

  Students need repeated practice in interpreting physics formalism and relating it to the real world.

Pretest on *light*

Sketch what you would see on the screen.

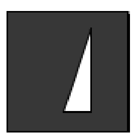
Explain your reasoning.



Correct responses

Single bulb	90%
Two bulbs	60%
Long-filament bulb	20%

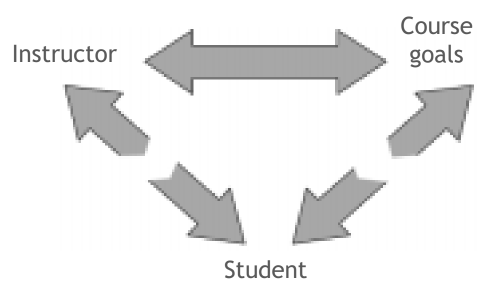
Most common incorrect response: image mimics shape of aperture



The results of the pretest with undergraduate students is offered at left. They did relatively well with a single bulb, not so bad with two bulbs, but with the long-filament bulb, students did not understand that each point on the filament represents a separate source and produces a trapezoid with a triangle on top. The fact that students don't see this right away is not at all unusual, McDermott remarks, but it can be taught so that students do see it and understand. This empowers the teacher even though they may not be teaching at this level because if you know more, it gives you the ability to judge what is appropriate for a given age level. "We want to give teachers the sense of confidence that they can do that which they are teaching and more," McDermott explains.

The evidence from research points to a gap, she continues. While the instruction and course goals are agreed, the instructor-student and student-course goals are not necessarily in agreement. Everyone knows that, McDermott acknowledges, but what most don't know is that the gap is much greater than most instructors realize. Or if they do realize it they don't act on that realization.

Evidence from research indicates a gap greater than most instructors realize



The Physics Education Group has substantial data on performance on certain types of qualitative questions, indicating that lectures, textbooks, demonstrations, homework and lab experiments often have little effect on student learning.

On certain types of qualitative questions, performance of undergraduates and K-12 teachers is essentially the same over a wide range of student ability:

- before and after instruction
- in calculus-based, algebra-based, and descriptive courses
- with and without demonstrations
- with and without standard laboratory
- in large and small classes
- regardless of popularity of the instructor

↓

Hearing lectures, reading textbooks, seeing demonstrations, doing homework, and performing laboratory experiments often have little effect on student learning.

The Need for a Different Approach: Guided Inquiry

Students need to go through reasoning involved in the process of constructing scientific models and applying them to predict and explain world phenomena. They must also be intellectually active to develop a functional understanding.

- **A coherent conceptual framework is not typically an outcome of traditional instruction.**

  Students need to go through the reasoning involved in the process of constructing scientific models and applying them to predict and to explain real world phenomena.

- **Teaching by telling is an ineffective mode of instruction for most students.**

  Students must be intellectually active to develop a functional understanding. (i.e., the ability to do the reasoning necessary to apply relevant concepts and principles in situations not expressly memorized)

A different instructional approach is required, McDermott states. "We teach by guided inquiry. What does this mean? This is a term that has different meaning for different people. For us, guided inquiry as our group interprets the term is intended to help students arrive at an understanding of a physical concept that a physicist would consider correct." She offers as an example the *Physics by Inquiry* and *Tutorials in Introductory Physics* approach to instruction on geometrical optics.

The generalizations are a practical guide in the process of curriculum development, McDermott observes, adding that Physics by Inquiry is characterized by two broad principles.

Generalizations serve as a practical guide in ongoing iterative process of curriculum development.

Physics by Inquiry is characterized by two broad principles.

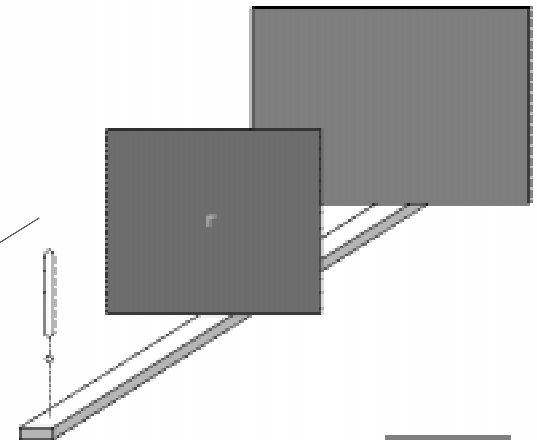
- Concepts, reasoning ability, and representational skills are developed together within a coherent body of subject matter.
- Physics is taught as a process of inquiry, not as an inert body of information. (There are no lectures.)

McDermott then displays a post-test administered after a tutorial on light and shadow. The post-test differs from the pre-test and is similar but harder.

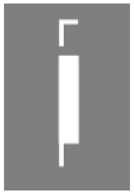
Post-test 1

administered after tutorial *Light and shadow*

Sketch what you would see on the screen when the bulbs are turned on.



Correct response

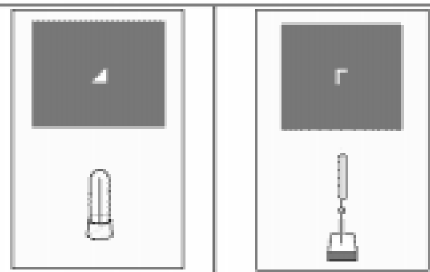


Physics by Inquiry & Tutorials in Introductory Physics

Instruction on geometrical optics

- Students are guided in constructing a basic ray model from their direct experience with light sources and apertures of different shapes.
- Questions that require qualitative reasoning and verbal explanations help students develop a functional understanding through their own intellectual effort.
- Curriculum explicitly addresses conceptual and reasoning difficulties identified through research.

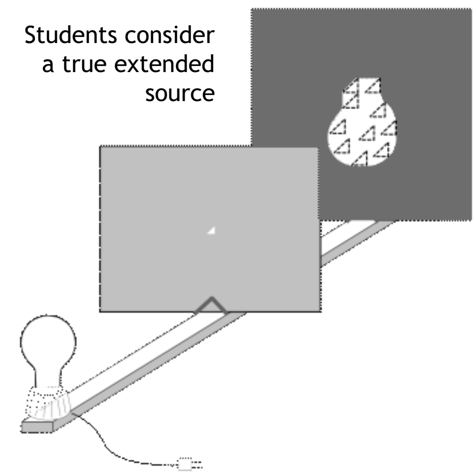
This type of laboratory-based instruction is very important for teachers.



	Pretest before and after traditional instruction $N > 2100$	Post-test 1 after tutorial $N = 415$
correct or nearly correct	20%	60%
image mimics hole in mask	70%	25%

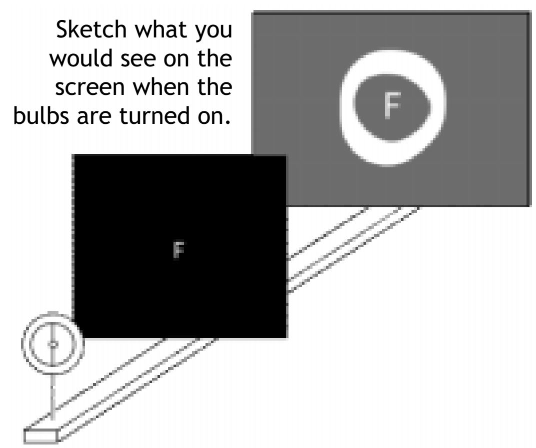
The comparative results from the pre-test and post-test are offered here. These results weren't satisfactory, McDermott notes, and the question was how to address this. The graduate student working on this as part of her dissertation decided to try a truly extended source, a light bulb, where each point of the light source gives rise to the image of the triangle. That is now part of the curriculum and this is the post test administered after that curriculum.

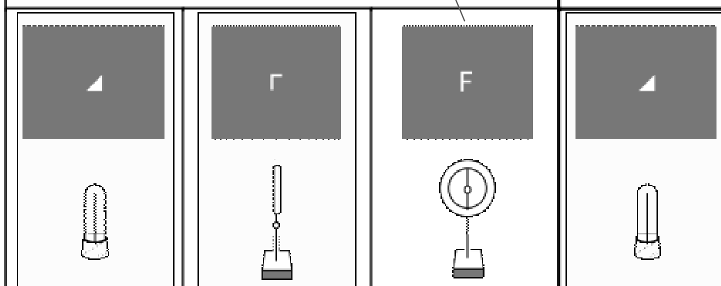
Revision to tutorial:



Are the improved results after the revised tutorial good enough? In response, McDermott notes that the graduate TAs admitted on the basis of their GREs are required to come once a week and to take the pre-test. The undergraduate scores reached or surpassed what the TAs, with four years of

Post-test 2
administered after revised tutorial





	Undergraduates			Graduate TAs
	Pretest with "hint" $N > 2100$	**After original tutorial** $N = 415$	**After revised tutorial** $N = 175$	**Pretest (before tutorial)** $N = 110$
correct or nearly correct	20%	60%	75%	65%
image mimics hole in mask	70%	25%	10%	30%

instruction behind them, were able to do.

Certain conceptual difficulties don't go away unless you do something, McDermott observes, and they won't go away unless you do something specific.

> **Certain conceptual difficulties are not overcome by traditional instruction nor are they likely to be overcome in advanced study.**
>
> *Persistent conceptual difficulties must be explicitly addressed.*

She provides the following practical criterion for the effectiveness of a tutorial, as seen in the previous example.

> **Practical criterion for effectiveness of a tutorial:**
>
> *Post-test performance of introductory students matches (or surpasses) pretest performance of graduate students.*

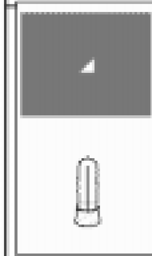
That is not good enough for teachers, however, McDermott notes. A question that arises is, what happens to their problem solving ability? The results in terms of student learning are offered below.

> **Assessment of student learning**
>
> Effect of tutorials on student performance
>
> - On qualitative problems:
>   - much better
> - On quantitative problems:
>   - typically somewhat better
>   - sometimes much better
> - On retention:
>   - sometimes much better
>
> *despite less time devoted to solving standard problems*

With regard to teachers, results with the *Physics by Inquiry* module were much better. Of particular interest to MSP projects, McDermott observes, will be what happens when you get to K-12 classrooms. While the Physics Education Group doesn't have many opportunities to find that out, they do have a few due to contacts with the local public school. Teachers who have been through the courses continue to cooperate with the Physics Education Group and give these tests to their students.

Though Physics by Inquiry is not intended for high school, in an unofficial preservice practicum, teachers from grades 9-12 were guided in adapting the curriculum, using it with students, and assessing the results. Below is data on 9th grade students working with preservice teachers familiar with the material, and an inservice teacher with added teaching expertise as well as familiarity with the material.

Results with *Physics by Inquiry* module were better.

	In-service K-12 teachers	
	 Pretest with "hint" N = 22	 After PbI N = 22
correct or nearly correct for all bulbs	5%	90%
image(s) mimic hole in mask	75%	5%

Adaptation of *PbI* by teachers for 9th grade students

1. In an "unofficial" practicum, preservice teachers [9-12] were guided in adapting *PbI*, using it with students, and assessing the results.
2. An experienced, well-prepared teacher adapted *PbI*, used it with her students, and assessed the results.

% correct responses			
Undergraduates & preservice teachers	Preservice teachers [9 - 12]	9th grade students	
after standard instruction	after *PbI*	1. *PbI* modified by preservice teachers	2. *PbI* modified by well-prepared teacher
N > 2000	N ~ 60	N ~ 55	N ~ 55
20%	85%	45%	85%

Reflection on results

Success rate of 9th-grade students with:
- experienced, under-prepared teacher < *20%*
- inexperienced, well-prepared teacher ~ 45%
- experienced, well-prepared teacher ~ 85%

Experience of pretesting and post-testing helped preservice teachers recognize the importance of assessing the results of instruction.

Another outcome of these courses, McDermott notes, is that teachers recognize the importance of assessment as you go along and modifying what you are doing based on what students can do.

Improving K-12 Science Education and PD for Teachers

To improve K-12 science education we must ask what we want young students to know and be able to do and prepare teachers accordingly, McDermott states. She emphasizes the fact that science education occurs in science departments, not education departments, and is a critical responsibility of university physics or science faculty. "If our group didn't believe in this it wouldn't happen. However," McDermott notes, "we couldn't do it if we didn't do the other things the department values."

Subject matter preparation of K-12 teachers occurs in science departments, not in education departments.

↓

Teacher preparation is a critical responsibility of university physics faculty.*

*recognized in the "Statement on the Education of Future Teachers" by AAPT, APS, and AIP in 1999.

McDermott then outlines the characteristic deficiencies of most physics courses available to teachers, and the elements that teachers require as part of their preparation.

Most physics courses available to teachers:

- Do not provide enough experience with phenomena
- Give too little attention to development of concepts and scientific reasoning
- Place too much emphasis on mathematical formalism in courses taken by high school teachers
- Place too little emphasis on arithmetical reasoning in descriptive (or "hands-on") courses taken by elementary and middle school teachers
- Provide poor role models for K-12 teachers

Teachers tend to teach as they have been taught (both what and how).

Teachers need intensive preparation to be able to help students develop a functional understanding of physics.

- Should understand basic concepts and principles in depth
- Should recognize what makes physics difficult for students
- Should know how to address common difficulties

They really need special courses combining subject matter and instructional method that are not routinely part of traditional course offerings.

Teachers need to learn (or relearn) physics in the way that they are expected to teach.

Subject matter and instructional method should be taught together in special physics courses for teachers.

Another thing that doesn't happen in traditional courses, she adds, is that reasoning ability does not develop by itself.

Growth in reasoning ability does not result from traditional instruction.

Scientific reasoning skills must be expressly cultivated.

↓

How we know is at least as important as *what we know.*

Lillian McDermott

McDermott then reviews some of the common recommendations regarding teacher professional development.

Some common suggestions for teacher professional development

- Send content "experts" (scientists, graduate students) into classrooms

  Concern expressed by APS President Marvin Cohen in *APS News* (Jan. '05): "If we could get members to go to K-12 schools and levitate a magnet or something, we really think these efforts could bring great rewards."

  Results may be motivational but volunteers are unlikely to promote meaningful learning without extensive professional development in content and instructional approach.

- Provide "cutting-edge" research experiences for teachers

  Results may be motivational but teachers are unlikely to develop depth of understanding necessary for transferring either the content or the processor of such research to their students.

  ***(not** a substitute for developing conceptual understanding or scientific reasoning skills)*

McDermott offers an example, the cover of *Physics Today*, depicting a physicist demonstrating sinking and floating to a group of third graders. "There's nothing wrong with getting people interested in that," McDermott observes, "but you cannot look at that as something that is going to help somebody become the best teacher."

Another thing teachers do in workshops, McDermott observes, is work through and reflect on K-12 curriculum. This short-term solution doesn't help them understand physics in greater depth or deal with unexpected situations. What teachers need to be able to teach by inquiry is intensive preparation in subject matter and instructional methods.

Teachers need intensive preparation to be able to teach by inquiry.

- **in subject matter**
  - *They must understand physics at a deeper level than most university students.*
  - *They must be able to recognize and address common conceptual and reasoning difficulties that they may have and their students will have.*
  - *They need to reflect on their own intellectual development.*
  - *They need to consider the developmental level of their students*
- **in instructional methods**
  - *They should be given the opportunity to learn (or relearn) physics in a manner consistent with how they are expected to teach.*

McDermott then reviews the implications of the results from research in terms of professional development for teachers.

Is working through (and reflecting upon) K-12 curriculum sufficient preparation for teachers?

This short-term solution is often wanted by teachers, but it does not help them:

- to understand physics in greater depth than their students
- to deal with unexpected situations

Implications of results from research

- Teachers have the same conceptual and reasoning difficulties as many undergraduates and K-12 students and may lack functional understanding.
- Experience in teaching a topic does not necessarily help teachers deepen their conceptual understanding of that topic.
- Certain persistent difficulties may preclude development of a functional understanding and need to be explicitly addressed.
- Good pedagogy in courses for teachers is not sufficient for the development of a functional understanding.
- Students of well-prepared teachers do better on questions that probe functional understanding than students of less well-prepared teachers. (even if experienced).
- Broad assessment instruments *(e.g., FCI)* are not adequate measures of conceptual understanding for teachers.
- Standard courses cannot be modified (or supplemented) sufficiently to prepare K-12 teachers to teach physics and physical science by inquiry.

Some general intellectual goals for science courses

The study of science by undergraduates and K-12 teachers should help develop ability in:

Scientific thinking
understanding nature of science (method, models, explanations)

Critical thinking
distinguishing scientific reasoning from personal belief or opinion

Reflective thinking
learning to ask the types of questions necessary for recognizing when they do or do not understand a concept or principle
learning to ask the types of questions necessary for helping themselves (and their students) develop a functional understanding

These goals transcend the study of a given science

A perspective on the teaching of science

"Science is a way to teach how something gets to be known, what is not known, to what extent things *are* known (for nothing is known absolutely), how to handle doubt and uncertainty, what the rules of evidence are, how to think about things so that judgments can be made, how to distinguish truth from fraud, and from show."

Richard Feynman from *Genius The Life and Science of Richard Feynman* by James Gleick p. 285, Pantheon Books, New York (1992)

McDermott details some general intellectual goals for science courses, and closes with a quote from Richard Feynman.

Question and Answer Session

STEM and Education Faculty Working Together

- I was wondering why it seems like physics is a place where, historically, education and STEM faculty have come together. Is it happening in other fields as well? • Mary Stapleton, University of Maryland, Biotechnology Institute

- That's difficult to answer because it depends somewhat on circumstances. I don't know if it's so much a question of physics and education faculty coming together. In some places that's truer than other places. I can say that at our university, I have the greatest respect for the education faculty, but we operate in a totally different framework. In some places there is a more common background. In our case, our particular faculty is hypothesis-driven and uses language that nobody would pay any attention to if it appeared in a physics journal. I think the goals are the same, to prepare teachers to understand the material, but the cultures are very different. It's a problem, and I don't have a good answer for you. • Lillian McDermott

Reducing Content Coverage

- I want to reinforce something Lillian said. We just finished a study which will appear in *Science Education,* looking at this issue of coverage because we're covering many fewer topics when you teach in this way. We've found that students who take high school courses in biology, chemistry or physics in which they cover fewer topics do much better when they get into their college courses. I think the movement to reduce coverage and cover fewer topics in greater depth is really positive. • Philip M. Sadler, Director, Harvard-Smithsonian Center for Astrophysics

- I agree with you but will tell you that the direction in which university physics is going is quite the opposite. The idea is we should cover more. In my own department we cut back on some of the basic material so you could get to quantum mechanics in an introductory course and other things that supposedly inspire the students to love physics. While I agree with what you're saying, that doesn't seem to be the way the wind is blowing. • Lillian McDermott

- What seems to inspire students is actually understanding the content. • Philip M. Sadler

Force Concept Inventory

- What is the FCI? • Anon.

- The Force Concept Inventory, a multiple choice test on Newtonian dynamics and a popularly quoted measure of whether instruction has been effective. All I'm saying is that it's good, it's fine, but it's not enough. • Lillian McDermott

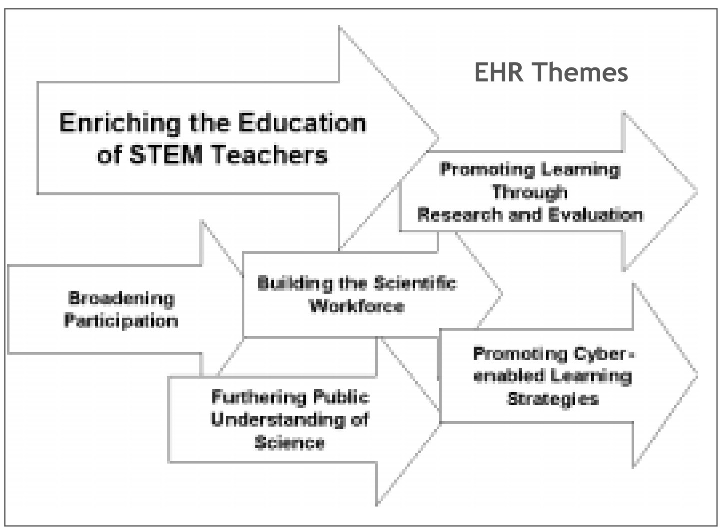
NEW DIRECTIONS IN TEACHER EDUCATION AT THE NATIONAL SCIENCE FOUNDATION

New Students, New Challenges: How Should EHR Support Teacher Education?

Linda Slakey
Division Director, Division of Undergraduate Education, National Science Foundation

Linda Slakey begins her remarks by setting the context, emphasizing teacher education as a priority in the Directorate for Education.

Slakey reports that within the EHR themes, Cora Marrett, now Acting Deputy Director of NSF, has called on the entire EHR Directorate to think about what part they play in making sure that teachers in K-12 and IHEs are as effective as they can be. Each theme, Slakey notes, can be seen as a gateway into the overall work of STEM education, and every MSP project is working on at least three of these. An ongoing focus of MSP from its inception has been the extent to which projects are working to promote learning through research and evaluation, and Slakey reports that she has frequently cited the MSP program as a model in this regard.



Slakey employs a developmental perspective in her description of how the directorate should approach education. How do you end up with adults who are confident in their ability to use scientific knowledge? You start with children who are innately curious and bring them through the long process in which they gain conceptual understanding and confidence. The process begins in early childhood, continues through undergraduate and graduate degrees, and extends to STEM professionals who may be switching to teaching careers. At every stage in this process, you address the questions outlined at right.

Switching gears, Slakey offers a brief overview of the current political climate and the support available for teacher education. That support includes the stimulus bill currently before Congress and the ongoing vested interest members of Congress have in education. In the private sector, Slakey points to the $100 million from Exxon to replicate the YouTeach model at the University of

STEM Teaching – A Life Trajectory

- Early childhood, K-16, 16+, Working adult
  - Pre K – 5
  - Middle school
  - High school
  - Undergraduate
  - Graduate and professional

- Curiosity and engagement
- Gaining conceptual understanding
- Acquiring teaching skills

- At every stage –
  - Are students drawn in or put off?
  - Does their confidence increase?
  - Are essential skills and knowledge learned?
  - Can the learning be applied to every day problems?
  - Will understanding be retained?
- NSF Programming
  - Supports gain in STEM knowledge and conceptual understanding
  - Focuses on the need for teaching skills

MSP brings the parts together

Enriching the Education of STEM Teachers

Support for Teacher Education
- Congressional
- Private – the ExxonMobil awards
- The NASULGC initiative

NSF Support for Teacher Education
- Math and Science Partnerships
- Robert Noyce Scholarships
- Advanced Technological Education
- DR K – 12 and REESE
- LSAMP pilot

Linda Slakey and Joan Prival

New Students

- Diverse
- Technologically savvy
- Used to social networks

What are our goals in teacher education?

- Enough STEM teachers
- Diverse STEM teacher pool
- STEM teachers who can engage all students
- Confident teachers who can draw students

Texas, Austin. And finally, Slakey reports, the National Association of State, University and Land Grant Colleges (NASULGC) decided two years ago to launch a new ongoing project and take on improvement of science and mathematics teacher education, with a public rollout this past fall at their annual meeting to gain commitment from their members.

Slakey also reviews the various contexts at a programmatic level at which the NSF exclusively supports teacher preparation initiatives, noting that it is worth reading the solicitations for these programs, particularly those with which participants are less familiar, to see which aspects may be appropriate for their interests and capabilities.

Referring back to the title of her presentation, Slakey defines what she means by "new students." It is a hallmark of good teaching to begin where the student is, she observes, and that is shifting in contemporary times. The population is increasingly diverse, technologically savvy, and accustomed to social networking as a way of life. These changes are reflected in more recent statements of goals.

Slakey adds a goal to this list, and segues to a new element: "We really need teacher leaders who can teach and share cyberlearning resources. That is making a significant new demand on the system, but one we really can't ignore."

About a year ago Dr. Marrett and Dan Atkins, Director of the Office of Cyberinfrastructure convened a task group to advise them what they should be doing about cyberlearning.

While those immersed in the cybertechnology field often predict that all education will go online and the entire educational structure will change radically, Slakey expresses her doubts. She notes that the school system is a social structure as well and a place where young people spend their day. It is our way of making sure that students get not only a range of information but become socialized. While she can't envision schools going away, Slakey acknowledges that the cyberinfrastructure and way that young people use it aren't going to go away either. "I think we're at a moment at which those two things have to engage in a serious way," she states.

Below is the task force's definition of cyberlearning.

What Is Cyberlearning?

- The use of networked computing and communications technologies to support learning
- Interactions among communities of learners across space and time
- Customized interaction with diverse materials, on any topic, at any age

- from report of the Task Force for Cyberlearning

Slakey notes the use of the word "networked" and the point that the task becomes how to manage and digest all of the information and resources available in ways that are meaningful for teachers and children.

The task force also recommended some key strategies as a way to proceed.

Key Strategies for Cyberlearning for NSF

- Develop and advance technologies
- Enable students to use data
- Harness learning data
- Support broader audiences
- Sustain cyberlearning materials

- from report of the Task Force for Cyberlearning

Slakey points out that "enable students" doesn't refer to hardware so much as curriculum, providing students with the ability to tap into and use publicly available data sets. The strategy of supporting broader audiences is intended to mitigate the cybergap. That of sustaining cyberlearning materials is to assure that materials developed remain accessible for a reasonable amount of time.

The following text is from a task group slide, and emphasizes the need to support teachers who may not be comfortable with these materials and approaches. "It's a key challenge of the moment to think about how we do the teacher development necessary to bridge this gap," Slakey notes.

She encourages participants to begin to let the EHR theme of promoting cyberenabled learning strategies begin to be a focus MSP projects' work going forward. Slakey concludes by asking participants to discuss with their tablemates their response to the following question.

How do you envision school systems that make optimum use of the power of cyberlearning?

What might be the role of the MSP program?

For a copy of the report by the NSF Task Force on Cyberlearning, Fostering Learning in the Networked World, go to:

http://www.nsf.gov/pubs/2008/nsf08204/nsf08204_1.pdf

Emphasize the transformative power of technology

- Potential for learning, from "K to grey"
- Information and communication technologies that
  - Allow interaction with data, visualizations, remote and virtual laboratories, and experts
  - Bridge multiple learning environments and technologies
- Support teachers' professional development through
  - Training programs
  - Professional societies
  - Collaborating to create new teaching materials

- from report of the Task Force for Cyberlearning

A Sampling of the Discussion

Group One

There are social networks that already exist and are already funded. Maybe what we need to do is find about more about it and reinforce it. Kids are already using these networks. In MSP project's, we've observed how teachers love to network and interact with one another about intellectual issues. There could be a role for social networking that sense.

Group Two

As you think about optimizing use of cyberlearning, you often think about the hardware, software, and peer connection pieces. Our experience is that it is at least as important to think about the curriculum and the delivery of the curriculum. No matter what the technological power is, if you don't think about how students are going to interact with that technology and each other, you're probably not going to succeed.

Group Three

We had a strange idea that we didn't get to completely play out. What if we created a new school with cyberlearning at its core? We don't yet know what it looks like. We know that we need young, we know that we need old, we know that we need experience to help us design it. We think the learning centers around science themes, from which we manage to explore writing and reading and social studies. We think cyberlearning leads to communication and discovery, and we think it starts early and runs K through 12.

Robert Noyce Teacher Scholarship Program

- Initiated by Act of Congress in 2002
- Reauthorized in 2007 (America COMPETES Act)
- To encourage talented mathematics, science, and engineering undergraduates to pursue teaching careers
- To encourage STEM professionals to become teachers
- To prepare Master Teachers

Robert Noyce Teacher Scholarship Program

Joan Prival
Lead Program Officer, Robert Noyce Teacher Scholarship Program, Division of Undergraduate Education, National Science Foundation

Joan Prival offers an overview of the Robert Noyce Teacher Scholarship program's history, goals, and operation.

The current 2009 solicitation includes two tracks, the original Noyce Teacher Scholarship Track and a new track introduced this year, the Teaching Fellowships and Master Teaching Fellowships Track.

Noyce Scholarship Program: FY 2009 Solicitation (NSF 09-513)

Robert Noyce Teacher Scholarship Track

- Scholarships (at least $10,000 per yr) for undergraduate STEM majors preparing to become K12 Teachers
- Summer internships for freshmen and sophomores
- Stipends (at least $10,000 for 1 yr.) for STEM professionals seeking to become K12 teachers

NSF Teaching Fellowships & Master Teaching Fellowships (TF/MTF) Track

- Fellowships for STEM professionals receiving teacher certification through a master's degree program
- Fellowships for science and math teachers preparing to become Master Teachers

Noyce Scholarship Program Scholarship Track

- Scholarships and stipends capped by cost of attendance
- Students graduate with a degree in a STEM discipline and teacher certification and/or licensing.
- Recipients commit to teaching in a high need school district for 2 years for each year of scholarship/stipend support.
- Recipients failing to meet service requirement must repay scholarship

Prival reviews the structure of the Noyce Teacher Scholarship Track. Phase I of this track is for those who haven't been funded previously under this program; Phase II is for those who have previously been funded under this program to continue with scholarships and stipends and also conduct longitudinal studies of their earlier cohorts. Smaller grants are awarded to enable projects to continue monitoring recipients to assure they're fulfilling the teaching commitment.

Noyce Scholarship Program

Scholarship Track Phase I

- Scholarships, Stipends, Internships
- Award size up to $900,000
- Duration up to 5 years
- No indirect costs
- Administrative/programmatic costs may not exceed 20% of total budget
- 80% of budget for direct support to participants

Scholarship Track Phase II

- <u>Scholarships and Stipends</u> plus longitudinal evaluation studies of previously supported cohorts of students
  - Award size up to $600,000; up to 4 yrs.
- <u>Monitoring and Evaluation</u>
  - Award size up to $150,000; up to 3 yrs.
  - Indirect costs allowed

Prival then turns to the new track for NSF Teaching Fellows and Master Teaching Fellows, summarizes the requirements for TF/MTF proposals, and describes how the TF/MTF Track funding and selection work. Both types of Teaching Fellows must commit to teach in a high need school district, a requirement that is fundamental to the Noyce Scholarship Program.

NSF Teaching Fellowships & Master Teaching Fellowships Track

<u>NSF Teaching Fellows</u>
STEM professionals who enroll in a master's degree program leading to teacher certification or licensing

<u>NSF Master Teaching Fellows</u>
STEM teachers who have master's degrees and participate in a program for developing Master Teachers.

TF/MTF Proposals Must Include:

- A department within an IHE that provides an advanced program of study in math and science,
- A department or entity within an IHE that provides teacher preparation or a 2-year institution that offers a teacher preparation program or a dual enrollment or an articulation agreement with an IHE that credentials teachers,
- At least one high need school district and public school(s) within this district, and
- At least one nonprofit organization with the capacity and expertise to support the goals of the project.

NSF Teaching Fellowships & Master Teaching Fellowships Track

- Fellows receive a salary supplement of at least $10,000 for each year of their teaching obligation.
- Selection of Fellows based on professional achievement, academic merit, and demonstration of advanced content knowledge in STEM
- Matching funds from non-Federal sources equal to 50% of the award (required by the America COMPETES Act)
- Piloted in 2008 through supplements to Noyce and MSP awardees

This is much more than a scholarship program, Prival notes, and projects much include the following elements.

Noyce Scholarship Program Projects Include

- STEM faculty collaborating with Education faculty
- Strong partnership with school district
- Recruitment and selection strategies
- Exemplary teacher preparation programs leading to certification (or professional development program for Master Teaching Fellows)
- Support for new teachers
- Mechanism for monitoring recipients
- Institutional support
- Evaluation

Prival concludes her presentation by reviewing the TF & MTF Track award amounts and requirements, the achievements to date of the Noyce Scholarship Program, and important dates for those interested in pursuing these grants.

NSF TF & MTF Track

- <u>NSF Teaching Fellows</u>:
  - STEM professionals pursuing master's degrees leading to teacher certification
  - Receive one-year stipend of at least $10,000 while enrolled in the Master's degree program
  - Commit to teach for 4 years in a high need school district
  - Receive annual salary supplement of at least $10,000 while fulfilling teaching commitment
- <u>NSF Master Teaching Fellows</u>:
  - Fellowships for math and science teachers preparing to become Master Teachers
  - Commit to teach for 5 years in a high need school district
  - Receive annual salary supplement of at least $10,000 for 5 years while fulfilling the teaching commitment

NSF Teaching Fellowships & Master Teaching Fellowships Track

<u>NSF Teaching Fellows & Master Teaching Fellows</u>

- Award size up to $1.5 million over 5 -6 years
- No Indirect Costs
- Matching funds required equal to 50% of grant request
- At least 80% of budget for direct support to participants (stipends, salary supplements, professional development)

<u>TF/MTF Planning Grants</u>

- Award size up to $75,000 over 1 year
- Indirect costs allowed

Noyce Scholarship Program

- 135 awards made between 2002 and 2008 are projected to produce approximately 4900 new science and mathematics teachers who will be teaching in high need school districts.
- The portfolio of awards includes 240 institutions of higher education and over 850 school districts in 36 states and the District of Columbia.

<u>Important Dates</u>

- Letters of Intent (*optional*): February 10, 2009
- Full Proposal Deadline: March 10, 2009
- 5:00 P.M. proposer's local time
- Proposal writing workshops: January 29, Atlanta; February 5, Denver
- Webinars: Early Feb.