STEM Smart: Lessons Learned From Successful Schools

February 28, 2012 | Pacific Science Center | Seattle, WA

CONTENTS

Elements of Successful STEM Education—*Breakout Sessions*

Engineering is Elementary®
Engineering and Technology Lessons for Children

Problem Solving, Inquiry, and Innovation®

www.mos.org/EiE

Children are born engineers—they are fascinated with building, with taking things apart, and with how things work. However, K-12 educational settings have traditionally done little to develop children's engineering and technological literacy. The *Engineering is Elementary* (EiE) project fosters engineering and technological literacy among elementary school students and educators. EiE has created a research-based, standards-driven, and classroom-tested curriculum that integrates engineering and technology concepts and skills with elementary science topics. EiE lessons not only promote science, technology, engineering, and mathematics (STEM) learning in grades 1-5, but also connect with literacy and social studies. To date, EiE has reached over 2.7 million students and 32,000 teachers and is presently used in all fifty states.

EiE Project Goals

- **Goal 1.** Increase children's technological literacy.
- **Goal 2.** Improve elementary educators' ability to teach engineering and technology.
- **Goal 3.** Increase the number of schools in the U.S. that include engineering at the elementary level.
- **Goal 4.** Conduct research and assessment to further the first three goals and contribute knowledge about engineering teaching and learning at the elementary level.

The EiE Curriculum

Each EiE unit integrates an elementary school science topic with a specific field of engineering. EiE units are designed to engage students in the engineering design process and include:

- **Storybooks** featuring child characters from a variety of cultures, who introduce students to an engineering problem. Students are then challenged to solve a similar problem. In addition to providing context, the storybook also serves to introduce engineering and technology concepts and terms, and reinforce science vocabulary.
- **Lesson plans** for teachers. EiE teacher guides include vocabulary, learning objectives, tie-in science content, detailed materials and preparation sections, and step-by-step instructions on how to facilitate each EiE activity.
- **Duplication masters (DMs)** for student handouts. To accommodate differences in students' abilities, EiE units contain two versions of many DMs: Basic (lower reading level, less cognitively complex, suggested for grades 1 and 2) and Advanced (higher reading level, more cognitively complex, suggested for grades 3-5).
- **Student assessments and rubrics**. Multiple choice and open-ended questions that teachers can use to gauge their students' understanding and learning of engineering, technology, and science concepts are provided in each EiE unit. Rubrics are provided at the end of each lesson to help teachers evaluate students' progress.
- **Background information** and additional reference resources for teachers.

Each EiE unit takes about 8-10 hours of instructional time to complete. EiE has developed materials for 20 elementary science school topics and engineering fields. For a complete list of EiE units and their related science topics, please visit **www.mos.org/eie/20_unit.php**. All EiE units are designed to meet the ITEEA Standards for Technological Literacy. At its core, EiE is designed to have students engineer. The program develops interesting problems and contexts and invites children to have fun as they use their knowledge of science and engineering to design, create, and improve solutions.

Professional Development

Engineering is a new discipline for many teachers. To learn more about engineering and technology content and pedagogy, the EiE project offers workshops for elementary school teachers and teacher educators. These sessions provide teachers with an overview of engineering and technology concepts and skills, review the structure and philosophy of the EiE curriculum, engage participants in activities from the curriculum, and foster reflection about effective instructional strategies. EiE workshops are held at the Museum of Science and EiE staff are also available to facilitate off-site workshops as requested. For more information on EiE professional development and a list of upcoming workshops, please visit **www.mos.org/eie/workshops_programs.php**.

Research and Assessment

Research, evaluation, and assessment studies are integral to the development of the EiE curriculum, and an important facet of our curriculum development philosophy. The EiE team believes that a high-quality curriculum is one that is well-researched and thoroughly tested at all stages, from garnering a basic understanding of what students and teachers know about engineering and technology to the published product. From its inception in 2003, EiE has been committed to creating high-quality teacher guides and professional development for teachers and a world-class curriculum for students through multiple cycles of research, development, testing, and improvement. We are collecting qualitative and quantitative data from students and teachers across the nation to better understand how children best learn about engineering and how our materials impact their understandings.

National, statistical, controlled studies indicate that children who engage with EiE materials have a much better understanding of engineering and technology than children who do not use EiE. Findings have also shown that children who engage with EiE perform better on assessment questions about the related science topic than children who do not use EiE. For links to EiE's formal research findings and publications, please visit **www.mos.org/eie/research_assessment.php**.

Multimedia Initiatives

The EiE website contains multimedia resources, such as a 16-minute informational video that provides an overview of the EiE project, footage of students engaged in EiE activities, and teacher interviews. The website also has a series of shorter videos designed to help educators organize and prepare materials for EiE lessons, as well as longer videos which capture footage of classroom teachers using EiE with their students. These longer videos include teacher interviews in which teachers reflect on their engineering practice and pedagogy. In addition to video resources, the website has a Content Connections page that contains a searchable, dynamic database of lessons, authored by EiE staff, teachers, and community members, that explicitly connects EiE lessons to mathematics, social studies, language arts, science, and fine arts.

Out of School Time: Engineering Adventures

Engineering Adventures (EA) is a fun, engaging, hands-on, engineering curriculum being created by the EiE team for use in out-of-school-time (OST) settings such as after-school and camp programs. EA challenges children to solve design challenges using creativity, teamwork, science, and engineering. EA is arranged as a series of thematic units, each focusing on a field of engineering. EA is not yet available to the public. The first EA unit will be tested nationwide in the spring of 2011 thanks to the generous support of the S. D. Bechtel, Jr. Foundation. For more information on EA, please visit **www.mos.org/eie/engineeringadventures/**.

For much more information about the EiE project, please visit our website at **www.mos.org/eie**.

The Scaling Up SimCalc Project

Background

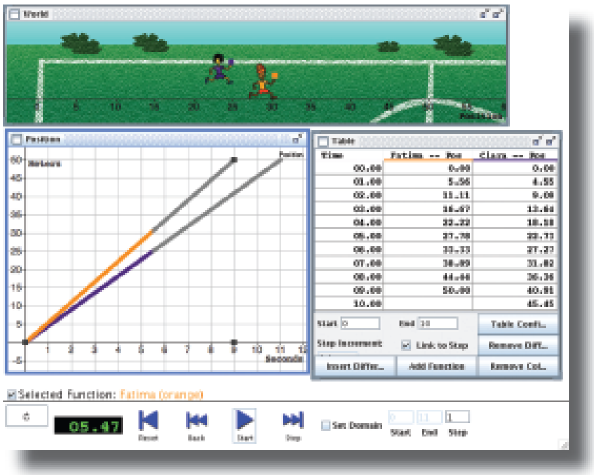
This project investigated the scale-up of an innovative integration of technology, curriculum, and teacher professional development aimed at improving mathematics instruction in grades 7 and 8. The SimCalc approach integrates teacher professional development, curriculum and software called SimCalc MathWorlds.

The project builds on an almost 30-year research program. Dr. James J. Kaput, Ph.D. of the University of Massachusetts, Dartmouth designed the SimCalc program in the late 1980s to achieve his vision of "democratizing access to the mathematics of change," i.e., making concepts of proportionality, linearity and rates of change accessible to middle school students of all cultural and demographic backgrounds. Through use of interactive software, the SimCalc program advances student learning of proportionality beyond the traditionally taught cross-multiplication procedure.

The SimCalc MathWorlds Software and Curriculum

SimCalc is an interactive software-based curriculum that supports students in developing a robust, integrated, multi-faceted understanding of the concept of "rate of change."

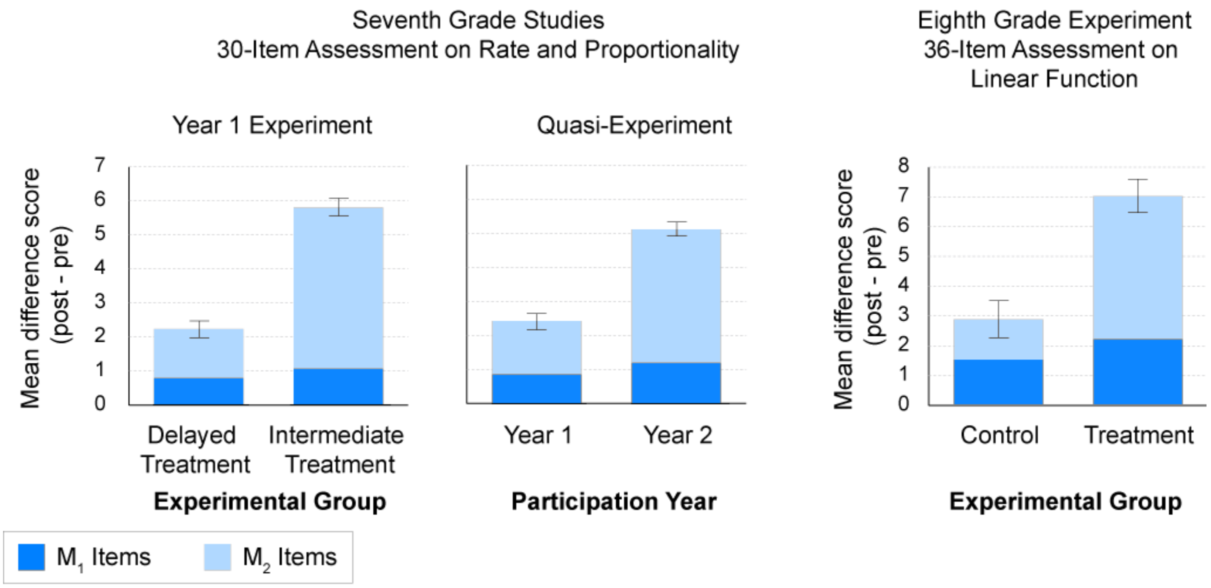
- Engages students in creating and analyzing graphs that control animation
- Anchors students' learning of complex mathematics in everyday situations
- Connects students' understanding of rate and proportionality across key mathematical representations, stories and animations
- Integrates curriculum, software, and teacher professional development
- Structures pedagogy around making predictions, testing predictions, and explaining any differences



In one 7th grade activity, students control two runners by adjusting the slopes of the colored lines in the graph. By running the animation students see how slope relates to speed.

Documented Results

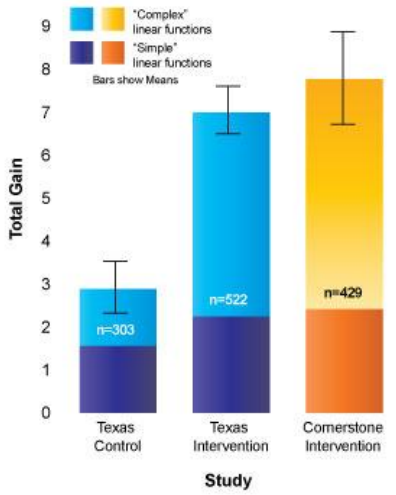
Across three large-scale studies in the state of Texas, we replicated a strong main effect demonstrating that SimCalc enables a wide variety of teachers in a diversity of settings to extend students' learning to more advanced mathematics. In each study, teachers in the treatment group taught with a 3-week replacement unit that used the MathWorlds software; the control group taught the same content using their traditional curriculum. For the seventh-grade study, the seventh-grade quasi-experiment (delayed treatment teachers across years 1 and 2), and the eighth-grade study, the main effects were statistically significant and showed that students in the treatment group (or year 2) learned more than students in the control group (or year 1). Student-level effect sizes of .63, .50, and .56, respectively.



We measured learning for two types of items: ***M_1*** *items measured the foundational concepts typically covered in the grade-level standards, curricula, and assessments.* ***M_2*** *items measured understanding of essentials of concepts of mathematics of change and variation found in algebra, calculus, and the sciences.*

Scaling and Adaptation within the US and Beyond

While the first study took place in the state of Texas, we have since successfully scaled and adapted our approach for use in the state of Florida and the UK. The Cornerstone Maths project adapted our curriculum for grade 8 students for students in England's key stage 3 (similar to middle school), showing comparable results in learning.



For More Information

For publications and free downloads of software and curricula: http://math.sri.com/

Workshop contact:
Nikki Shechtman, Senior Education Researcher
Center for Technology in Learning, SRI International
nicoles.shechtman@sri.com
(650) 859-5692

Student Voice & STEM Learning

In the context of a federally funded research and development project, the UW Institute for Science and Math Education is collaborating with Sammamish High School, a comprehensive high school serving a socially and economically diverse community in suburban Seattle, to transform that school's curriculum into a problem-based, STEM-rich experience for all students. STEM opens up opportunities to explore the relevance of subject matter to students, contemporary disciplines, and the workplace. To privilege what is, in fact, relevant to students, we must first unveil it. In this session, we are sharing work related to our efforts to collaborate with teachers and students to elicit student voice to inform curriculum design.

Research on the importance of learners' relationships to subject matter is unambiguous: it can have a profound influence on learner outcomes. Whether we call it learner disposition, background knowledge, prior experience, or identity, how learners relate to subjects they wish to learn is paramount in shaping successful outcomes. Our conceptualization of student voice and design of practices to elicit voice build on these findings. We are designing processes within the school intended to put student voice at the heart of instruction.

We have designed a process through which we (a) collaborate with practitioners to discuss upcoming units of instruction, their impressions of student successes and struggles related to the unit, and to generate topics to explore with focus-group students; (b) recruit a group of students to discuss these questions, following which we (c) debrief with teachers focusing on specific students tasks, instructional practices, and assessments that can be infused with findings.

Initial indications are that students are generous and sincere about their education, they seek learning opportunities that are relevant to the subject matter, and they are eager to share their views. We have also found the teachers to be well intentioned and, while uncertain how to do this work, eager to identify and build on what students care about. In this session, we will share specifics of the process we have designed, focusing on illustrative cases. We will briefly share strategies we've developed and engage participants in a discussion of their approaches, questions, and concerns related to student voice and STEM.

Contact Information:
Andrew Shouse
Associate Director, Institute for Science and Mathematics Education
University of Washington
Phone: 206-221-6149
1100 N.E. 45th Street
Suite 200
Seattle, WA 98105
awshouse@uw.edu

Engineering and Technology in Tomorrow's Science Classroom

By the end of 2012, states will be considering a final draft of *Next Generation Science Standards* (NGSS) in an effort to develop common core educational standards to complement those in English language arts and mathematics that have already been adopted by 46 states. Although the public release of the NGSS is not due for a few months, a preview can be seen in *A Framework for K–12 Science Education: Practices, Core Ideas, and Crosscutting Concepts*, published by the National Research Council in July 2011. The *Framework* is intended to serve as the blueprint for the *Next Generation Science Standards*. I have had the good fortune to serve as a consultant on *Framework* with the charge of assisting the study committee in deciding how best to include engineering and technology as an integral part of science. The results of that effort appear in Chapter 3 and Chapter 8.I am also a member of the writing committee working on the *Next Generation Science Standards*, and although I can't discuss details yet, I can say that we are following the *Framework* very closely.

In brief, Chapter 3 of the *Framework* describes the practices of science and engineering that students are expected to develop during 13 years of schooling, and emphasizes the similarities between science and engineering. Chapter 8 of the *Framework* presents core ideas in technology and engineering at the same level as core ideas in the traditional science fields, such as Newton's laws of motion and the theory of biological evolution. Although prior standards documents included references to engineering and technology, they tended to be separate from the "core content" of science, so they were often overlooked.

An important contribution of the *Framework* is to provide a clear definition of technology and engineering as they relate to science:

> *In the K–12 context, "**science**" is generally taken to mean the traditional natural sciences: physics, chemistry, biology, and (more recently) earth, space, and environmental sciences. . . . We use the term "**engineering**" in a very broad sense to mean any engagement in a systematic practice of design to achieve solutions to particular human problems. Likewise, we broadly use the term "***technology***" to include all types of human-made systems and processes—not in the limited sense often used in schools that equates technology with modern computational and communications devices. Technologies result when engineers apply their understanding of the natural world and of human behavior to design ways to satisfy human needs and wants.* (NRC 2011, pages 1–3,4)

Notice that engineering is *not* defined as applied science. Although the practices of engineering have much in common with the practices of science, engineering is a distinct field and has certain core ideas that are different from those of science.

Chapter 3 of the *Framework* describes the practices of science and engineering, pointing out where they are similar and where they are different. Unlike previous standards documents, which focused on scientific inquiry, the new document gives equal attention and status to engineering design as both a means for teaching science and a set of abilities that all students should master.

Chapter 8 of the *Framework* describes three core ideas that all students should learn. As core ideas, these have the same status as core ideas in the traditional science disciplines of physical science, life science, and earth and space science. Each idea is developed in some detail, and recommendations are given about what students should learn about these ideas in successive grade bands. The core ideas are as follows:

> ***Core Idea 1: Engineering design.*** *From a teaching and learning point of view, it is the iterative cycle of design that offers the greatest potential for applying science knowledge in the classroom and engaging in engineering practices. The components of this core idea include understanding how engineering problems are defined and delimited, how models can be used to develop and refine possible solutions to a design problem, and what methods can be employed to optimize a*

design.(NRC 2011, page 8-1)

Core Idea 2A: Interdependence of science, engineering, and technology. *The fields of science and engineering are mutually supportive. New technologies expand the reach of science, allowing the study of realms previously inaccessible to investigation; scientists depend on the work of engineers to produce the instruments and computational tools they need to conduct research. Engineers in turn depend on the work of scientists to understand how different technologies work so they can be improved; scientific discoveries are exploited to create new technologies in the first place. Scientists and engineers often work together in teams, especially in new fields, such as nanotechnology or synthetic biology that blur the lines between science and engineering.* (NRC 2011, page 8-7)

Core Idea 2B: Science, engineering, and society. *Society has changed dramatically, and human populations and longevity have increased, as advances in science and engineering have influenced the ways in which people interact with one another and with their surrounding natural environment. Not only do science and engineering affect society; society's decisions (whether made through market forces or political processes) influence the work of scientists and engineers.* (NRC 2011, page 8-8)

For Discussion

Giving equal status to engineering and technology raises a number of important issues for curriculum developers and teachers, a few of which we can discuss during our breakout session. For example:

- Why is there increased emphasis on engineering and technology?
- Is it redundant to have engineering practices *and* core ideas?
- Do we need to have special courses to teach these core ideas?
- What will it look like in the classroom?

References

Achieve, Inc. (in press). *Next generation science standards*, a project of the National Governors Association, and Council of Chief State School Officers, managed by Achieve, Inc. http://www.nextgenscience.org/

National Research Council (2011). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas.* Committee on New Science Education Standards, Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: National Academy Press.http://www.nap.edu/catalog.php?record_id=13165

Professional Development to Provide Access to Standards-Based STEM Education for All Learners

Background

Standards-based reform holds great promise for increasing the rigor and quality of mathematics education for students with disabilities. The recently released Common Core Standards in Mathematics (2010) and those of the National Council for Teachers of Mathematics (2000) clearly recognize that all students, including those with disabilities, "*must have the opportunity to learn and meet the same high standards if they are to access the knowledge and skills necessary in their post-school lives*." (CCSSI, 2010). To date, however, this promise has not been readily fulfilled. Research shows that, while teacher quality is the single most powerful influence on student learning, teachers often are not well prepared to implement standards-based mathematics education with heterogeneous groups of students that include students with disabilities and students with different capabilities, needs, and learning styles.

To address the need for improved professional development for teachers, Bank Street College and Education Development Center, Inc. (EDC), with support from the National Science Foundation, have developed *Math for All*, a professional development program that enhances the preparation of both general and special education teachers to improve the mathematics education of students with disabilities in grades K–5. The program, which consists of five one-day workshops conducted over a period of 15–20 weeks, engages teams of general education and special education teachers in the analysis of video case lessons and collaborative lesson planning in an effort to improve their ability to adapt math lessons to meet individual students' strengths and needs while maintaining the integrity of the mathematical goals of the lessons. The project has developed two sets of professional development resources (one focusing on grades K–2 and one on grades 3–5) to support district-based staff developers in implementing the program.

Documented Results

The *Math for All* program has been pilot tested and field tested in multiple school districts over an extended period of time. The purpose of this research was to establish the feasibility and usability of the program and to obtain some initial evidence of its impact on teachers. Our findings indicate that when implemented with fidelity, the *Math for All* program is successful in (1) improving teachers' knowledge of mathematics content and pedagogy and (2) in increasing teachers' use of informal assessment and of instruction that is tailored to individual students' strengths and needs. These aspects of teachers' knowledge, skills, and teaching practices have been linked in the research literature with improved learning outcomes for students with and without disabilities.

Potential Applications

The *Math for All* facilitator guides and participant books are designed to support district-based staff developers in their implementation of the program. The results from our field-tests show that the program still has a significant effect on teachers' knowledge and classroom practices when it is implemented by facilitators other than the developers, a finding which attests to the scalability of the program. The model underlying the design of the *Math for All* program can be adapted to other grade levels and subject areas in STEM and beyond.

Resources

Moeller, B., Dubitsky, B., Cohen, M., Marschke-Tobier, K., Melnick, H., Metnetsky, L., Brothman, A. & Cecchine, R. (2012). *Math for All Facilitator Guide Grade 3–5.* Thousand Oaks, CA: Corwin Press.

Moeller, B., Dubitsky, B., Cohen, M., Marschke-Tobier, K., Melnick, H., Metnetsky, L., Brothman, A. & Cecchine, R. (2012). *Math for All Participant Book Grade 3–5.* Thousand Oaks, CA: Corwin Press.

Moeller, B., Dubitsky, B., Cohen, M., Marschke-Tobier, K., Melnick, H., Metnetsky, L., Brothman, A. & Cecchine, R. (in Press). *Math for All Facilitator Guide Grade K–2.* Thousand Oaks, CA: Corwin Press.

Moeller, B., Dubitsky, B., Cohen, M., Marschke-Tobier, K., Melnick, H., Metnetsky, L., Brothman, A. & Cecchine, R. (in Press). *Math for All Participant Book Grade K–2.* Thousand Oaks, CA: Corwin Press.

Contact Information

Dr. Babette Moeller
Education Development Center, Inc.
Center for Children and Technology
96 Morton Street, 7th Floor
New York, NY 10014
212-807-4205
bmoeller@edc.org
http://cct.edc.org/
http://www.corwin.com

MESA® Mathematics Engineering Science Achievement

MATHEMATICS, ENGINEERING, SCIENCE ACHIEVEMENT (MESA)

One of the country's most successful programs of its kind, Mathematics, Engineering, Science Achievement (MESA) provides academic support for thousands of educationally disadvantaged students so they can excel in math and science and graduate with baccalaureate degrees in science, engineering, computer science, and other math-based fields.

MESA works closely with industry partners and the University of California, the California State University, the California Community Colleges, the Association of Independent Colleges and Universities, the California Department of Education, school districts, and individual schools. MESA is nationally recognized for its innovation in academic development. MESA was founded in 1970 and is administered by the University of California.

MESA provides rigorous academic development that includes math and science curriculum based on the California Math and Science Standards. MESA also offers individualized academic planning, study skills training, peer group learning techniques, career exploration, parent involvement, professional development, transfer assistance, and special orientation classes and services for students in community college and four-year institutions.

MESA serves students through three programs. The MESA Schools Program supports pre-college students throughout the state to excel in math and science and go on to higher education. The MESA Community College Program assists community college students academically so they can transfer to four-year institutions as majors in math-based fields. The MESA Engineering Program supports students at major California universities to attain degrees in engineering and computer science.

MESA enjoys strong support from companies because they recognize MESA's success in producing technical professionals needed by industry to stay competitive. Leaders such as AT&T, Bayer, General Electric, HP, IBM, Intel, PG&E, Southern California Gas Company and Verizon have provided funding, in-kind contributions, scholarships, and internships to assist MESA students. Corporate representatives serve on state and local MESA advisory boards.

MESA has been named as one of the most innovative public programs in the nation by Innovations in American Government, a project of the Kennedy School of Government at Harvard University, and the Ford Foundation. MESA also is a winner of the Presidential Award for Excellence in Science, Mathematics and Engineering Mentoring.

California MESA is the model for similar programs operating in over a dozen other states.

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WEB: mesa.ucop.edu

MESA® Mathematics Engineering Science Achievement

BEATING THE ODDS:
MESA PROGRAM OUTCOMES FOR 2008-09

- 70% of schools participating in MESA are among the most underperforming in the state. Of the remaining 30%, MESA is involved with the most educationally disadvantaged student sectors.

- 70% of MESA high school graduates go on to college directly after graduation, compared to 48% of California high school graduates.

- 59% of MESA high school seniors are eligible to attend UC, compared to 13% of California high school graduates.

- Of MESA high school graduates who went to college,
  - 30% went to UC
  - 23% went to CSU
  - 34% went to community college
  - 7% went to independent California universities or colleges
  - 7% went to other institutions, mostly out-of-state universities or colleges

- Of MESA high school graduates, 60% went on to postsecondary education as majors in science, technology, engineering or math (STEM) fields.

- The top university destinations of MESA high school graduates are 1) UC Berkeley and UC Davis (tie), 2) UCLA, 3) UC Santa Barbara, 4) UC San Diego, 5) UC Riverside and University of the Pacific (tie).

- Of the MESA community college students who transferred to four-year institutions, 49% transferred to CSU, 43% transferred to UC, and 8% transferred to independent California or out-of-state universities and colleges.

- Of those MESA community college students who transferred to four-year institutions, 100% entered as math or science majors.

- The top campus transfer destinations for MESA community college graduates are 1) UC Davis, 2) San Jose State University, 3) UC San Diego, 4) Cal Poly San Luis Obispo, 5) UC Berkeley.

- The top majors of MESA engineering program graduates are 1) civil engineering, 2) electrical engineering, 3) mechanical engineering, 4) computer science, 5) computer engineering.

- California MESA is the model for similar programs in over a dozen other states, including a national HP community college initiative designed to increase the number of African American, Latino American, American Indian, and female engineers and computer scientists.

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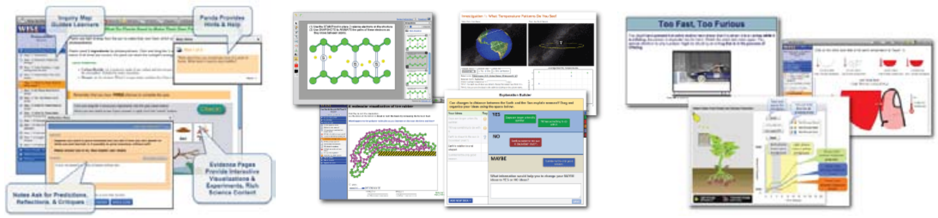
WEB: mesa.ucop.edu

Technology Enhanced Science Instruction via the WISE Learning Environment



Background and Documented Results

Building on years of successful research and development, WISE (The Web-based Inquiry Science Environment) is a powerful, open-source online learning environment that supports guided inquiry, embedded assessments, peer collaboration, interactive computer models, and teacher customization (Lee, Linn, Varma& Liu, 2010; Gerard, Spitulnik, & Linn, 2010). WISE 4.0 has been developed since 2008 and publicly available in 2010. It allows curriculum designers, researchers, and teachers worldwide to design, customize, share, and enact their digital curricula using the WISE platform. Students observe, analyze, experiment, and reflect as they navigate WISE projects. Teachers guide and evaluate the process using a suite of classroom-based and online tools.

The current WISE projects are designed to help students learn abstract science concepts and complement science teachers' regular classroom instruction. These standards-based curricula are developed through teams of content experts, school teachers, educational researchers, and computer scientists with iterations of refinement and revisions. WISE curricula have been tested in middle and high school classrooms for over two decades in more than 10 school districts. Prior research has shown that WISE curriculum units improve student learning of difficult standards-based science topics (Linn et al., 2006) and that students continue to integrate their ideas and strengthen their understanding even after the units have been completed.

Students and teachers who have worked with WISE curricula find the curricula engaging and informative (Chang & Linn, 2010; Gerard et al., 2010, Varma, et al., 2009). Research data have shown the modules are effective in helping students learn complex science concept areas such as earth science, physics, and chemistry (e.g., Shen& Linn, 2010; Varma & Linn, 2011).

Potential Applications

Individual students differ in their experiences, their interests, and their abilities. Some may excel at writing, while others may have a penchant for drawing. Some may speak multiple languages fluently, while others may be learning English as a second or third language. That's why WISE provides a variety of tools, activity patterns, and instructional scaffolds that afford multiple ways for expressing and assessing understanding—so no students' abilities go unrecognized, and all have the chance to succeed.

WISE subsists on generous support from the National Science Foundation, which means it's available for anyone with a computer and Internet connection. Driven by an active community of technology developers, WISE is continually being expanded and improved. Teachers can access the WISE project library or customize their own technology-enhanced curricula. WISE's powerful teaching tools make grading and classroom management easier, so teachers can focus on quality individual interactions with their students.

For More Information

- WISE learning results - telscenter.org/publications
- WISE learning environment - http://wise4.berkeley.edu/webapp/index.html

Professional Learning Communities for STEM Teachers

Background

Administrators and leaders of professional development have, in recent years,developed professional learning communities (PLCs)—one of the most common professional development strategies in use today across education at large. And leaders in STEM education have universally advocated their use—the *Successful K–12 STEM Education* report specifically urges considering "factors that strengthen and sustain learning communities." There are exciting rationales for PLCs, such as the desire to morph teaching from solo artisan instruction to a synergy of great teaching.

But what effects can be expected? Under what conditions? Could widespread unrealistic expectations placed on weakly designed and implemented PLCs at some point evaporate support for them? Through NSF support, WestEd and the National Commission on Teaching and America's Future (NCTAF) recently tackled these questions through an intensive "knowledge synthesis" in which researchers:

- exhaustively collected and studied the existing research about teacher PLCs, specifically in STEM, and
- convened a panel of experts (professional developers, administrators, researchers) who have designed and run STEM PLC projects.

Two versions of the results by Kathleen Fulton and Ted Britton are available online at NCTAF and WestEd (www.wested.org).

- *STEM Teachers in Professional Learning Communities*: *A Knowledge Synthesis*. 2010. (full report, with detailed research results and practice-based insights)
- *STEM Teachers in Professional Learning Communities*: *From Good Teachers to Great Teaching*. 2011. (summary report, released for a U.S. Congressional briefing)

Documented Results: *What effects can be expected?*

Research has shown that STEM teachers in PLCs can:

- increase their discussion of STEM content and how to teach it,
- learn STEM content,
- feel more prepared to teach STEM content,
- enhance their inquiry-oriented teaching methods, and
- pay more attention to students' reasoning and understanding.

And student learning improved for the content discussed in the teachers' PLCs. Only a little research has been conducted that can clearly link students' standardized test scores to teacher PLCs, in part because of large challenges in designing and conducting research on this particular topic; the limited studies/results to date show some positive gains in mathematics. (No studies have yet been conducted for science.)

Documented Results: *Under what conditions can the above effects be expected?*

The STEM Seattle breakout discussions will focus on this question. The prior research studies and the WestEd/NCTAF project's panel of experts found the following design and implementation factors to be critical:

shared values and goals	collective responsibility
leadership support	good facilitation
use of student data and work	trust

In each 25-minute breakout session, participants will choose a few of these design-level issues to discuss. Participants and the session leader will raise questions and offer research or "wisdom of practice" about how to address them.

Potential Applications

Research studies focused on wide-ranging sites where STEM PLCs were being created and implemented. Similarly, the panel of experts had successfully implemented PLCs in varied settings (or observed this), including school districts having diverse students and challenges. Disclaimer: There was little research on PLCs specifically for technology or engineering teachers.

For More Information (beyond the NCTAF/WestEd reports) about key issues in PLC design and implementation:

Research-based, scholarly advice.

Slavit, Holmlund-Nelson, & Kennedy.(2009). *Perspectives on supported collaborative teacher inquiry*. New York: Routledge.

Expert Advice on key design issues:

(1) Additional "knowledge synthesis"/advice by the Knowledge Management and Dissemination Project (KMD), funded by NSF's Mathematics and Science Partnership Program (MSP). www.mspkmd.net. [Most of the focal PLCs involved STEM teachers*plus*scientists/mathematicians.]

(2) Mundry& Stiles (2009). *Professional learning communities for science teaching*: *Lessons from research and practice*. NSTA.

Designing Learning Organizations for Instructional Improvement in Mathematics

Background
The overall goal of this research project is to understand what it takes to support mathematics teachers in improving the quality of their mathematics instruction at the scale of large, urban US districts.The project has two major phases.

Phase 1: 2007–2011
The first phase of the research project was conducted in collaboration with four large, urban districts that serve a total of 360,000 students. The districts were all implementing inquiry-oriented instructional improvement initiatives in middle-grades mathematics (e.g., three of the four districts adopted the *Connected Mathematics Project 2* text).The participants were:
- 6–10 schools in each of 4 districts
- 30 middle school mathematics teachers in each district
- 15–20 school and district leaders in each district

The data we collect (in both phases) allow us to document (1) teachers' instructional practices, visions of high-quality instruction, mathematical knowledge for teaching, and views of students' mathematical capabilities; (2) mathematics coaches' practices, visions of high-quality instruction, mathematical knowledge for teaching, and views of students' mathematical capabilities; (3) school and district leaders' instructional leadership practices, visions of high-quality instruction, and views of students' mathematical capabilities; and (4) supports for teachers', mathematics coaches', and school leaders'development of effective practices (e.g., district professional development, interactions with more accomplished peers). In addition, we have access to district student achievement data.

Each year, we provided the four districts with feedback on how their instructional improvement efforts in middle-grades mathematics were playing out in their schools, and made actionable recommendations about how their strategies might be revised to make them more effective. During Phase 1, the leaders in all four districts acted on our recommendations and, as a consequence, we became co-designers of their improvement strategies.

The primary product of the first phase was a provisional theory of action that can inform instructional improvement efforts in mathematics at the level of large urban districts.

Phase 2: 2011–2015
The second phase of the project involves a continued four-year collaboration with two of the districts that participated in Phase 1.The primary goal in this phase is to test, revise, and elaborate conjectures inherent in the theory of action for district-wide instructional improvement developed in Phase 1.To this end, we are collaborating with district leaders to co-design and co-lead coordinated professional development for teachers, coaches, and school leaders.The participants are:
- 12 schools in each of 2 districts
- 60 middle school mathematics teachers in each district
- 25–30 school and district leaders in each district

During Phase 2 we will continue to provide feedback to districts every year on how their instructional improvement efforts in mathematics are playing out in their schools, and we will continue to make actionable recommendations about how their strategies might be revised to make them more effective.

Theory of Action for Instructional Improvement in Mathematics at the Scale of a Large Urban District

In its current iteration, the theory of action includes five interrelated components: (a) coherent system of supports for inquiry-oriented teaching that include curriculum materials and instructional guidance instruments such as curriculum frameworks; (b) pull-out teacher professional development and teacher collaborative meetings; (c) mathematics coaches' provision of job-embedded support for teachers' learning; (d) school instructional leadership in mathematics; and (e) school system leadership to support the development of schools' capacity for instructional improvement. A central aspect of the theory of action concerns the coordination of professional development across contexts (district-based and school-based) *and* across role groups (teachers, mathematics coaches, and school leaders).We are currently investigating conjectures about coordinated professional development for teachers, coaches, and school leaders that focuses on high-leverage instructional practices in Phase 2 of the research project.

For more information, including publications:

Please see the project's website http://www.peabody.vanderbilt.edu/mist.xml

Contact Information:

Erin Henrick, Project Manager and Co-PI, Vanderbilt University
erin.henrick@vanderbilt.edu

Kara Jackson, Assistant Professor of Mathematics Education, McGill University
kara.jackson@mcgill.ca

Paul Cobb, Professor of Mathematics Education, Vanderbilt University
paul.cobb@vanderbilt.edu

Thomas Smith, Associate Professor of Public Policy and Education, Vanderbilt University
thomas.smith@vanderbilt.edu

Ilana Horn, Associate Professor of Mathematics Education, Vanderbilt University
ilana.s.horn@vanderbilt.edu

Culturally Relevant Ecology, Learning Progressions, and Environmental Literacy

Our Mathematics and Science Partnership focuses on enhancing environmental literacy in K–12 schools and beyond through research on student and teacher learning, professional development informed by the research, and institutional reform. We work at the critical education juncture of middle school through high school (grades 6–12). The project connects the research strengths in the environmental sciences and education of our partner universities and sites within the NSF-funded Long Term Ecological Research (LTER) Network with K–12 teacher professional development in science and mathematics of our partner schools. The program takes advantage of the local and regional partnerships between the universities and the K–12 districts and provides a common research framework and professional development model. As such, site-based research and professional development are implemented and coordinated within a network. Our work emphasizes a core set of environmental issues defined by researchers within the LTER network, alignment of those issues to state science and mathematics content standards, research on student and teacher understanding of principles underlying the environmental issues, and the development and implementation of professional development and instructional strategies that are informed by this research. Partnership between K–12 and higher education and engagement of each in the others' activities, institutions, and cultures are key elements to approach and success.

Our research on the effectiveness of our work includes longitudinal studies of teacher and student performance on standardized tests, longitudinal qualitative studies on student and teacher understanding of science content and process, learning progressions–based research on student and teacher understanding of science content, and learning progression–informed teaching strategies and professional development activities. The early longitudinal studies focused on the effectiveness of multi-year academic year and summer immersion and enrichment programs targeting first generation and low-income students funded by the USDE. Students who participated in the program for two or more years exhibited significant gains in ACT scores, and were more likely to graduate from high school and matriculate to college compared with non-participants. Teachers demonstrated an increased level of engagement with higher education. Current work is focusing on student understanding of key concepts and instructional strategies to increase content knowledge, and effective modes of engagement between K–12 and higher education to meet these ends.

We have conducted our research and implemented our modes of engagement in a variety of school settings (e.g., rural, urban, small schools) with diverse students. Specific examples of engagement include partnering STEM graduate student with K–12 teachers in their classrooms following the NSF GK–12 model, providing research internships for K–12 teachers, establishing a teacher-in-residence program for teacher sabbaticals at the universities, developing graduate programs for teachers and adopting options within existing graduate programs to facilitate engagement of STEM graduate students and faculty with K–12, and redefining outreach at the universities to include engagement with the K–12 community.

Information about our programs can be found at www.nrel.colostate.edu, www.lertnet.edu, and http://edr1.educ.msu.edu/EnvironmentalLit.

Lenses on Learning: Research-Based Mathematics Professional Development for Instructional Leaders

"…districts should provide instructional leaders with professional development that helps them to create school conditions that appear to support student achievement…" (NRC, 2011)

The NRC report, *Successful K–12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics* recommends that schools and districts provide professional development for instructional leaders that will support their efforts to create school conditions conducive to STEM learning. The *Lenses on Learning* professional development materials support K–12 principals, teacher leaders, and district leaders to develop their instructional leadership for mathematics by focusing on issues of equity, assessment, data use, and support of high-quality mathematics instruction in schools.

INSTRUCTIONAL LEADERSHIP MATTERS

- Principals play a critical role in strengthening schools' mathematics programs (Grant, Nelson, Stimpson, 2009).
  - Foster a shared commitment to improving mathematics learning outcomes for all students
  - Engage with teachers and support strong mathematics teacher PD
  - Set expectations regarding teachers' integration into their classrooms of practices highlighted in PD
  - Relate math initiatives to wider school and district contexts
  - Publically support math initiatives to all stakeholders
- Instructional leaders' "leadership content knowledge" (LCK)—their ideas about the nature of mathematics and about mathematics learning and teaching—affects the ways they enact their roles (Nelson & Sassi, 2005; Stein & D'Amico, 2000; Stein & Nelson, 2003)

RESEARCH EVIDENCE

- *Thinking about Mathematics Instruction Research Project* (Goldsmith & Nelson (Eds), in preparation)
  - Mixed-methods experimental design
  - N=485 elementary and middle school principals
  - Participation in *Lenses* PD resulted in:
    - Increased emphasis on students' conceptual, as well as procedural, understanding
    - Gains in principals' mathematical knowledge for teaching
    - Increased use of mathematics knowledge when analyzing classroom events
- Secondary Lenses Study (Grant, Nelson, & Stimpson, 2009)
  - Investigated pre- and post-test changes in participants' understanding of math education
  - N=81 participants attended as part of district teams
  - Participation in *Lenses* PD resulted in:
    - Qualitative shift in pedagogical beliefs toward more student-focused instruction for 40% of participants
    - Increase in focus on collaborative, team-based work within school/district

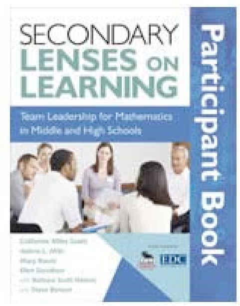
LENSES ON LEARNING PROFESSIONAL DEVELOPMENT MATERIALS

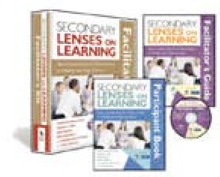
The *Lenses on Learning* professional development materials support K–12 principals, teacher leaders, and district leaders in developing their instructional leadership through focus on:

- The nature of high-quality mathematics instruction in schools
- Equitable access to rigorous mathematics education for *all* students
- A balanced assessment approach (assessment for and of learning)
- Strategic use of data

Lenses participants engage in hands-on mathematics work, analyze classroom video and student work, discuss research articles, and inquire into their own practice. *Lenses* materials address the mathematical processes and proficiencies emphasized in the Common Core State Standards.

Secondary Lenses on Learning: Team Leadership for Mathematics in Middle and High Schools (Corwin Press)

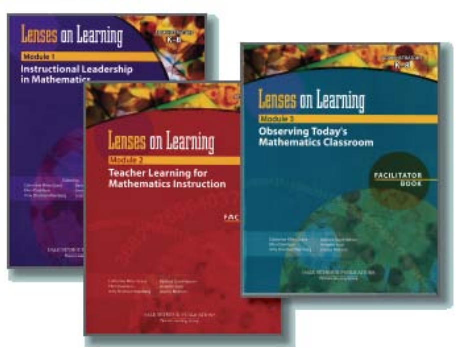




Participants attend the course in school district–based teams and do the following:

- Learn about research-based practices supporting engagement and mathematics learning for a broad spectrum of students
- Examine current practices within the school and identify strengths, needs, and potential leverage points for future development
- Use these findings to create action plans addressing short-term and long-term goals
- Identify and commit to specific first steps to take, and plan for involving other critical players.

Lenses on Learning (grades K–8) (Pearson School Publishers)



Course 1: A New Focus on Mathematics and School Leadership

- Module 1: Instructional Leadership in Mathematics
- Module 2: Teacher Learning for Mathematics Instruction
- Module 3: Observing in Today's Mathematics Classroom

Course 2: Supervision: Focusing on Mathematical Thinking

For more information:
Visit www.mathleadership.org or contact Kristen Reed at kreed@edc.org or 617-618-2913.