Modeling Instruction:

Meaningful Professional Development

By Jane Jackson, Co-Director, ASU Modeling Instruction Program

I thank Larry Dukerich & David Hestenes for input. Larry has led Modeling Workshops since 1994.
History of Modeling Instruction — still going!

• 1980-1990: PER to develop *Modeling Instruction* and curriculum design
• 1990-2005: NSF support to disseminate *Modeling Instruction* nationwide
  –2001: Creation of ASU Master of Natural Science (MNS) program for teachers
• 2005: American Modeling Teachers Association (AMTA) began. Growing fast now!

National Impact

• To date: 3,000 physics teachers & 6,000 STEM teachers have taken intensive 2- or 3-week summer Modeling Workshops

• In 2013, 50 Modeling Workshops for 800 teachers

• At ASU since 2001: 1,000 teachers took Modeling Workshops & other MNS courses, including 31 teachers from Singapore. 65 physics MNS degrees; \( \frac{1}{2} \)-dozen PER doctorates

• **Teacher buy-in:** 1600 AMTA members

• **University buy-in:** FL Intl Univ, Brigham Young Univ, Buffalo State College, Illinois State Univ, PhysTEC-AMTA partnership
University buy-in

- ASU: 9 Modeling Workshops, 11 other graduate courses; MNS degree for teachers. 2 undergraduate methods courses. PhysTEC grant with Teacher-in-Residence who is long-time Modeling Workshop leader.

- FIU: 2 Modeling Workshops; freshman physics for science majors. NSF & PhysTEC grants. Tenured modeler does PER. Huge impact!

- BYU: tenured HS modeler teaches 2 methods courses; 15 teachers/year.

- Buffalo State: 2 Modeling Workshops: Master degree. Huge impact!

- Illinois State Univ: HS modeler directs largest undergrad physics teacher preparation program in state. 12 graduating teachers/year.

- Cal Poly-SLO: 2 faculty modelers. Outreach only; no freshman labs.
The defining issue of our century is global warming.

- Thus we need an enlightened citizenry, who can think -- to address the looming planetary destabilization.
- Physics is at the heart of understanding global warming.
- High school physics teachers can teach thinking skills, core concepts, and basic modeling, to empower people to be planetary stewards.
- That is why I have worked in Modeling Instruction at ASU for 20 years.
Contrasting reform strategies

**Current top-down:** Increase teacher accountability and incentives. Standardized testing to separate “good” from “bad” teaching
- Fire teachers who under-perform
- Raise pay for the “best” teachers
- Increase student time in school
- Promote competition among schools, public and private

**We promote bottom-up:** Improve teacher competence, opportunities and collaboration!
- Opportunities for lifelong professional development (PD)
- Easy access to best pedagogy and curricula
- Facilitate contact of STEM teachers with scientists & engineers
- Establish a community of peers to
  — mentor new teachers
  — collaborate on improving teaching practice

Vision: teacher is change agent! All reform is ultimately local (in classroom)!
Three K-12 STEM goals needed, locally to nationally

1. Establish stable systems to improve the quality of K-12 math and science teaching;

2. Increase the number of math and science teachers, and improve the quality of their preparation;

3. Improve the working environment, and make the teaching profession more attractive for K-12 math and science teachers.
The Need

From the Glenn Commission Report (2000)

“The teaching pool in mathematics and science is inadequate to meet our current needs; many classes in these subjects are taught by unqualified and under-qualified teachers.

Our inability to attract and keep good teachers grows. As a result, newer, technologically oriented industries are having trouble finding enough qualified employees from among those teachers’ students. Worse, creativity atrophies and innovation suffers.”
Glenn Commission recommends

“We are of one mind in our belief that the way to interest children in mathematics and science is through teachers who are not only enthusiastic about their subjects, but who are also steeped in their disciplines and who have the professional training—as teachers—to teach those subjects well.

Nor is this teacher training simply a matter of preparation; it depends just as much—or even more—on sustained, high-quality professional development.”
Why start with physics?

High school physics is the chief STEM pathway. A student who takes “reform” (active learning) high school physics like Modeling Instruction is three times more likely to earn a STEM degree than a student whose last high school science course was chemistry.

[I thank Paul Cottle, FL State University, for informing me. References: http://modeling.asu.edu/modeling/STEMpathways-Physics.htm]
“Increase significantly the number of math and science teachers, and improve the quality of their preparation.”

- In Arizona, 15 new physics teachers/year are needed, but Arizona's three public universities graduate only 6.

- Thus some schools stop offering physics, the quality of instruction is inferior, and physics enrollment dwindles.

- 3/4 of Arizona’s 280 physics teachers are out-of-field; half of the chemistry teachers, & most 9th grade physical science teachers.

- PhysTEC grant slowly increases the number of teachers, but PD of inservice physics teachers can quickly improve student learning.
As the only program of its kind in the state, we help maintain physics in high schools, improve its quality, and increase enrollment.

Each summer, we hold 4 Modeling Workshops and 2 other graduate courses for 80 HS teachers.

We developed 9 Modeling Workshops & 11 other courses. Master of Natural Science (MNS) degree.

Since inception in 2001, ~1000 participants. ~65 teachers earned MNS degree (practical! - culminates in action research in classroom).

9 MNS courses in Integrated Science & Contemporary Physics prepare teachers to entice and inform their students (e.g., projects, activities for grade 12 courses & STEM clubs)
Read about our ASU work


Download both publications (& see our schedule & syllabi) at http://modeling.asu.edu/MNS/MNS.html
What we wanted to do

We submitted a dozen NSF & DoEd proposals; all were rejected. Some focuses:

- **Energy Modeling Workshop** for grade 9 physical science & physics
- **Coherent curriculum** for grades 8, 9, 10: physical science with math, then physics, then chemistry. Energy theme; models & modeling cycle, discourse
- Institute **for research-based STEM improvement** in Arizona schools:
  - **Graduate program** for life-long professional development of STEM teachers.
  - **State-wide STEM Teacher Alliance**: STEM clubs, connect with ASU STEM outreach; teacher research; student projects with industry; STEM careers.
  - **Partner with schools** for STEM improvement: buy-in among superintendents and principals. Assist in planning. *Council of Master Teachers to lead. PLCs for mentoring of new teachers and to implement... Authentic assessment.*
  - **STEM education R&D program at ASU** …
Paul Cottle, Physics Professor at Florida State University and chair of the APS Forum on Education, wrote to us:

"Congratulations on the Excellence in Physics Education award! One of my pet peeves is the millions of dollars poured down rat holes to support poor professional development. I hope we can find a way to use this award to highlight Modeling as the leading example of a scalable research-based PD program that works by improving student achievement."
What Makes MI Effective?

(1) **Modeling Instruction** design.

**Modeling Workshop** design.
- (2) Duration
- (3) Deliberate practice
- (4) Follow-up
- (5) Community
Why modeling?

- Modeling Instruction is based on the way people **think**. Powerful! (*Robert Karplus* made models and systems central to his *SCIS* K-6 curriculum!)

- It reveals the **structure** of physics. Courses become **coherent**.

- Students’ classroom experience is closer to research scientists.

- **Models and systems** are unifying ideas for all sciences.

Modeling Instruction is super-compatible with ISLE and PUM by Eugenia Etkina at Rutgers; a next step beyond PTRA (& used by many PTRAs); enhances project-based instruction; adds effective pedagogy to PSSC, Chem-Study, IPS.
Why begin cycle by DOING science?

“I hear and I forget.
I see and I remember.
I do, and I understand.”
Why is student discourse crucial?

“You don’t know what you know, ‘til you’ve heard yourself say it.”

Also, research at MIT’s Center for Collective Intelligence supports model-centered discourse, especially circle whiteboarding (board meetings). [http://cci.mit.edu](http://cci.mit.edu)

See videos of Dwain Desbiens board meetings, and 2 dissertations on modeling discourse, at [http://modelinginstruction.org](http://modelinginstruction.org)
Summary: Modeling Instruction

- **Year-long course objectives:**
  - improve the quality of model-centered discourse,
  - deepen student understanding of models & modeling with each pass thru the 2-week modeling cycle,
  - get students to see models everywhere!

- **Ultimate objective:**
  autonomous scientific thinkers, fluent in all aspects of conceptual and mathematical modeling
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<td>constructivist</td>
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Modeling Workshops
(2) Modeling Workshop duration

• MI workshops are much longer than conventional PD.
  • 3 weeks is typical
  • some are 2 weeks with follow-up
  • 6 to 8 hours/day, 5 days/week

• This provides time for teachers to reflect on what they’ve learned.
  • Many teachers admit that they didn’t “get it” until middle of 2nd week (even PhDs in physics or chemistry!)
Duration ➔ Change

• Most PD adds another tool to a teacher’s toolbox.
• But MI workshops fundamentally **change** a teacher’s toolbox.
• Most teachers liken the experience to an epiphany: “I can’t go back to teaching the way I did before.”
• Many are “repeat offenders”, who take up to 5 distinct 3-week Modeling Workshops in physics!
(3) Deliberate Practice

- Workshop participants work in “student mode.”
  - do experiments, report findings & draw conclusions
  - work sample problems in groups
- Then participants reflect in “teacher mode.”
  - discuss pedagogy, classroom logistics
- Teachers practice model-centered discourse (hard!)
  - Teaching is not telling. Teaching is listening.
  - Learn to be “guide on the side” rather than “sage on the stage”
(4) **Follow-up**

In most PD inflicted on K-12 teachers, presenter/leader swoops in, delivers pitch, then disappears. No support after initial PD.

When grant funding is sufficient, Modeling Instruction has multiple 1 or 2-day follow-up workshops. These allow teachers to

- report successes, difficulties
- clear up confusion about content or pedagogy
- create a sense of community with fellows
- resolve concerns that weren’t addressed in summer workshop.

(Grants are hard to get! NSF no longer funds teacher PD. DoEd Math-Science Partnership requirements disallow physics and chemistry teachers. So we must rely on corporate funding.)
(5) Community

Modeling listservs
- Physics listserv (started in 1995) has 3000 subscribers
- Chemistry listserv (started in 2005) has 1500 subscribers.
- Teachers get help; & they tell others when they find success.

AMTA website: see [http://modelinginstruction.org](http://modelinginstruction.org) for
- schedules of 50 Modeling Workshops nationwide this summer
- articles, presentations, recommendations for modelers
- Modeling Instruction curriculum resources (editable) for teachers
Testimonials

From Mansfield University, PA Modeling Workshops (3 held in 2010)

- Participating in the process has forever changed how I will teach!

- I have taken courses at Cornell’s CNS Institute for Physics Teachers which yielded excellent labs, but this workshop provided in-depth techniques to improve my practice by facilitating true student understanding. I rank this experience above the National Board Certification Process.

- My expectations were surpassed with this workshop. Every minute proved to be of great value to me.

- The “traditional” way of teaching chemistry seems like such a disservice. I love how modeling unfolds the story of chemistry.
Teachers have sent thousands of comments to Jane Jackson.

- I really thought that modeling wouldn't work until I tried it, and I can’t believe what I’m hearing and seeing as far as the amount of student understanding. My classes are so much fun and they like to come to class.

- The value of the modeling course is well beyond any other teaching support or education I have ever, or expect to receive.

- I am a true believer. And so are my students. They have said on numerous occasions that they have learned more this year than they ever did in all of the other science classes.

- Better trained teachers make for higher achieving students. Tuition costs are a real obstacle for teachers to take these courses, which I believe are the best form of professional development.
How can you help?

- Support modeling teachers in your region.
  - Visit your local physics teacher. Urge him/her to take a Modeling Workshop.
  - Sit in on a Modeling Instruction lesson, if possible.

- Take a Modeling Workshop. (College faculty have done so.)

- Ask your university “Policy Affairs & Federal Relations” official (i.e., lobbyist) to prioritize funding of science teacher PD: urge Congress to require NSF to re-instate summer Teacher Institutes.

- AMTA can give advice and support. http://modelinginstruction.org
What can a physics department do?

Vision: Let’s expand the community of physicists to include high school physics teachers as valued colleagues. That will improve teachers’ expertise and societal impact!

- One committed faculty member is sufficient to get started.
- Host a Modeling Workshop. (Many universities have done so.)
- Replicate the ASU program, or FIU, or BYU, or Buffalo State College. [See Hestenes et.al. A graduate program for high school physics and physical science teachers, Am. J. Phys.79: 971-979 (Sept. 2011). http://modeling.asu.edu/MNS/MNS.html]
- AMTA can give advice and support. http://modelinginstruction.org