MEMO
To: colleagues interested in K-12 science and mathematics education
From: Jane Jackson
Subject: 2014 annual report on ASU Modeling Workshops

Introduction:

The Modeling Instruction Program in the ASU Department of Physics has successfully addressed a severe shortage of qualified physics teachers in Arizona since 1998, even while the number of local physics teachers doubled. Since 2005 we have addressed a shortage of local chemistry teachers as well. A surplus of biology teachers exists, and we have prepared many of them to teach chemistry and/or physics.

Modeling Instruction was developed by ASU professor David Hestenes and Malcolm Wells, a veteran high school physics teacher, to correct many weaknesses of the traditional lecture-demonstration method, including fragmentation of knowledge, student passivity, and persistence of naive beliefs about the physical world. Courses are coherent, since they are organized around a small number of scientific models.

Modeling Instruction is designated by the U.S. Department of Education as an Exemplary K-12 science program and a Promising K-12 Technology program.

Recent Awards:
* In January 2015, the ASU Modeling Instruction Program and Master of Natural Science (MNS) degree program were designated “Accomplished STEM Programs” and added to the online STEMworks Database at http://changetheequation.org/stemworks, after a rigorous review. STEMworks is sponsored by Change the Equation, a coalition of Fortune 500 companies. It is a critical resource for funders.

* In April 2014, High School Modeling Instruction was recognized with the 2014 Excellence in Physics Education Award of the American Physical Society (APS). The APS is the largest professional organization of physicists worldwide. The Award included $5,000. It was presented to David Hestenes, Jane Jackson, and Colleen Megowan at the APS April 2014 meeting in Savannah, Georgia. http://meetings.aps.org/Meeting/APR14/Session/J11.

Actions for sustainability in 2014:
* began the “Improving physics and chemistry teachers scholarships” endowment fund, with a target of $1,000,000, for teachers nationwide.
* worked on developing a graduate certificate program in Modeling Instruction.
* submitted proposals to six corporations and foundations.
News stories:

**Boeing funds Valley science teacher scholarships.** Arizona Republic, March 20, 2014.

**Boeing, ASU collaborate to support science teacher training.** ASU News, March 28, 2014.
https://asunews.asu.edu/20140328-asu-boeing-support-science-teachers

ASU graduate courses in summer 2014:

Fifty-five Arizona science and math teachers and 15 out-of-state teachers participated in four peer-led Modeling Workshops and two other graduate courses. Included were five physics and chemistry teachers sent by the Ministry of Education in Singapore. This brings their total to 36 teachers in eight years. Singapore students have the highest math and science scores in international tests; that is strong evidence for the high quality of Modeling Instruction.

Our courses are for lifelong learning for teachers of high school physics, chemistry, physical science and math, and grade eight science and math. They can lead to a Master of Natural Science (MNS) degree. Since inception in 2001, ~70 teachers have earned this degree. Physics professor Robert Culbertson has directed the MNS degree program since 2005.

Courses are content-intensive; and integration of physics, chemistry, and math is emphasized. The ultimate target is not the teachers themselves but their students. Therefore each course addresses the subject at a level that prepares them to entice and inform their students.

We are thankful for our two major donors, The Boeing Company and Salt River Project. Their donations made our summer 2014 program possible. They provide program support and partial tuition scholarships. ASU tuition is unaffordable for most teachers. We can no longer get big grants; hence now we serve half as many Arizona teachers, with one-fifth the budget.

**About Modeling Instruction:**

Modeling Instruction is an innovative, effective pedagogy: it is guided inquiry structured by modeling principles. It develops in students the ability to analyze data, reach a conclusion and defend it; and it emphasizes experiment design. Other 21st century skills developed include scientific use of computers and probeware, teamwork, and verbal and written communication skills. Students become self-directed, independent learners. It is aligned with the National Research Council (NRC)’s Framework for K-12 Science Education, the research-based document upon which the Next Generation Science Standards (NGSS) have been developed.

Student achievement on tests of concept understanding is typically double that of traditional instruction. A modeler wrote, "One can only imagine the future of science if only we all could understand the power of modeling."

**Effect of ASU Modeling Instruction in Arizona:**

Since 1998, more than 900 unique Arizona teachers have taken 15-day Modeling Workshops. Estimating one-third retirement/relocation/advancement and 160 students per teacher, ~95,000 Arizona students each year are benefiting.

Modeling Instruction is used in many high schools in metropolitan Phoenix, notably Bioscience High School, Arizona School for the Arts, Tempe Preparatory Academy, some Great Hearts Academies, Pinnacle High School in Paradise Valley USD, Hamilton High School in Chandler USD, and Red Mountain High School in Mesa USD.

**Resources:**

* Information about our summer courses is at [http://modeling.asu.edu/MNS/MNS.html](http://modeling.asu.edu/MNS/MNS.html).
SUPPLEMENTARY DETAILS:

Our seven ASU courses for teachers in summer 2014 (each is three graduate credits):
  4 Modeling Workshops: mechanics, electricity & magnetism, light, chemistry (first semester content)
  Integrated Physics & Chemistry
  Spacetime Physics
  Leadership workshop (1 credit)

Modeling listservs:
We maintain these content-focused modeling listservs for year-round professional development & support of modeling teachers worldwide. As of March 2015:
  * physics has 3250 subscribers
  * chemistry has 1600 subscribers
  * physical science & middle school science has 800 subscribers.
  * biology has 700 subscribers.
  * 9th grade physics (camod) has 540 subscribers.

Typical teacher comments about ASU Modeling Instruction and MNS programs:
* I'm a better teacher after modeling, I like my job more, I feel the kids walk away with real transferable skills.
* It moves students in the direction of being independent learners, and it puts the responsibility for learning where it belongs - on the students.
* The Modeling program is the only one I have found that is truly grounded in how students learn and attacks head-on the misconceptions students have.
* Thanks to taking physics modeling course work, I am highly qualified in physics.
* I learned a tremendous amount and am all fired up to teach physics this fall!
* Great chem workshop.
* It was, without a doubt, the single greatest professional development experience of my career.

A metropolitan Phoenix teacher in a high-poverty school wrote in 2008:
"I make about 38k a year. I have a degree in chemical engineering -- I should be making at least double that. This almost kept me out of teaching. But some things are more important than money.

I'm reaching the end of my fourth year teaching science and my second teaching physics. In those last two years, I've doubled the population of students registering for the general physics class at my school. I've poured enormous effort into improving the program. The reason I've been able to do this is because of what I've learned through the modeling program at ASU, both in terms of knowledge and superior teaching practices.
It is by far the best science methodology out there. Unlike traditional science classroom practices, the modeling program stresses the PROCESS of science. Students not only \textit{learn} the requisite science curriculum but how to design and implement experiments that will address a question, how to work well in a community of peers, how to collect and process data, how to think logically and critically - basically, how to be effective problem solvers. Not only do these skills serve to help knowledge retention and increase general interest in science but these are skills that transcend the science classroom.”

**The need for the ASU Modeling Instruction Program:**

Arizona has a chronic shortage of high quality teachers of physical sciences, exacerbated in recent years by retirements, opening of new "rigorous" charter high schools, attrition, and Arizona's recent requirement that all high school students take three years of lab science. Three-fourths of the metro Phoenix’s ~180 physics teachers don’t have a degree in physics; and half of the ~400 chemistry teachers don’t have a degree in chemistry. Arizona's three public universities collectively graduate only a half-dozen physics teachers each year; thus local schools must find and prepare physics teachers from in-service teachers of other subjects (usually biology or chemistry) and second-career teachers (often engineers). Teaching jobs would go unfilled for lack of highly qualified (NCLB) teachers, were it not for our program.

Low salaries drive science teachers out of the profession, and turnover is highest in physics, according to American Institutes for Research -- but numerous physics teachers have written that professional development in the ASU Modeling Instruction Program saved their career! Our survey of 110 teachers revealed that our summer professional development is the \textit{best} way we can help keep them in the classroom. Teachers wrote: "ASU’s summer program is a national treasure!“ “If I had not found the Modeling Instruction pedagogy, I would most likely left teaching by now because I was so discouraged with the mile-wide, inch-deep approach that I was using.”

The shortage of qualified physics teachers is dire and worsening. For example, in 2011, there were 60 physics job openings in Arizona (out of 280 physics teaching jobs total); some were not filled. Many chemistry job openings occur each year. Thus many new teachers and out-of-field physics and chemistry teachers need ASU summer Modeling Workshops.

For example, a Phoenix math teacher who was asked by his principal to teach physics wrote, "I'm just trying to do my best until we can find a "real" physics teacher. It seems that they are very hard to come by." Teachers from overseas (most often from Asia) are hired to teach chemistry, physics, and math in high-poverty schools that have many English language learners (especially in isolated rural schools). Although these teachers are dedicated, a language barrier exists in some cases, and stability is lacking because their visa is good for only three years.

**The chief obstacle, in almost all cases, is unaffordability of ASU tuition.** Many physics and chemistry teachers’ salaries are ~ $36,000, and their salaries have been frozen for up to 8 years. Many teachers have young children; some are single parents. Some are putting children through college. They can't afford the ASU resident tuition of ~$1900 for one course. They wrote, “I’d have to choose between feeding my children and taking classes” and “I lose money taking classes instead of working in the summer; to me these classes are worth it, but I could not pay the tuition.” A family of 4 needs an income of twice the official annual poverty threshold of $24,000 to cover basic expenses: housing, food, transportation, health care, and child care. That is $48,000 per year. [Ref. The Annie E. Casey Foundation (2014): Creating opportunity for families: A two-generation approach. Baltimore, MD. \url{http://www.aecf.org}]
How the program is funded:

For the fourth year in a row, the Boeing Company contributed funds ($40,000 in 2014) for wages of peer co-leaders, trainee stipends, instructional materials, and partial tuition scholarships for 20 teachers taking 22 courses. For the sixth year, the Salt River Project contributed $10,000, providing partial tuition scholarships for 8 teachers. The Arizona Technology Council donated $1850 for partial tuition scholarships at the last minute, since we had so many requests from financially needy teachers.

Until 2011, we were funded for $225,000 per year for ESEA (aka No Child Left Behind) Title IIA "Improving Teacher Quality" grants administered by the Arizona Board of Regents, and we served typically 100 Arizona teachers each summer. That funding source is no longer available. Thus now we serve half as many Arizona teachers, on a budget of one-fifth as much.

In the impending Federal ESEA reauthorization, it appears that no funding will be provided for discipline-specific professional development for K-12 science teachers. This is contrary to the U.S. goal to maintain its global competitiveness, and we find it very troubling. Long-term professional development of in-service high school science teachers is essential for improvement of student learning. It takes 10 years of deliberate practice to become an expert, research shows. Thus teachers need a series of Modeling Workshops, in several summers. Details are at http://modeling.asu.edu/modeling/ConvincingDocuments.html.

Modeling Workshops nationwide:

Until 2013, our ASU Annual Reports, at http://modeling.asu.edu, included summaries of Modeling Workshops nationwide. The numbers doubled in the past few years, to 60 multi-week workshops in summer 2014.

In 2013 our scale-up partner, the American Modeling Teachers Association (AMTA), assumed oversight of nationwide Modeling Workshops. AMTA is a grassroots professional society of, by, and for teachers who use Modeling Instruction. It is focused on effective teaching. The AMTA Executive Officer is Colleen Megowan (amtaexec@modelinginstruction.org). Nationwide Modeling Workshops are summarized in AMTA Annual Reports: http://modelinginstruction.org

Description of Modeling Workshops:

Modeling Workshops thoroughly address most aspects of science teaching, including integration of teaching methods with course content. Workshops incorporate up-to-date results of physics and science education research, best curriculum materials, use of technology, and experience in collaborative learning and guidance. Workshops are aligned with all 8 science practices of NGSS.

Participants are introduced to Modeling Instruction as a systematic approach to design of curriculum and instruction. The name Modeling Instruction expresses an emphasis on making and using conceptual models of phenomena in science as central to learning science. Mathematics instruction is integrated seamlessly in each course by an emphasis on mathematical modeling.

In each workshop, content for an entire semester course is reorganized around models to increase its structural coherence. Participants are supplied with a complete set of course materials and work through activities alternately in roles of student or teacher. Teachers use computers as scientific tools to collect, organize, analyze, visualize, and model real data.