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MEMO
To: colleagues interested in K-12 science and mathematics education
From: Jane Jackson
Subject: 2015 annual report on ASU Modeling Workshops

Introduction:

The Modeling Instruction Program in the ASU Department of Physics has 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.

Physics is STEM! Physics is a true STEM course, when Modeling Instruction is used. It includes more math, technology, and engineering than any other high school science course.

High school physics is the chief pathway to STEM majors in college. A student who takes active learning (hands-on, minds-on) high school physics, such as Modeling Instruction, is three times more likely to earn a STEM degree than a student whose last high school science course was chemistry. (See http://modeling.asu.edu/modeling/STEMpathways-PhysicsAZ.htm for references). Physics is the foundation of all sciences, engineering and technology. Thus, Arizona's economic health depends on a strong K-12 education that includes robust physics courses for all students.

Modeling Instruction began in the 1980's, developed by ASU professor David Hestenes and Malcolm Wells, a veteran physics teacher at Marcos De Niza High School in Tempe. It corrects 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. It was recognized with the 2014 *Excellence in Physics Education Award* of the American Physical Society (APS), the largest professional organization of physicists worldwide.

Recent award: 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.

Actions for sustainability in 2014-15:

* founded the "Improving physics and chemistry teachers scholarships" endowment fund for teachers nationwide, with a $40,000 gift from Jane and Paul Jackson. The target is $1,000,000.

* worked on a graduate certificate program in Modeling Instruction, & a 4+1 BS/MNS program.
* submitted six proposals. Those to Boeing Company and Salt River Project were successful.
* on Sun Devil Giving Day (3/19/2015), got $5650 for scholarships (donations & CLAS match).

Recent news stories:

* Alumni: Jane Jackson '70, in Jan. 2015 Newsletter for alumni & friends of ASU College of Liberal Arts and Sciences. https://clas.asu.edu/alumni/spot/jackson?j=35143
* Arizona Education News, Oct. 29, 2015: ASU alleviates physics teacher shortage, strengthens STEM pathway. http://azednews.com/2015/10/29/asu-alleviates-physics-teacher-shortage-strengthens-stem-pathway/
* ASU NEWS: https://asunow.asu.edu/20151106-asu-alleviates-physics-teacher-shortage-strengthens-stem-pathway

ASU graduate courses in summer 2015:

Seventy physics and chemistry teachers -- 54 in Arizona and 16 from out-of-state -- participated in four peer-led Modeling Workshops and three other graduate courses. Included were four physics and chemistry teachers sent by the Ministry of Education in Singapore. This brings their total to 40 teachers in nine years. Singapore students have the highest math and science scores in international tests: 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. 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 2015 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 hands-on 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, almost 1000 unique Arizona teachers have taken 15-day Modeling Workshops. We estimate that 100,000 Arizona students benefit each year.

Modeling Instruction is used in many high schools in metropolitan Phoenix, notably Hamilton High School in Chandler USD, Red Mountain High School in Mesa USD, Mountain

Pointe High School in Tempe UHSD, Arizona School for the Arts, Tempe Preparatory Academy, and Great Hearts Academies. Our chief school partner is Phoenix Union High School District.

Resources:
* Information about our summer courses: http://physics.asu.edu/graduate/mns/pos .
* Modeling Instruction resources, research, annual reports: http://modeling.asu.edu .
* Would you like to contribute to the success of ASU Modeling Instruction and MNS programs by donating a partial tuition scholarship or contributing to our $1M endowment fund for teacher scholarships? http://asufoundation.org/modeling or http://asufoundation.org/endowmodeling .

SUPPLEMENTARY DETAILS:

Our seven ASU courses for teachers in summer 2015 (most are three graduate credits):
* 4 Modeling Workshops: mechanics, mechanical waves & sound, chemistry (first semester content), chemistry (second semester & AP content).
* Structure of Matter, Astronomy & Physics, Leadership workshop (1 credit).
* Invited speakers: Earl Barrett, retired teacher-leader from Dobson High School in Mesa (how to increase physics enrollment); Colleen Megowan, Executive Officer of AMTA (why AMTA); Dwain Desbien, Physics Professor at Estrella Mountain Community College (student discourse).

Modeling listservs:
We maintain five content-focused listservs for year-round professional development & support of modeling teachers worldwide. As of Aug. 2015, the number of subscribers in each listserv is:
* physics: more than 3500 teachers
* chemistry: 1750
* physical science & middle school science: 850
* biology: 725
* 9th grade physics: 530.

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 this eloquent statement 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 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."

<u>The need for the ASU Modeling Instruction Program:</u>

Arizona has a chronic shortage of high quality teachers of physical sciences. 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 *best* way ASU 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. A 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."* A solution is for schools to ask out-of-field teachers to re-train. Dozens of out-of-field teachers have written statements such as, "*Thanks to taking ASU physics modeling course work, I am highly qualified in physics."*

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 for professional development is unaffordability of ASU tuition. Many physics and chemistry teachers struggle to pay tuition. Salaries for newer teachers are ~ $37,000. Salaries were 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 summer 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. http://www.aecf.org]

How the program is funded:

For the fifth year in a row, **the Boeing Company** contributed funds ($40,000 in 2015) for wages of peer co-leaders, trainee stipends, instructional materials, and partial tuition scholarships for teachers. For the seventh year, the **Salt River Project** contributed $10,000 for partial tuition scholarships for 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. ASU provided 55 tuition waivers, and we served typically 100 Arizona teachers each summer. That funding source is no longer available. Thus now we serve *half* as many teachers, on a budget of *one-fifth* as much. (In summer 2015, 63 teachers took a Modeling workshop; in 2014, 2013, 2012, 2011, 2010, 2009, and 2008 the numbers are 67, 64, 59, 90, 101, 124, and 134.)

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. High school physics is the chief STEM pathway. 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 several Modeling Workshops. Details 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. Growth is fast: 60 multi-week workshops were held in 2015.

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 listed at the AMTA website: 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 focus on all 8 science practices and cross-cutting concepts of the NRC *Framework for K-12 Science Education* (2012).

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. Math 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.