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MEMO
To: colleagues interested in K-12 science and mathematics education
From: Jane Jackson
Subject: 2020 & 2021 annual reports on ASU Modeling Workshops (combined due to pandemic)

Introduction:

Modeling Instruction in the ASU Department of Physics is world-renowned professional development. We have 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, too. A surplus of biology teachers exists, and we have prepared many of them to teach chemistry and/or physics.

Physics is STEM! Physics includes more math, technology, and engineering than any other science course. Physics is the foundation of all sciences, engineering and technology.

High school physics is the chief STEM pathway. A student who takes interactive engagement (hands-on, minds-on) high school physics, such as Modeling Instruction, is far more likely to earn a STEM degree than a student whose last high school science course was chemistry. (http://modeling.asu.edu/AZ/PhysicsEnroll-NeedDouble.htm) STEM jobs are the future. **Arizona's economic health depends on a strong K-12 education that includes robust physics courses.**

Modeling Instruction was developed in the 1980s by Malcolm Wells, a veteran physics teacher at Marcos De Niza High School in Tempe, in collaboration with his doctoral advisor, ASU physics professor David Hestenes. 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. They align with the Arizona high school science standards.

Modeling Instruction is designated by the U.S. Department of Education as an *Exemplary* K-12 science and a Promising K-12 Technology program. It received the 2014 *Excellence in Physics Education Award* of the American Physical Society (APS), the largest professional organization of physicists worldwide. *Change the Equation*, a coalition of Fortune 500 CEOs, designated the ASU Modeling Instruction and Master of Natural Science (MNS) degree programs as "Accomplished STEM Programs": see http://stemworks.wested.org.

Actions for sustainability in 2020 and 2021:

* Special recognition to long-time supporter Salt River Project, repeat supporters ON Semiconductor Foundation and Core Construction, and first-time supporter First Fidelity Bank.
* On Sun Devil Giving Day, several people gave to our teacher scholarship endowment fund. Teachers and the community that benefit from Modeling Instruction support it!
* Featured in **Campaign ASU 2020**: the university-wide comprehensive philanthropic effort.
* All donations to the *Improving Physics and Chemistry Teachers* endowment fund are matched by Jane Jackson, until $250,000 is in the fund. http://www.asufoundation.org/endowmodeling

* At least 37 scholarships for our courses were from the 2019 Arizona legislature appropriation of $1.2M for "Get Set for STEM" $2000 scholarships for K-12 certified teachers, for professional development to add certifications in CTE and STEM subjects – including becoming qualified to teach dual enrollment, which requires 18 graduate credits in the discipline.

ASU graduate courses in summer 2020 and 2021:

In 2020, 76 teachers (62 in Arizona) participated in three live online multi-week peer-led Modeling Workshops in physics and chemistry and two other live online graduate courses. The 18 long-distance teachers are from all over Arizona: Rio Rico, Benson, Springerville, Kayenta, Page, Lake Havasu City, Parker, Salome, Yuma; 7 came from Marana USD, near Tucson.

In 2021, 70 teachers (54 in Arizona, including 10 long-distance) participated in four Modeling Workshops (3 live online and 1 in-person) and three other in-person graduate courses.

Teachers learned to teach effectively, using Modeling Instruction -- and they were glad to learn ways to teach *remotely*. Most long-distance Arizona teachers were able to participate *only* because the courses were online and because the teacher had a $2000 scholarship awarded by the ADE. For most teachers, their scholarship was to earn graduate credits in chemistry or physics to qualify to teach dual enrollment. Teachers and instructors were satisfied with the synchronous online courses, even though all agree that in-person courses are better.

Our courses are for lifelong learning for teachers of high school and community college physics, chemistry, physical science and math. They can lead to a Master of Natural Science (MNS) degree. Since inception in 2001, 93 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. Thus each course addresses the subject at a level that prepares them to entice and inform their students.

We are thankful for the $15,000 contributed by each of our major donors, Salt River Project and ON Semiconductor Foundation. SRP contributed for the 12 and 13th times (program support). We are thankful for contributions in 2020 for technology for at-home labs by First Fidelity Bank and Core Construction, and for a $1000 donation in 2021 for similar technology from an ASU alumnus in chemistry. ON Semiconductor Foundation scholarships were awarded in 2021 for 11 courses. These scholarships and the $2000 scholarships from the Arizona legislature make our summer program possible. ASU tuition is unaffordable for most teachers. Federal and state grant programs no longer exist; so we serve *half* as many Arizona teachers with *one-fifth* of the budget that we had in 2006-2010; we rely on donations by local companies.

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 'soft 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 on which the Next Generation Science Standards (NGSS) and the Arizona science standards (2018) 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, about 1150 unique Arizona teachers have taken 15-day Modeling Workshops (or 5.5 weeks online). We estimate that 35,000 Arizona students benefit each year.

Modeling Instruction is used in many high schools in Greater Phoenix, including those in Chandler Unified SD, Mesa USD, Gilbert USD, Scottsdale USD, Tempe UHSD, Peoria USD, Arizona School for the Arts, Tempe Preparatory Academy, some Great Hearts Academies, Estrella Mountain Community College, and Chandler-Gilbert Community College. Our main urban (i.e., high poverty) school district partners are Phoenix UHSD and Tolleson UHSD.

Resources:

* Information about our MNS degree: https://physics.asu.edu/degree/graduate/mns-natural-science-physics
* 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 .

As of Nov. 2016, donations to our endowment fund are matched 1-for-1, thus doubling your investment. For advice, call Linda Raish, Executive Director of Development: 480-727-2767**.**
A 2-minute video interview of the matching donor is at https://vimeo.com/178494222 .

SUPPLEMENTARY DETAILS:

Our ASU courses for teachers in summer 2020 (3 graduate credits except Leadership workshop):

* 3 Modeling Workshops: mechanics, microscopic electricity & magnetism, chemistry (first semester content), and advanced/second semester chemistry.
* Integrated Physics and Chemistry, Astrophysics, Leadership Workshop.

Our ASU courses for teachers in summer 2021 (3 graduate credits except Leadership workshop):

* 4 Modeling Workshops: mechanics (in-person; live online), chemistry (first semester content), and advanced/second semester chemistry.
* Physics of Music & Musical Instruments, Structure of Matter, Spacetime Physics, Leadership Workshop.

Modeling listservs: For two decades, we have maintained five content-focused listservs for year-round professional development & support of modeling teachers worldwide. In summer 2021, our national partner, the AMTA, started a Discord server as the main support, so we reduced our service to just physics and chemistry. As of September 2021, the number of subscribers in each listserv is a little lower than last year: physics has about 3000 teachers; chemistry has ~ 1900.

Press/media in 2020 and 2021

ASU NOW article (Aug. 25, 2020):
https://asunow.asu.edu/20200825-asus-modeling-instruction-program-continues-teaching-legacy-online-format
Industry media article by ON Semiconductor Foundation (Sept. 2020):
https://www.3blmedia.com/News/Semiconductor-Helps-Transform-Science-Education-Arizona
ScienceModelingTalks.com podcast with Jane Jackson (Aug. 1, 2021, ½ hour; transcript too):

https://sciencemodelingtalks.com/episodes/episode-23-jane-jackson-27-years-developing-modeling-instruction/
Harvard Physics of Life Systems (PoLS-T) teacher network: talk by Jane Jackson: "Physics for All Requires Deliberate Practice by Teachers: Why and How" (June 2021, 15 minutes). https://www.youtube.com/watch?v=eoDzvuTgUdo

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.*

An out-of-field teacher in a local high-poverty school wrote this eloquent statement:

"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."

The need for the ASU Modeling Instruction Program:

Arizona has a chronic shortage of high quality teachers of physical sciences. Only about 160 currently employed physics teachers in Arizona are certified in physics (ADE, 2016). Three-fourths of Greater Phoenix's physics teachers don't have a degree in physics; and half of the chemistry teachers don't have a degree in chemistry. Arizona's three public universities collectively graduate only about 8 physics teachers each year; thus local schools must find physics teachers from in-service teachers of other subjects (usually biology or chemistry) and second-career teachers (usually engineers). Teaching jobs go unfilled for lack of highly qualified teachers. (We remedied this until 2010 with our grants that required ASU to give FREE tuition.)

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. In 2017-18, 8 district high schools in Greater Phoenix did not have a physics teacher (out of 100 district high schools total). 25% of rural high schools no longer offer physics. In spring 2016, there were 25 physics job openings in Greater Phoenix (out of 200 physics teaching jobs); 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."*

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 rural schools). Although these teachers are dedicated, a language barrier exists for some, and stability is lacking because their J-1 'cultural exchange' visa is good for only five years.

A practical solution is for schools to ask out-of-field teachers to re-train. Most schools do not do this, unfortunately; they do not prioritize physics. Thus we do it; we recruit teachers to re-train! This is our main strategy, and dozens of out-of-field teachers have told us, "*Thanks to taking ASU physics modeling course work, I am highly qualified in physics."*

The chief obstacle for professional development is unaffordability of ASU tuition. Many teachers struggle to pay tuition because their salaries are near $40,000 and they are paying student loans. 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 ~$2100 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 2021 poverty threshold of $26,500 to cover basic expenses: housing, food, transportation, health care, and child care. That is $53,000 / 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:

Until 2011, we were funded for $225,000 per year for ESEA (aka No Child Left Behind) Title II-A "Improving Teacher Quality" grants administered by the Arizona Board of Regents. ASU provided 55 tuition waivers, and we served up to 130 teachers each summer. That funding source has not been available since 2011. Thus now we serve *half* as many AZ teachers, with *one-fifth* the budget, relying on donations from local companies. (In summer 2021, 51 teachers took a Modeling Workshop; in 2020 and going back to 2008 the summer numbers are 70, 64, 57, 71, 65, 63, 67, 64, 59, 90, 101, 124, and 134.)

In the Federal ESEA reauthorization of December 2015, funding was supposed to be provided for discipline-specific professional development (PD) for K-12 science teachers; it didn't happen. In fact, the U.S. government has ended the two programs that funded local teacher PD: the Title II-A set-aside in each state for higher education competitive grants, and the Title II-B state math-science partnerships. **If the U.S. is to re-gain its global competitiveness, it must fund local teacher PD, and act on research showing that high school physics is the chief STEM pathway.** Long-term PD of science teachers is essential to improve student learning; typically 10 years of *deliberate* practice are needed to become an expert, research of K. Anders Ericsson shows. Thus teachers need several Modeling Workshops. Learn more on these important issues at https://www.youtube.com/watch?v=eoDzvuTgUdo .

Modeling Workshops nationwide:

Until 2013, our ASU Annual Reports, at http://modeling.asu.edu , included summaries of Modeling Workshops nationwide, which we oversaw. Our national partner, the *American Modeling Teachers Association* (AMTA), assumed oversight of nationwide Modeling Workshops in 2013. In 2019, 40 multi-week Modeling Workshops were held in physical, life, and computational sciences – down from 60 two years earlier, due to demise of all Federal grant programs for local teacher professional development. AMTA is a grassroots professional society of, by, and for teachers who use Modeling Instruction - focused on **effective** teaching. In 2017, Bill Thornburgh of Louisville, Kentucky (amtaexec@modelinginstruction.org) became AMTA Executive Officer. AMTA Modeling Workshops are listed at: 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.