STEM PATHWAYS & LITERACY IN ARIZONA: HIGH SCHOOL PHYSICS IS CRUCIAL

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THE NEED: Arizona has a fast-worsening shortage of qualified high school physics teachers, and a dearth of physics courses. In Greater Phoenix, 12 of the 100 large public high schools did not have a physics teacher in 2017-18. Only 20% of local high school students take physics. Nationwide, 40% do. Federal funding for teacher professional development (PD) has ended. Whereas ASU prepared many out-of-field teachers to teach physics until 2010 using Federal funding, now we have 1/5 the budget. (See http://modeling.asu.edu/AZ/AzCrisisInPhysics.htm)

PROPOSED ACTION: Re-instate public funding of teacher PD at ASU in physics and chemistry. It is critical for Arizona's STEM workforce, economic health, & a literate citizenry.

WHY PHYSICS? High school physics is the chief pathway to STEM careers after graduation.
* Physics correlates better than any other course, with STEM career interest (Sadler et al., 2014).
• Students who take high school physics are **twice as likely** to be ready for college science, ACT research finds. Thus ACT recommends a **minimum core curriculum** that includes 3 years of science, including rigorous courses in biology, chemistry, and **physics** (ACT 2006, 2013, 2017).
* College students who took **physics** in high school are **twice as likely** to earn a STEM degree as students who stopped at high school chemistry. (Tyson et al., 2007).
* Modeling Instruction is interactive engagement: experiential and lab-based, with quick feedback via student discourse. It strengthens the STEM pathway (TIMSS, 2000).
* Modeling Instruction produces world-class scientific and mathematical literacy (TIMSS, 2000). Modeling Instruction in physics makes math make sense. It is STEM!

Physics teacher PD outcomes in Arizona support these findings. The Milken Institute found that Arizona improved to 6th place nationwide in 2007 (from 22nd in 2005) in the number of university STEM bachelor degree graduates per 1000 civilian workers. Timewise, that matches with statewide PD in Modeling Instruction, which reached 1/2 of Arizona high school physics teachers by 2001, and hence college graduates by 2007. Modeling Instruction was the only statewide PD in high school STEM -- physics enrollments and learning gains increased greatly.

RECOMMENDATION: Re-instate public funding of PD in Modeling Instruction at ASU, to prepare and improve Arizona high school physics & chemistry teachers. Modeling Instruction is research-validated and intensive (90 contact hours); it focuses on physics & chemistry content and how to teach the content effectively. It is face-to-face and mostly in summer. Benefits: a well-prepared STEM workforce, retention of teachers, and a science- & math-literate public.

Insights of many Arizona physics teachers about their needs for PD and their praise for Modeling Instruction are at http://modeling.asu.edu/MNS/MNS.html (at the bottom of the page.)

WHY THE NEED IS CRITICAL for stable public funding of the ASU Modeling Instruction program of summer PD for high school physics and chemistry teachers:
1. High school physics is the hardest core subject to staff and has the greatest teacher turnover (22% in 2011 in AZ). Only 1/4 of the 300 Arizona physics teachers have a degree in physics. Yet they are committed and enthusiastic to learn deep content and effective teaching methods.
2. High school physics is crucial to Arizona's economic development, and central to addressing societal challenges. Physics and chemistry are key to understanding global climate change.
3. Physics is essential to produce a science- and math-literate citizenry. **Physics is STEM!**
4. Lecture-based instruction is ineffective. Teaching method is the most important factor in student learning. (Research at http://modeling.asu.edu/R&E/Research.html & http://timss.com)
5. Becoming an expert takes 10 years of deliberate practice (research of K.Anders Ericsson).
6. Teachers need content-based PD & graduate credit to teach AP physics and Dual Enrollment.
6. Teachers need partnerships with a university physics department, since higher education is their students' next step. ASU is least expensive, for 2/3 of AZ physics teachers can commute.
7. Teachers need tuition scholarships to make it affordable. Typical salaries are under $40,000.
8. The ASU Modeling Instruction Program needs stable funding, for continuity of staff & PD services. To serve 100 Arizona teachers/year: $50,000 (program) & $200,000 (scholarships).

ACCOMPLISHMENTS OF ASU's MODELING INSTRUCTION PROGRAM, as of 2018:
1. Three-week Modeling Workshops each summer for up to 100 teachers of high school physics, chemistry, & physical science. S*tudent learning gains are double* those under lecture instruction. 1100 teachers have participated since 2001, reaching a million students. Ten distinct Modeling Workshops are the foundation of a Master of Natural Science (MNS) degree in physics, earned by 75 teachers since 2003: http://modeling.asu.edu/MNS/MNS.html .
2. The American Modeling Teachers Association (AMTA) is ASU's scale-up partner since 2005. AMTA oversees 60 multi-week Modeling Workshops each summer. 12,000 teachers have taken a Modeling Workshop, including more than 10% of the nation's physics teachers. AMTA is an affiliate of American Assn. of Physics Teachers (AAPT) & NSTA, & a 100Kin10 partner. Executive Officer: amtaexec@modelinginstruction.org . http://modelinginstruction.org .

REFERENCES
1) Philip M. Sadler et al. (2014). *Science Educator*, Vol.23, No.1, pp. 1-13. Fig. 3 shows that ONE year of high school physics is more strongly correlated with **STEM career interest**, than ANY other science course. http://nsela.org/images/stories/scienceeducator/Summer2014/Sadler_231.pdf
2) ACT (2006): Developing the STEM Education Pipeline, page 2 & 3. "… students who take high school physics are **twice as likely** to be ready for college science."
Download at http://files.eric.ed.gov/fulltext/ED493179.pdf
3) ACT Policy Platform K-12 (2013), page 8. "ACT research has demonstrated the benefits to student academic performance of a **minimum core curriculum** that includes the following: ... Three years of science, including rigorous courses in Biology, Chemistry, and Physics…"
http://www.act.org/content/dam/act/unsecured/documents/Policy-Platforms-k-12-online.pdf,
ACT (2017): https://www.act.org/content/act/en/research/stem-education-in-the-us-2017.html
4) Will Tyson, Reginald Lee, Kathryn M. Borman and Mary Ann Hanson (2007). Science, Technology, Engineering, and Mathematics (STEM) Pathways: High School Science and Math Coursework and Postsecondary Degree Attainment, *Journal of Education for Students Placed at Risk,* Vol. 12, No. 3, pp. 243-270. (Tyson was at the University of South Florida.)

5) *TIMSS Physics Achievement Comparison Study*, by Eugenio Gonzalez (April 2000). Conducted for the National Science Foundation by TIMSS International Study Center, Boston College, Chestnut Hill. http://modeling.asu.edu/Evaluations/TIMSS_NSFphysicsStudy99.pdf

6) FLINN FOUNDATION, http://www.flinn.org/bio-briefs/3165 , Jan. 31, 2011
A quote: ... released this week was the Milken Institute's annual state technology and science index, which ranked Arizona 15th, up from 17th last year. That's good, by itself. But look closer, and there are particular niches to be excited about.

One of Milken's sub-assessments is the Human Capital Investment Composite Index. It contains some sobering statistics -- especially related to education funding -- and some exciting ones**. It sure looks like the work done at the community colleges and universities in recent years to encourage students toward degrees in STEM subjects is paying off -- In some areas, Arizona is among the nation's best:**
* All Recent Degrees in Science and Engineering per 1,000 Civilian Workers (2007): Rank: 4
* Recent Bachelor's Degrees in Science & Engineering per 1,000 Civilian Workers (2007): Rank: 6
* Recent Master's Degrees in Science & Engineering per 1,000 Civilian Workers (2007): Rank: 2

RESEARCH DETAILS:
1) Tyson et al. (University of South Florida): "Students in the Physics I category obtain STEM degrees at 18.7% … Physics course-taking is a primary factor in STEM attainment… only 8.8% of students who took Chemistry I, but not Physics I completed a STEM bachelor's degree."

2) TIMSS Physics Achievement Comparison Study: Modeling Instruction was one of six NSF-funded high school physics "reform" (active learning) programs evaluated by TIMSS (Gonzalez 2000). The report documents that these programs greatly increase the percentage of students pursuing STEM careers. In particular, **48% of 12th grade students in physics reform programs intended to major in STEM in college**, compared to 25% in non-reform programs (Table 15). TIMSS scores have not been made public, but were released to the respective Principal Investigators. Thus, we can report that the highest score was made by a Modeling class, and it is comparable to the highest score in the entire international TIMSS study. Of the six reform programs, Modeling Instruction has grown the most by far -- to 10% of the nations' physics teachers; and it has expanded to chemistry, physical science, biology, & middle school.

3) Milken Institute published data at http://www.milkeninstitute.org/tech. In 2007, Arizona ranked 6th and 2nd nationwide in recent Bachelor's Degrees and Master's Degrees, respectively, in Science and Engineering per 1,000 Civilian Workers. This is a huge increase from two years earlier (22nd and 18th in rank in 2005). These high rankings persisted 'til 2012, then plummeted. Arizona rankings in 2001, 2005 and 2007 (published in Jan. 2004; 2008, and 2011, respectively):

CATEGORY	RANK AMONG ALL STATES (for graduates in 2001, 2005, and 2007).					
(year published:)	(2004)	(2008)	(2010)	(2012)	(2014)	(2016)
Bachelor's degrees:	28	22	**6**	10	1	41
Master's degrees:	16	18	**2**	2	2	12

See http://statetechandscience.org/statetech.taf?page=state&state=AZ&sub=hcic&year=2

Read more at http://modeling.asu.edu in the section called "Arizona Community".