STEM PATHWAYS & LITERACY IN MATH AND SCIENCE: HIGH SCHOOL PHYSICS IS CRUCIAL

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THE NEED: High school physics is the chief pathway to college STEM majors and STEM careers. Active learning physics, such as Modeling Instruction, strengthens that pathway and also produces world-class scientific and mathematical literacy. The U.S. has a shortage of qualified physics teachers and a shortage of physics courses for all. Yet Federal funding that can be used for physics teacher professional development is states' responsibility, as of Dec. 2015 in ESSA.

ACTION: Public funding of high school physics teachers professional development (PD) is critical for the STEM workforce, the nation's economic health, & a literate citizenry.

WHY PHYSICS? A student who takes *active learning (as opposed to lecture)* high school physics is three times more likely to earn a STEM degree than a student whose last high school science course was chemistry. Also, physics greatly enhances science & math literacy of citizens.

EVIDENCES:
1) A student who completes a physics course in high school is *twice as likely* to earn a STEM bachelor's degree as a student whose highest science course is chemistry (Tyson et al., 2007).
2) **Active learning** (hands-on, minds-on) high school physics programs *almost double again* the number of students who intend to major in STEM (TIMSS, 2000).
3) Active learning high school physics classes score *highest in the world*, in science & math literacy (TIMSS, 2000)!
4) One year of physics *most strongly* correlates with STEM career interest (Sadler et al., 2014).

RECOMMENDATIONS: The federal government (through State Departments of Education) should **re-instate** funding for research-validated professional development (PD) for high school physics & chemistry teachers. Statewide or regional programs are needed. PD should be intensive (90 contact hours); it should focus on physics & chemistry content and how to teach the content effectively. It should be face-to-face and in summer. (Long-term, NSF summer institutes for science teachers need to be re-instated, too. This would take an act of Congress.)

Benefits: a prepared STEM workforce, retention of teachers, a science- & math-literate public.

REFERENCES
1) 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.)

2) *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

3) 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

DETAILS ABOUT THE RESEARCH:

1) Tyson et al. (University of South Florida):

The relevant quote is: "**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. Consequently, 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.

Math and science literacy results are in Table A1 (page 36). NSF programs were highest.

3) Philip M. Sadler et al. (2014). A relevant quote: Students who take "one or two years of physics in high school exhibit a significantly higher STEM career interest, as a group… Those who take a course in another science [other than two years of chemistry] or an additional year of biology show no significant increase, on average ….."

WHY THE NEED IS CRITICAL for stable public funding of physics teacher PD:

1. High school physical sciences are crucial to economic development, and central to addressing societal challenges. Physics and chemistry are key to understanding global warming.
2. Physics is essential to produce a science- and math-literate citizenry. Physics is STEM!
3. High school physics is the hardest core subject to staff and has the greatest teacher turnover. Out-of-field teaching predominates in schools of all socioeconomic strata. Teachers are isolated. Yet they are committed and enthusiastic to learn deep content and effective teaching methods.
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 partnerships with local university science departments for PD, since higher education is the next step for their students.
7. Most teachers need graduate credit and tuition scholarships to make it affordable.
8. University PD programs need stable long-term funding, for continuity of staff & PD services.

ACCOMPLISHMENTS OF AMERICAN MODELING TEACHERS ASSOCIATION & MODELING INSTRUCTION, as of 2018:

1. High School Modeling Instruction was recognized with the 2014 **Excellence in Physics Education Award** of the American Physical Society (APS), the largest professional organization of physicists worldwide. *"Modeling Instruction is the leading example of a scalable research-based PD program that works by improving student achievement."* – Paul Cottle, Awards Chair.

2. Modeling Instruction began at Arizona State University (ASU) in 1990. Three-week Modeling Workshops are held each summer for 70 teachers of high school physics, chemistry, & physical science. It is research-validated; *student learning gains are double* those under lecture instruction. 1000 teachers have participated since 2001, reaching a million students. Nine distinct Modeling Workshops are the foundation of a Master of Natural Science (MNS) degree in physics, earned by 70 teachers since 2003: http://modeling.asu.edu/MNS/MNS.html .

3. The American Modeling Teachers Association (AMTA) has expanded Modeling instruction nationwide, since 2005. AMTA oversees 50 multi-week Modeling Workshops each summer, in physics, chemistry, physical science, biology, & middle school. 9000 teachers, including 10% of the nations' physics teachers, have taken a Modeling Workshop, reaching many millions of students. AMTA is an affiliate of the American Association of Physics Teachers (AAPT) and NSTA, and it is a 100Kin10 partner. Bill Thornburgh, Ph.D., is Executive Officer: amtaexec@modelinginstruction.org . http://modelinginstruction.org .

For more information, see http://modeling.asu.edu/modeling/ConvincingDocuments.html.