Governor's Commission on Education Reform in New York State
Testimony at Mohawk Valley Community College
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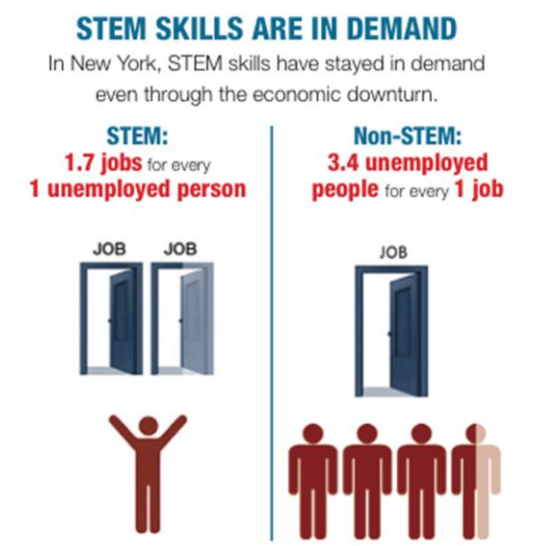
Good afternoon, I am Julie Nucci, Director of the CNS Institute for Physics Teachers (CIPT) created by the Center for Nanoscale Systems, which is an NSF-funded Nanoscale Science and Engineering Center. I am also an Adjunct Professor of Materials Science and Engineering at Cornell University and a member the NYS Leadership Team for development of the Next Generation Science Standards. Five years ago I chose to change my focus from scientific research to science education and science teacher professional development. My research background brings a valuable perspective to my work in education. It is from this position that I will share my vision and recommendations for strengthening K-12 science education through teacher recruitment and development undertaken collaboratively by higher education faculty in the science and education disciplines in partnership with local schools.

The Need: Qualified people needed to fill STEM positions

Projected US Need for Science and Technical Services: Employment in the U.S. economy is shifting away from goods producing towards service-providing industries. Professional, scientific, and technical services are the second fastest growing industry and are expected to contribute over 2,000,000 of the anticipated 18 million new wage and salary jobs between 2010 and 2012. [1]

Projected NYS Need for STEM jobs: Change the Equation's report recently released states that "Business leaders in New York have sounded an alarm. They cannot find the science, technology, engineering and mathematics (STEM) talent they need to stay competitive". [2]



Source: Change the Equation, Vital Signs, NY Report

The problem: Too few students in NYS 1) possess the science skills necessary to fill these STEM-based positions, 2) demonstrate interest in these professions, and 3) earn degrees to qualify them to fill these positions. As stated by Change the Equation, "Students lagging performance in K-12 is a critical reason why." [2]

A Four Component Solution: The following K-12 science education measures will help secure the future STEM-based economy:

1. Attract more qualified people into the profession of science teaching.
2. Reform the K-12 curriculum to make it more reflective of the process of science.
3. Reform teacher training and provide professional development to improve teacher content knowledge, pedagogical content knowledge, and science process skills.
4. Create hands-on, engaging laboratory experiences relevant to everyday life consistent with this reformed model for teaching and learning science. Provide centralized access to this hardware.

A New Vision: Integrating the Four Component Solutions into a Unified Whole

There are successful models/programs that address each of these four components of the solution to the STEM-based job problem in NYS and the country. **While these four measures are inherently interrelated, they are currently approached independently, which is unfortunate, since the whole is much greater than the sum of the parts. NYS could be the first state to connect the dots and emerge as a national leader for science education reform. Such a program would be ambitious, yet effective, since it would be based on exemplary, scalable, and cost effective models/programs in each of these four critical areas.** While this proposed solution will be laid out with a focus on physical science/physics, it clearly extends to other STEM disciplines.

This unified solution yields an all-important pipeline of qualified, competent teachers as well as the students they will inspire to earn STEM degrees. **Mentorship is key part of this integrated plan since an overarching organization can weave the component programs together to bring students interested in the teaching profession into contact with pre-service and in-service teachers.** A veteran teacher and former President of the Science Teachers Association of NYS (STANYS) recently told me "teaching is the only profession that eats its young". That is a powerful statement about inadequacies of the education system and the need for reform to better support teachers. **Mentors and networks are critically needed to foster and maintain student interest in the teaching profession, assist new teachers through the often overwhelming first years in the classroom, and enrich and renew the experience of more veteran teachers.**

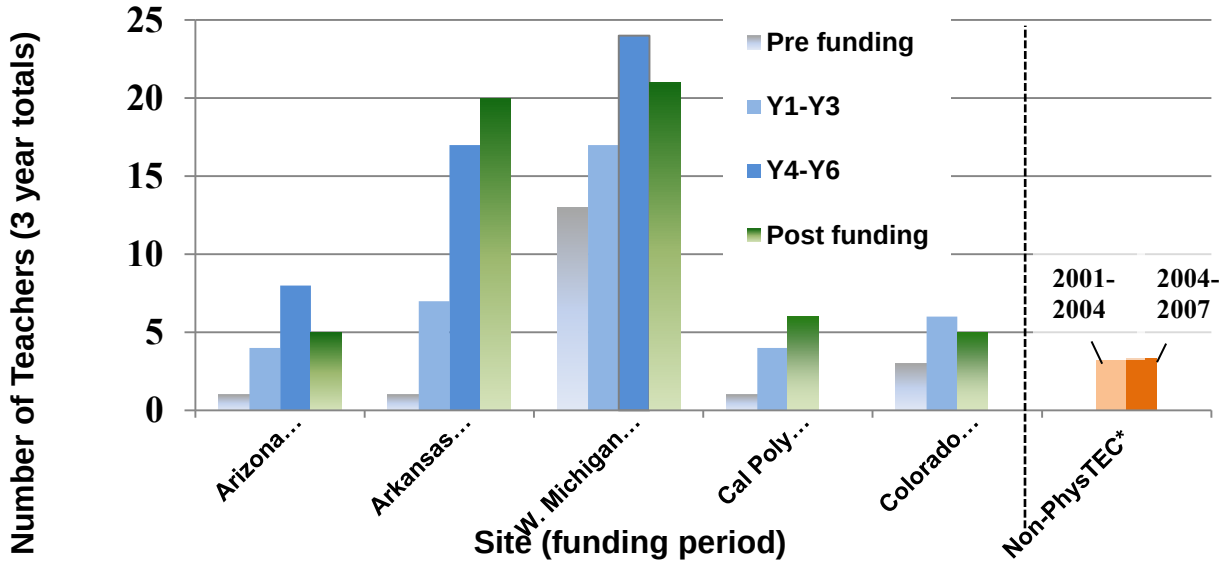
Solution Component 1: Attract more qualified people into the profession of science teaching.

There is a critical shortage of science teachers in the US. The *2010 Educator Supply and Demand in the United States Report* [3] shows that the scarcest teacher is a physics teacher. Chemistry and math teachers are not far behind. Programs like PhysTEC the Physics Teacher Education Coalition [4] have created an effective model for recruiting physics teachers. PhysTEC funds and trains undergraduate teaching assistants as UTAs (undergraduate teaching assistants), requires coursework in education as a part of program participation, and funds a master physics teacher-in-residence to mentor program participants. PhysTEC programs have been successfully implemented at 20 universities with seven new PhysTEC sites starting up in 2012/2013. PhysTEC's performance is impressive; not only does a PhysTEC program greatly increase the number of physics teachers produced by a university, the effect is sustained after the seed funding has ended. Outstanding PhysTEC outcomes are graphically shown on the next page.

Another highly successful teacher recruiting and training program is UTeach [5], originally from UT Austin, which has now been successfully replicated in 33 universities nationwide. There are currently over 5000 students enrolled in UTeach programs. NYS has not yet participated in this program. UTeach and PhysTEC are now partnering further improve their impact.

The soon to be published *Report of the National Taskforce on Teacher Education in Physics* [6] highlights eleven model teacher preparation programs for pre-service teachers and in-service teachers teaching out of certification. These programs are among the top producers of physics teachers in the nation and exhibit exemplary teacher preparation practices, as identified by the task force. Buffalo State and CCNY are on this distinguished list and clearly have expertise to leverage with the rest of the state. The highly lauded physics teacher preparation program from Rutgers University is also in close proximity to NYS schools.

PhysTEC Project Outcomes Show Effectiveness and Sustainability



*Number of physics **certifications** averaged over 319 institutions in 15 states. Note that all PhysTEC teachers are more highly qualified than the minimum standard in most states.

Source: Dr. Monica Plisch, Associate Director of Education and Diversity, American Physical Society

Solution Component 2: Reform the K-12 curriculum to make it more reflective of the process of science.

Through a collaborative, state-led process, the Next Generation Science Standards (NGSS) [7] are currently being developed for K-12 education in science, technology, and engineering. The standards are being created from *A Framework for K-12 Science Education*, released by the National Research Council [8]. The framework "emphasizes that learning about science and engineering involves integration of the knowledge of scientific explanations (that is, content knowledge) and the practices needed to engage in scientific inquiry and engineering design." [8] As one of approximately 30 people on the New York State leadership team I have been currently assessing these standards for the past year. As a research scientist with a keen interest in K-12 education, I am thrilled at the strong focus on developing students' science and engineering practices and the diminished focus on teaching broad and shallow content knowledge. The latest draft of the standards is now being released to lead state partners and the final standards are due to be released in the spring of 2013. NYS will then determine if they choose to adopt these standards and adapt them to reform state science, technology, and engineering curriculum. *If they do, then a critical next step will be the development of instruments to assess the science and engineering process skills and practices detailed in the standards.*

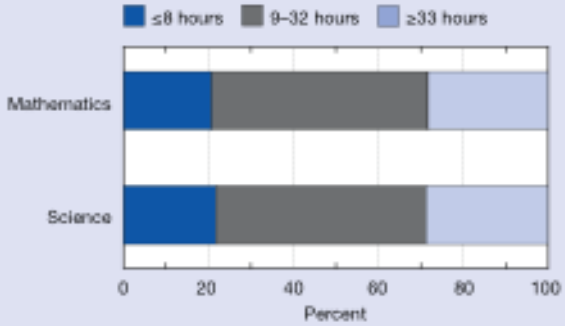
Solution Component 3: Reform teacher training and provide professional development to current teachers that improves their content knowledge, pedagogical content knowledge, and science process skills.

A huge challenge associated with the NGSS is the fact that most middle and high school physical science teachers are ill-equipped to implement the fundamental changes necessary to teach to these standards and thereby improve student outcomes in science. Many teachers have not honed their own scientific abilities since they did not receive science process skills training. As such, they have much to learn themselves before they can even begin to take on the challenge of effectively cultivating those skills in their students, as will be mandated by the NGSS. Without an increased focus on professional development, implementing the promising new standards could be thwarted by the inability of teachers to teach to them. This is also an issue for pre-service teacher training. Science methods classes vary greatly and more research-informed, pre-service teacher preparation programs aligned with the NGSS are needed. Such courses could be created at a few sites and promoted at teacher training programs around the state to bring a more uniform approach to the meeting the challenge of these new standards.

The lack of high quality science teacher PD is already a problem. A 2010 national study by Ashley Keigher and Freddie Cross [9] showed that 9% of science teachers annually left the profession in 2008–09. Attrition rates from 1988 to 2005 ranged between 5.5 and 7.5%. The main reasons science teachers gave for leaving the profession were maximum potential salary, student discipline problems, and few opportunities to receive useful content-focused professional development [10].

According to the National Science Board's Science and Engineering Indicators 2012, "In 2007…77% of science teachers in public middle and high schools said they had received professional development in their subject matter during the previous 12 months." [11] The figure to the right shows that only 29% of those science teachers received 33 hours or more of professional development. In addition to contributing to teacher attrition, insufficient professional development for teachers may also hamper school change, as research has suggested that 80 hours or more may be required to affect teacher knowledge and practice. It is all-important to recognize that before you can change the classroom and the experience for the students, you need to change the teacher.

Figure 1-10
Duration of professional development received by public middle and high school teachers in the content of subject(s) taught, by teaching field: Academic year 2007–08



NOTE: Figure includes mathematics and science teachers who received professional development in their subject area during past 12 months.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2010) of 2007–08 Schools and Staffing Survey, National Center for Education Statistics. See appendix table 1-22.

Science and Engineering Indicators 2012

America's Lab Report: Investigations in High School Science [12] notes that current "professional development opportunities for science teachers are limited in quality, availability, and scope and place little emphasis on laboratory instruction." Another of its conclusions says, "Improving high school science teachers' capacity to lead laboratory experiences effectively is critical to advancing the educational goals of these experiences. This would require major changes in undergraduate science education, including providing a range of effective laboratory experiences for future teachers and developing more comprehensive systems of support."

What is unique about the CIPT is that laboratory instruction is at the heart of the physics teacher professional development we provided over the past decade. To date the CIPT has trained

584 NYS physics teachers, which is nearly 50% of all physics teachers in the state (1138 teachers in 2012) [13]. Since ~ 15% [13] of these teachers are currently teaching without certification in physics, the need for high quality physics teacher professional development is clearly high.

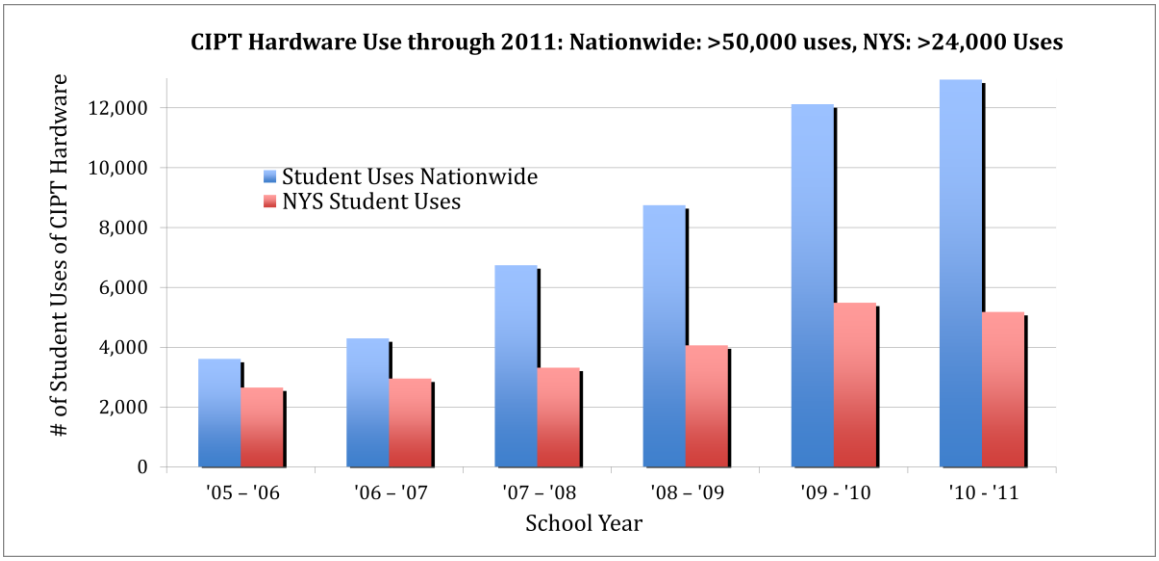
It make good sense to extend teacher professional development to middle school physical science. All students take physical science in middle school. A much smaller percentage goes on to study high school physics. By actively engaging middle school physical science teachers and providing them quality professional development and resources a big leak in the pipeline can begin to be plugged. There are two other important reasons for engaging middle school. Middle school physical science teachers are less well trained than their high school counterparts [14]. Another important reason to include middle school is that it is during these years that students typically turn away from science.

Solution Component 4: Create hands-on, engaging laboratory experiences relevant to everyday life consistent with this reformed model for teaching and learning science. Provide centralized access to this hardware.

One of America's Lab Report's seven conclusions states that for most students, "the quality of current laboratory experiences is poor." This report points out that the limited lab activities available "do not help them to fully understand science process." The report *Reaching the Critical Mass* [15] states, "Funding available per class for equipment and supplies has fallen from about $300 in 1987 to about $250 in 2005. After adjusting for inflation, physics teachers have less than half of the funds available to support the purchase of equipment and supplies than they did twenty years ago." Teachers need access to quality hardware and a high-quality laboratory program to successfully implement the NGSS.

A particularly effective and efficient solution to this problem was developed by the CNS Institute for Physics Teachers (CIPT) at Cornell University. The CIPT created a lending library for which it developed ~ 40 up-to-date, engaging physics lab activities that teachers borrow free of charge. The graph on the next pages shows the increasing popularity of the CIPT lending library. Students used CIPT lending library hardware more than 50,000 times over 6 school years. This library is the backbone of many NYS and US physics teachers lab program. Roughly half of all CIPT lending library use is by NYS students. A lending library of labs is a high return on investment, cost effective way to give teachers access to the hardware they would otherwise be unable to afford. This is especially true for rural and high needs school districts. In addition, CIPT labs put physics concepts in the context of everyday life and as such can genuinely generate student interest in science.

The 2010 NSF panel review of CIPT stated "The Center for Nanoscale Systems (CNS) developed an exceptional educational outreach program for high-school physics teachers, the CNS Institute for Physics Teachers (CIPT), which has had an amazing impact on physics education in New York State high schools. This institute has enhanced high-school physical science through a hands-on, discovery-based educational approach…To date, CNS has trained over 40% of the physics teachers in New York State…This includes workshops, summer institutes, and short one-day workshops. It also includes a lending library for dissemination of developed hands-on lab kits and learning activities for teachers to use in their classrooms. The tremendous outreach of this outstanding program reflects the true passion its director, Dr. Nucci." [16]



Demonstration Site Recommendation: This four component approach to science education would increase the number of critically needed, hard to find science teachers, keep them in the teaching profession through a strong mentor network and support system, develop their content and pedagogical content knowledge, hone their scientific abilities, and provide them with access to high quality, hands-on laboratory resources. These efforts will fiscally pay off by reducing teacher attrition, creating model pre-service teacher curriculum that can cost-effectively be spread across the state, and providing centralized hardware lending libraries, which can both save financial resources and bring laboratory resources to many teachers and students who would otherwise have no access to them. Students will greatly benefit from having much better trained teachers and access to high quality laboratory activities that cultivate their interest in science. A demonstration site could include partnerships among Cornell University, colleges/universities with pre-service science teacher training programs, and NYS public school districts. Given Cornell's teacher successful professional development organizations in biology and chemistry, as well as physics, this first effort could also include those disciplines. This model could clearly be expanded to encompass the entire state as well as other aspects of STEM education.

Respectfully submitted,

Julie Nucci

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