Testimony

U.S. House of Representatives

House Committee on Science and Technology

The National Nanotechnology Initiative Act of 2008

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Dear Chairperson and Members of the Committee,

I am honored to present testimony on the "National Nanotechnology Initiative Amendments Act of 2008." My name is Joe Krajcik and I have been involved in science education for the last 34 years, first as a high school science teacher and now as a professor of science education. As a professor of science education I have focused my work on improving the teaching and learning of science at the middle and high school levels. I am co-PI on an NSF-funded center, the National Center for Teaching and Learning in Nanoscale Science and Engineering, whose primary goal is to enhance the teaching and learning of nanoscience in grades 7 – 16 through learning research.

Let me begin by stating that we live in an exciting time with respect to the advances in science and technology, and that we know more about how people learn than ever before. Rapid advances in nanoscience have provided us with new products that have enhanced the quality of our lives ranging from diagnosing disease to improving the clothes we wear. At the same time, these new advances have also raised potential new dangers, because we have now created products that can penetrate the protective layer of skin that covers our bodies.

Nanoscale science and engineering are at the core of these changes and advancements. These new advances in nanoscience also have the potential to make the teaching of science more exciting and to build student engagement. Unfortunately, this promise has not been realized in most of our 7 – 12th grade science classrooms. These breakthroughs in science have brought new challenges to science teaching and learning. The advances of nanoscale science and the global economy in which we live challenge the educational community to help students develop deeper and more useful understanding of core science ideas that underlie nanoscience. Unfortunately, the current education system is failing to produce a populace scientifically literate enough to understand the scientific advances of nanoscience. It is also failing to prepare a workforce for the new jobs and professions that are emerging from nanoscience. Children in our country continue to lag behind in science and mathematics on international assessments; yet understanding science and mathematics is critical both for informed citizenship and for global competitiveness. To remedy these problems our country needs to invest in 1) professional development to support 6 - 12 science teachers in learning content related to nanoscience and new pedagogical ideas that are supported by learning research; 2) develop new standards and assessment that focus on the core ideas in science, including those central to nanoscience; 3) develop new instructional resources, including new learning technologies, that focus on nanoscience; 4) redesign undergraduate education, including science teacher preparation programs, so that new ideas in science and learning are incorporated into them; and 5) incentives to attract science majors and people who currently hold science majors into teaching careers.

We are also living in an exciting time because of the breakthroughs in understanding how to promote learning in science in general. Learning scientists and science educators are making important discoveries about ways to support learners in various aspects of inquiry, including the use of evidence and the construction of scientific explanations (Bransford, J. D., Brown, A. L., & Cocking, R. R., 1999; Duschl, Schweingruber, Shouse, 2007). The science standards on inquiry, described in the *National Science Education Standards* (1996) and the habits of mind articulated in *Benchmarks for science literacy* (American Association for the Advancement of Society, 1993), provide guidelines for how teachers should teach science. The science standards and benchmarks provide direction on the content ideas that children should know and the scientific practices they should be able to apply in order to be scientifically literate. New breakthroughs in technologies allow scientists and learners to explore the nanoworld and visualize data in new ways. Yet, even with these fascinating breakthroughs, many science classrooms in the United States still resemble classrooms of the early 1950s, with outdated equipment and pedagogical strategies that lack support for most learners. Perhaps most unfortunate, many of these classrooms are in locations where, typically, children do not succeed in science – our nation's large urban cities and rural areas. As our nation becomes even more diverse, with growing populations of Hispanics, African-Americans and other cultures, the challenge of how to provide quality science instruction is amplified. These children will grow up in a world where they will need to apply ideas, communicate ideas, make sound decisions based on evidence, and collaborate with others to solve important problems. Many of the new discoveries are in the area of nanoscience, and our children need to be prepared to enter this world. Yet most of our schools are not providing our students with the opportunities to develop the level of science understanding they will need to grasp emerging ideas of the nanoscale. Our science curriculum still concentrates on covering too much content without focusing enough on developing deep, meaningful understanding that learners will need to grasp these new areas or that they will need to make personal and professional decisions. Research has shown that students lack fundamental understanding of science in general and in particular the ideas that will help them understand nanoscience. What content should be taught? How should new ideas about nanoscience be introduced into 7 – 12 classrooms?

Through the Nanotechnology Research and Development Act (15 U.S.C. 7501(d)), the "National Nanotechnology Initiative Amendments Act of 2008" provides for the establishment of Nanoscience Education Partnerships. This Act will help provide important support to improve the education of all children in this country with respect to nanoscience education. The Act calls for 1) professional development activities to support secondary school teachers to use curricular materials incorporating nanotechnology and to inform teachers about career possibilities in nanotechnology; 2) enrichment activities for students, and 3) the identification of appropriate nanotechnology educational materials and incorporation of nanotechnology into the curriculum of schools participating in a Partnership. Although important first steps, I question whether this Act through the formation of Partnerships will provide sufficient resources that will make a difference for all children throughout the country. The advance in nanoscience requires a commensurate response from the educational community to prepare our youth. As such, the financial resources needed to make this response must be provided by the national government with help from the private sector. In particular, we need to ensure that all children in our country have access to first-rate science education that will help them understand the ideas of nanoscience and other emerging ideas.

The Nanotechnology Research and Development Act calls for providing support for professional development of teachers in nanotechnology. Yet, we need to make sure that this professional development is grounded in the science that teachers teach, focuses on teachers' practices and provides long-term, standards-based support (Garet, Porter, Desimone, Birman, & Yoon, 2001). The short-term professional development that most teacher experience will not provide enough or the type of support needed for most teachers to understand many of the new ideas and the changing ways of thinking about science at the nanoscale. The ideas of nanoscience were not in textbooks when many of our current teaching force attended college. As such, professional development will be needed that focuses on helping teachers understand the new ideas of nanoscience. Moreover, sustained professional development must provide science teachers support to use pedagogical strategies and techniques that will help students understand ideas behind nanoscience. One critical area that professional development needs to focus on is how to help teachers support students to generate, use, and evaluate evidence to create scientific explanations (Duschl, Schweingruber, Shouse, 2007). Another critical area includes support in using new learning technologies to engage students in visualizing the nanoworld; there are some good resources (see the Concord Consortium Web site, Concord.org, and the NCLT web site, NCLT.US) available to teachers already. Use of these new resources and instructional strategies will require sustained professional development.

Nanoscience is also an interdisciplinary field. Advances in science and technology are blurring the lines between the individual scientific disciplines. As science becomes more interdisciplinary, we can no longer rely on the traditional ways of teaching science as a set of well-understood, clearly depicted, stand-alone disciplines. However, how to teach in this fashion is not easy, particularly when teachers themselves did not experience education in this manner and pre-service programs preparing science teachers require science majors in specific science disciplines rather than providing interdisciplinary education. These present realities further the cycle of thinking within disciplines rather than between disciplines. We need to provide professional development and universities need to prepare teachers to teach in this interdisciplinary manner. Moreover, our nation needs to have learning research to support models of how to support teachers teaching in this manner.

Once teachers develop the content knowledge and pedagogical skills to teach nanoscience, they still will still face challenges teaching these new ideas to children unless they have appropriate classroom materials and resources. Some good instructional materials are beginning to appear, but more development and research is necessary to understand how they promote student learning. Although some teachers can develop curriculum materials, teachers modify curriculum to their local needs. If teachers can start with coherent materials that are known to promote learning, there is a great chance that students will learn important ideas (Kesidou, & Roseman, 2002).

Although the national science education standards in this country helped to bring about a focus on standards-based reform and coherent educational materials and assessments, the standards are now outdated and need revamping. New standards that focus on the big ideas of nanoscience (Stevens, Sutherland, Shank, & Krajcik, 2008) and other knowledge essential for the 21st century need to be developed and adapted by schools. Important ideas in nanoscience are not currently incorporated in the national standards. Nanoscience education introduces students to emerging ideas of science and supports understanding of the interconnections between the traditional scientific domains by providing compelling, real-world interdisciplinary examples of science in action. However, standards-based teaching with an interdisciplinary focus will also require extensive and sustained professional development.

The national science education standards also need renovation because there are too many standards. We know from successes in other countries and from research studies that attempting to cover too many ideas leads students to develop superficial knowledge that they cannot use to solve problems, make decisions, and understand phenomena. Hence, our national science education standards need reworking, updating and consolidating.

Renovating the standards is critical because assessments are driven by standards. If we develop standards that include the content understandings and scientific practices that we cherish for our children to develop, then more appropriate assessments will follow. Our current testing practices, however, put stress on classroom teachers, particularly when the testing practices do not align with important learning goals. Assessment, particularly assessment that challenges learners to use ideas and inform their development, is a good thing. We know that learners need to experience science in engaging contexts and *apply* ideas in order to learn; yet with so many standards, teachers feel as if they must cover topics in fear that students will not succeed on high stakes examinations rather than focus on helping students develop understanding. The national standards have allowed us to make headway in improving science instruction, but they still focus on too many content ideas and do not emphasis emerging ideas. Rather than focusing on covering too many ideas, our nation needs a long-term developmental approach to learning science that focuses on the ideas we most care about and takes into consideration learners' prior knowledge and how ideas build upon each other. The Act needs to include provisions that take into account this development and research work to develop new standards that can drive development of appropriate assessments, and new instructional materials and resources.

As our country now exists, each state has different standards, in addition to the national standards. This is not a workable system. We need to make certain that states buy into any new national standards and assessments by providing appropriate incentives. We need to find ways to ensure that states align themselves with these renovated national standards.

Learning nanoscience will not occur without appropriate resources for teaching these new ideas. The resources also need to include new laboratory equipment and technology equipment to teach nanoscience. Although the Nanotechnology Research and Development Act provides funds for course, curriculum and laboratory improvement for undergraduate education, the Act does not call for updating secondary science laboratories. The Act needs to provide support for improving secondary school science laboratory equipment. In order to learn science, students need to have essential firsthand experiences when possible and secondhand experiences to understand the complex ideas underlying nanoscience. Nanoscience cannot be taught and students will not develop understanding of the ideas underlying nanoscience without first- and secondhand experiences. Students need to experience and *do* science if they are going to learn with understanding. However, most U.S. high schools and middle school are ill-equipped for students to have these experiences. Budget cuts have caused schools to stop purchasing consumable science supplies and new materials, preventing students from experiencing phenomena. New laboratory equipment needs to allow learners to take part in inquiry experiences that will allow learners to put ideas together so that they can solve problems, make decisions, use and evaluate evidence, and explain phenomena.

The Nanotechnology Research and Development Act includes funds to revamp undergraduate education. Because of new content and the interdisciplinary nature of nanoscience, a revamping of how science is taught at the undergraduate level needs to occur. Lasting change, however, will only occur in K – 12 education if support is provided to revamp how we prepare new teachers to teach emerging sciences such as nanoscience. We need to provide incentives to attract college students who have a deep understanding of the science into the teaching profession by providing new models of how they can enter certification programs. A major recommendation of the Glenn Report is that we need to find ways to attract science and mathematics undergraduates into the field of teaching and provide viable ways for them to learn how to teach and obtain certification. Preparing science teachers to teach in schools so that they can help all learners develop the level of understanding of science they need requires the revamping of undergraduate science and mathematics courses so that they reflect more what it is like to do science and mathematics as well as new models of how to prepare teachers. The Act needs to provide funds for both of these critical efforts. We will not change k – 12 schools in the long run unless we change undergraduate teacher education programs that better prepare teachers how to teach.

To summarize, schools face pressing challenges with respect to resources, assessment and professional development. Many teachers did not experience science in which ideas built upon each other in a developmental approach, where evidence was used to support claims and where science ideas were used to explain important problems and phenomena; as such, we need models of professional development and the resources that can support teachers as life long learners to learn new pedagogical strategies and new assessment practices. New ideas that emerge in science, such as nanoscience, also present challenges for teachers with respect to integration into curriculum.

For our children to live fruitful and fulfilled lives in an ever-globalizing world, our nation needs a system of science education that can prepare a scientifically literate population and a competent scientific workforce that has a useful understanding of the big ideas of science, including those of nanoscience. We are at a moment in history in which we, as a nation, need to provide learners with the scientific experiences, skills, and habits of mind that will allow them to make important decisions regarding the environment, their health, and our social policies. We have a growing body of knowledge that can help bring about this reform to science education.

We are at a crossroads in science education. We can continue to push and build upon the knowledge, resources and models of exemplary teachers who know how to engage students deeply to reform science education, or we can retreat to old pedagogical strategies that don’t work. We need to build upon the strengths we have as a nation and resist yielding to testing pressures that focus on unimportant ideas and pedagogical strategies that we know do not work. Yet, we will only do so with leadership and support from our national government. We need funding to provide for and study the impacts of sustained professional development and the development of new science standards that take into consideration what we know about how children learn. We also need support to design curriculum resources and assessments that align with the new standards and to study the impact of these high quality resources on student learning. Finally we need support for the revamping of undergraduate education and developing new models of preparing teachers to teach. The National Nanotechnology Initiative Amendments Act of 2008 provides some support for these important initiatives, but to provide the education that all children, regardless of their backgrounds and culture, need to live in a technology-driven world will require more support for improving teaching and learning.

I would like to thank you for the opportunity to present testimony to the House Committee on Science and Technology. I hope that you have found some of my remarks valuable.

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