Testimony of

Wanda E. Ward, Acting Assistant Director
Directorate for Education and Human Resources
National Science Foundation

Before the
U.S. House of Representatives
Committee on Science and Technology
Subcommittee on Research and Science Education

July 30, 2009

Chairman Lipinski, Ranking Member Ehlers, and distinguished members of the Subcommittee on Research and Science Education, thank you for inviting me to participate in this hearing on "Systemic Change for Science, Technology, Engineering and Mathematics (STEM) Education."

Today, I will address your concerns that focus on: (1) student interest in and pursuit of careers in science and engineering; (2) enrichment of teacher education for the improvement of teaching and learning in STEM; (3) instructional resources linked to effective STEM teaching and learning; and (4) role of out-of-school learning in STEM education. I would also like to take this opportunity to share our vision for continuing our commitment to promoting excellence in STEM education for the 21st Century.

The National Science Foundation recognizes that STEM education is at a crossroad, in need of increased attention from a broad array of stakeholders who have the common goal of promoting STEM excellence for all learners. Over many decades, we have seen improvements in science attainment through our systemic approach to education reform. The lessons learned and the research findings on K-12 education in formal and informal settings have been synthesized in two recent publications by the National Academy of Science: ***Taking Science to School***[i] and ***Learning Science in Informal Environments***[ii]. For example, the six conclusions reached in *Taking Science to School (page 2)*[iii] about what students know and how they learn are:

- Children entering school already have substantial knowledge of the natural world, much of which is implicit.
    - *Children's intuitive concepts of the natural world can be both resources and barriers to emerging understanding. These concepts can be enriched and transformed by appropriate classroom experiences.*

- What children are capable of at a particular age is the result of a complex interplay among maturation, experience, and instruction. What is developmentally appropriate is not a simple function of age or grade, but rather is largely contingent on their prior opportunities to learn
- Students' knowledge and experience play a critical role in their science learning, influencing all four strands of science understanding.
    - *know, use, and interpret scientific explanations of the natural world;*
    - *generate and evaluate scientific evidence and explanations;*
    - *understand the nature and development of scientific knowledge; and*
    - *participate productively in scientific practices and discourse.*
- Race and ethnicity, language, culture, gender, and socioeconomic status are among the factors that influence the knowledge and experience children bring to the classroom.
    - *Children's experiences vary with their cultural, linguistic, and economic background. Such differences mean that students arrive in the classroom with varying levels of experience with science and varying degrees of comfort with the norms of scientific practice.*
- Students learn science by actively engaging in the practices of science.
    - *Motivation and attitudes toward science play a critical role in science learning, fostering students' use of effective learning strategies that result in deeper understanding of science. Classroom instruction and the classroom context can be designed in ways that enhance motivation and support productive participation in science.*
- A range of instructional approaches is necessary as part of a full development of science proficiency.
    - *Children's understanding of science appears to be amenable to instruction. However, more research is needed that provides insight into the experiences and conditions that facilitate their understanding of science as a way of knowing.*

Experts also documented the many and valued roles of the teacher in the pre-college years. *Taking Science to School*, (page 180) provides an example of the influence of teachers in helping elementary and middle school students to gain an understanding of how scientific knowledge develops, including more sophisticated understanding of nature and scientific models. A teacher can create such learning environments in the following progression of promoting metaconceptual skills in grade 1-6 [iv].

Grade	Teacher's Role
1	• Finds a variety of ways in which students can externally represent their thinking about the topic • Provides many experiences for students to begin to articulate the reasoning used to support ideas/beliefs

2	• Continues to provide an educational environment in which students can safely express their thoughts, without reproaches from others • Introduces concept of consistency of thinking • Models consistent and inconsistent thinking (students can readily point out when teacher is being inconsistent)
3	• Fosters metacognitive discourse among learners in order to illuminate students' internal representations • Provides lots of examples from their personal work (which is saved from year to year) of student ideas
4-6	• Provides historical examples of very important people changing their views and explanations over time • Begins to use students' external representations of their thinking as a way of evaluating their ideas/beliefs (in terms of intelligibility, plausibility, and fruitfulness) in order to (a) create, when necessary, dissatisfaction in the minds of the learner to facilitate conceptual exchange or (b) look for ways of promoting conceptual capture in the mind of the learner

Learning Science in Informal Environments points out that "a great deal of science learning, often unacknowledged, takes place outside school in informal environments—including everyday activity, designed spaces, and programs—as individuals navigate across a range of social settings; rich with educationally framed real-world phenomena, [informal science settings] are places where people can pursue and develop science interests, engage in science inquiry, and reflect on their experiences through conversations" (page 293).[v] Furthermore, the following principles are offered to promote interest in Science:

- address motivation to learn science, emotional engagement with it, and willingness to persevere over time despite encountering challenging scientific ideas and procedures
    - *An expressed interest in science during early adolescence is a strong predictor of science degree attainment (page 44)*[vi]
- learn about main scientific theories and models framing the understanding of the natural world
- ask and answer questions and evaluate evidence when doing science
- allow for dynamic refinement of scientific understanding of the natural world
- have learners develop [positive] views of themselves with respect to science

Relatedly, findings from research materials on motivation from *Taking Science to School (page 200)* indicate that interest is tied to the quality of learning. Research on the development of interest indicates that children tend to have general or universal interests at first, which become more specific relatively quickly. The development of career interests is thus a process of continuous elimination of interests that do not fit the individual's emerging sense of self, which includes gender, social group affiliation, ability, and then personal identity.[vii]

Additionally, members of cultural groups develop systematic knowledge of the natural world through participation in informal learning experiences and forms of exploration that are shaped by their cultural-historical backgrounds and the demands of particular environments and settings (page 199).[viii] Such knowledge and ways of approaching nature reflect a diversity of perspectives that should be recognized in designing science learning experiences and instructional materials.

Across the areas of informal education, teacher education, instructional materials, and career development since the late 80's, EHR has supported over 50 completed projects involving higher education institutions, Chicago Public Schools and/or informal institutions, addressing all education levels. In addition, 20 of 50 active EHR research and development efforts focus on learning how to enhance K-12 education. Let me draw your attention to several past and current projects.

Chicago EHR Story/Project Examples

- In 1996, the Columbia College of Chicago was funded to teach teachers in grades 7,8,9 in 50 of Chicago's public schools the basics of physical science using up-to-date pedagogical techniques with exemplary materials. Each year, 40 teachers, selected from 10 of the 50 participating schools, took an intensive three-week summer program, followed by 16 after school sessions and two Saturday sessions during the school year. In-class and in-school assistance were provided in subsequent years to aid in the classroom implementation of the materials.

  For teachers
  - There has been a consistent trend in the increase of participants' content knowledge following the summer intensive workshops. Analysis of the differences between the pre-test and the post-test among the eight years of the project shows a 22% gain in knowledge after participation in the summer workshops.
  - There was a significant increase in the number of teachers who encouraged their students to independently design and conduct science projects (from 5% of the teachers before participating in the project to 23% after their participation).
  - The percentage of teachers placing a heavy emphasis on developing problem solving strategies and inquiry skills increased from 26% prior to the workshops to 47% after the workshops.

  Students of the participating teachers also demonstrated gains in knowledge that, in many cases, exceeded the national urban average of 3.5 on the same tests. Overall, the fifth grade students moved from a pre-test score of 28.7 to a post test score of 33, for an average gain of 4.3. Seventh grade students also had an average gain of 4.3, moving from a fall score of 36.2 to a spring score of 40.5. English grade students had a slightly lower average gain of 3.9, moving from a fall score of 39.2 to spring score of 43.1.

- In 2000, the *North Central Regional Educational Laboratory Partnership for Mathematics Improvement* project implemented the reform curricula in all the schools in the Harvey School District. Grades K-5 used *MathTrailblazers* and Grades 6-8 used *Connected Mathematics*, and the curricula were use as tools for developing professional communities of teachers, administrators and parents committed to improving mathematics instruction in the district. All teachers in the district who taught mathematics in Grades K-8 participated fully in the project.

  It was found that after the implementation of the project, the percentage of third, fifth and eighth grade students who did not meet state standards in mathematics decreased markedly from 56%, 71% and 96% in 1999 to 36%, 38% and 78% respectively in 2005. And the number of students exceeding the state standards increased during the same period, from 5% to 17% for third grade students, and from none to 4.5% and 2% for fifth and eighth grade students, respectively.

- In 2001, the study team of *Elementary, Secondary, and Informal Education: Forging Partnerships with Libraries* used the library setting as a strong niche for informal space science learning. Eight topics were investigated through video presentations, hands-on activities, and other supporting resources. The Lunar and Planetary Institute Education and Public Outreach staff trained public and school librarians so that they could include space science in their out-of-school-time children's programs and family/community based programs.

  More than 700 librarians have been trained in the use of Explore! Materials. A follow-up discussion with the principal investigator revealed that 30 Children's Librarians developed programs that used Explore! Materials, and each of them have continued three after-school programs that are serving 20 students per program (with the support from NASA). The results of a summative evaluation will be forthcoming.

- The Nature Museum's *Teens Exploring and Explaining Nature and Science (TEENS)*, funded in 2001, is an example of an out-of-school program for building skills and educational aspirations among underserved urban students. TEENS was developed to provide students the opportunity to fulfill their service learning requirement while developing real-world job skills and learning about careers in science and technology, as well as providing the students with the necessary preparation for postsecondary study in the sciences. TEENS offered more than just science education; it provided participants with encouragement, academic assistance, and confidence-building activities. Over the duration of the project, more than 100 teenagers were reached and indicated that they would strongly encourage other youth to participate in the program for both its educational and career advantages.

  All of the students participating in the program graduated high school and 80% are in college. Plans are under discussion for a follow-up study regarding field of study and degree attainment. The TEENS program has now become one of the core education programs at the museum.

- In 2003, the *Induction and Mentoring in Middle Grade Science and Mathematics Accelerated Teacher Preparation Program* developed a three-year induction model for urban education, integrating university coursework with full-time classroom teaching. The first year included certification coursework and student teaching in their classrooms. Classroom support was twofold: mentors visited each teacher interns once a week and student-teaching supervisors visited each intern every other week.

  The second year coursework focused on remaining requirements for the graduate degree. The highlight was a yearlong action research project focused on improving classroom teaching. The action research projects shared a focus on integrating content-rich curriculum with inquiry-guided instruction, while increasing attention to the importance of literacy-based practices aimed at engaging a diverse student population. Regarding classroom support, mentors visited each teacher every other week to assist with their action research projects and other instruction, as needed.

  The third year curriculum focused on school leadership, and the need to foster a school culture that highlights the importance of science and mathematics education. A leadership project required that each teacher work within his or her school in collaboration with colleagues to improve school curriculum and professional development activities focused on science and mathematics education. Leadership projects included developing community-based science and mathematics units (e.g. Chicago River, bird migration, urban gardening), and leading school-wide professional development workshops. Classroom support included mentor visits to each teacher once a month to assist with leadership projects and other instruction, as needed.

  This project surpassed its targeted recruitment goal by 7% and at the end, recruited a total of 107 teachers. Its success provided the basis for the subsequent NOYCE Stipend Program started in 2004, which further addressed critical shortage of qualified science and mathematics teachers in the Chicago Public Schools, particularly in urban arrears of high need.

- With the support from Robert Noyce Teacher Scholarship program, NOYCE Stipend Program was built on the successful partnership between Chicago Public Schools and the University of Illinois at Chicago (UIC). It recruited 91 qualified career-changers with a strong background in math or science to become teachers in high-need schools.
  - All of the 91 Noyce scholars received Noyce stipends, completed their graduate degree programs and earned teaching credentials in their fields through UIC's teacher certification programs. Ninety scholars completed their teaching commitment, and 73 Noyce scholars have

continued to teach beyond their two-year commitment. Of those, 17 have completed their third year of teaching and 56 have completed their fourth year.

  - Moreover, eight of the Noyce scholars have gone on to become regional or district-wide curriculum and professional development leaders in math and science in CPS. Of the 13 regional science and math instructional specialists in CPS, seven specialists were supported through NOYCE program at UIC. In addition, the CPS district-wide curriculum supervisor of middle grades science is a former NOYCE Scholar.

- In 2009, UIC started NOYCE Phase II project, which continues the work begun in the previous NOYCE grant and expands its potential impact with the addition of an enhanced mentor program for new Noyce recipients. This new mentor program involves previous Noyce awardees and inducts new ones into a Noyce mentoring network. Second, the project extends the Noyce applicant pool by adding three new science certifications and introducing a one-year M.Ed. program option for secondary science education, with is available for secondary science teacher candidates in biology, earth and space science, environmental science, chemistry and physics. Over a three-year period, NOYCE Phase II project will offer 40 recruitment stipends to students in UIC secondary STEM teacher preparation programs.

- In 2004 and 2005, researchers at the University of Chicago and the University of Illinois at Chicago were funded to study how teachers and students construct shared knowledge about science topics in integrated units in primary and middle grades. This research is focusing on how students at various ages perceive concepts and how teachers communicate them. NSF is awaiting the final report of these research projects that may offer new insights for how we develop curricula and move students through the learning process.

- With a longstanding history in urban systemic reform, the University of Illinois at Chicago received an award in 2007 to conduct a multidimensional study of the reform efforts within the Chicago Public Schools for effective planning, implementation, scale-up, adaptation, documentation and evaluation of ongoing systemic reform in mathematics and science education in one of the nation's largest urban public school system.

These examples demonstrate NSF's support of meritorious STEM education activities that build on our current knowledge about learning. The Foundation supports projects that create high quality learning environments (as well as developing innovative models for utilizing cyberlearning activities) that provide the opportunity for students to think in sophisticated ways and for teachers to stimulate students' basic reasoning skills, personal knowledge of the natural world, and curiosity—all in order to increase proficiency and interest in science. Moreover, the value of these early investments in science interest and proficiency can be seen in the readiness of diverse precollege populations to pursue STEM careers in higher education with the support of programs like the Advanced Technological Education; STEM Talent Expansion Program; Scholarships in Science, Technology, Engineering and Mathematics; Louis Stokes Alliances for Minority Participation; Integrative Graduate Education and Research Traineeships; Graduate Teaching Fellows in K-12 Education; and Graduate Research Fellowships—all of which are active NSF higher education STEM programs in the state of Illinois.

It is with much commitment from the Foundation, with the focal point for STEM learning housed in the Directorate of Education and Human Resources, that we find ourselves uniquely positioned to transition from strengthening or building on our knowledge base regarding education reform to being responsive to a call of transforming STEM education and workforce development for the 21st century. EHR will collaborate increasingly NSF-wide to help meet national goals in STEM education. This future cross-directorate partnering on the learning portfolio will ensure that NSF:

- Develops a responsive and potentially transformative research and development continuum for education and workforce development, with rigorous evaluation
- Promotes openness and adaptability for new fields through support for public engagement and lifelong learning
- Leverages support for innovation in STEM education through strategic partnerships and coordination
- Links funding for a foundation for scale-up and sustainability
- Stays on the cutting edge in promoting excellence in STEM education to ensure the health, competitiveness and prosperity of the nation.

Partnering with other external stakeholders, NSF believes that the field is ready to pursue innovative ideas to advance current understanding of STEM education by linking novel approaches and best/effective practices to STEM-specific challenges for the 21st century. Our vision will be aligned with the STEM priorities in American COMPETES Act (ACA) and/or American Recovery and Reinvestment Act (ARRA). With multi-purpose strategic thinking we will sharpen our support on four foci:

- innovation in learning ecosystems of emerging areas like clean/alternative energy and climate change education with an emphasis on blending formal and informal education
- broadening participation to improve workforce development
- enrichment of teacher education for the 21st century, and
- fostering cyberlearning to enhance STEM education

One of the areas in which the U.S. is a recognized leader, but increasingly is challenged globally, is that of innovation. Recognizing that innovation plays a key role in U.S. economic competitiveness, the role of diverse intellectual capital in spurring innovation is a topic of great interest to us at the National Science Foundation. Key issues within this ecosystem, include research and understanding of the culture of innovation and the interplay between innovation and education.

STEM teacher education is an EHR-wide activity, building on NSF's 50-plus years of experience in this domain. Through collaborations we must discover research-based advances that enable the U.S. to produce 21st century, "cyber-prepared" STEM teachers for the 21st century, "cyber-savvy" students.
Hence, four areas of teacher education emphasis must inform future directions:

- Teacher education to support equity and excellence
- The undergraduate teacher preparation experience for professors
- Teacher education and mid-career entry at the graduate level
- The K-12 and policy interfaces with teacher education

Technology has the potential to transform education throughout a lifetime, enabling customized interaction with diverse learning materials on any topic, and supporting continuous education at any age. In the last decade, the design of technologies and our understanding of how people learn have evolved together. NSF has played a key role in these advances, funding interdisciplinary programs specifically to support research and activities in the area of cyberlearning. NSF can continue to lead this revolution by leveraging its investments in the productive intersections between technology and the learning sciences.

Creative thinking about STEM education and learning for the future will offer new challenges and new opportunities for transformative research on educational practices and learning tools. In summary, our STEM education and workforce development vision for the future will attend to a rich tapestry of:

- excellence and diversity in STEM attainment;
- access, availability, and "reach" across STEM lines of inquiry and geographical borders;
- innovation and transformation for stimulating STEM creativity for discovery and learning;
- depth and breadth of domains to promote STEM interdisciplinarity; and
- seamlessness and coherence to ensure a high level of continuity across the learning continuum

STEM education and workforce for the 21 century is key to promoting and sustaining an innovative society.

Mr. Chairman, I appreciate the opportunity to appear before the Subcommittee to speak to you on this important topic. I would be pleased to answer any questions that you may have.

---

[i] National Research Council. (2007). *Taking Science to School: Learning and Teaching Science in Grades K-8.* Committee on Science Learning, Kindergarten Through Eighth Grade. Richard A. Duschl, Heidi A. Schweingruber, and Andrew W. Shouse, Editors. Board on Science Education, Center for Education. Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

[ii] National Research Council. (2009). *Learning Science in Informal Environments: People, Places, and Pursuits.* Committee on Learning Science in Informal Environments. Philip Bell, Bruce Lewenstein, Andrew W. Shouse, and Michael A. Feder, Editors. Board on Science Education, Center for Education. Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

[iii] National Research Council. (2007). *Taking Science to School: Learning and Teaching Science in Grades K-8. page 2*

Committee on Science Learning, Kindergarten Through Eighth Grade. Richard A. Duschl, Heidi A. Schweingruber, and Andrew W. Shouse, Editors. Board on Science Education, Center for Education. Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

[iv] National Research Council. (2007). *Taking Science to School: Learning and Teaching Science in Grades K-8. page 180*

Smith, C.L., Maclin, D., Houghton, C., and Hennessey, M.G. (2000). Sixth-grade students' epistemologies of science: The impact of school science experiences on epistemological development. *Cognition and Instruction, 18(*3), 285-316.

[v] National Research Council. (2009). *Learning Science in Informal Environments: People, Places, and Pursuits.page 293*

[vi] National Research Council. (2009). *Learning Science in Informal Environments: People, Places, and Pursuits.* page 44

"Tai, R.H., Liu, C.Q., Maltese, A.V., and Fan, X. (2006). Planning early for careers in science. *Science*, 312, 1143-1144."

[vii] National Research Council. (2007). *Taking Science to School: Learning and Teaching Science in Grades K-8. page 200*

Hidi, S. (2001). Interest, reading, and learning: Theoretical and practical considerations. *Educational Psychology Review*, *13*(3), 191-209.

[viii] National Research Council. (2007). *Taking Science to School: Learning and Teaching Science in Grades K-8. page 199*

Ryan, R.M., Connell, J.P., and Plant, R.W. (1990). Emotions in non-directed text learning. *Learning and Individual Differences*, *2*, 1-17.