TESTIMONY

U.S. House of Representatives
Committee on Science and Technology

STEM Education Before High School: Shaping our Future Science, Technology, Engineering and Math Leaders of Tomorrow by Inspiring our Children Today
May 12, 2008
Martha and Josh Morriss Mathematics and Engineering Elementary School
4826 University Park
Texarkana, Texas
1:00-3:00 p.m.

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Chairman Gordon, Ranking Member Hall, and Representative Ross, thank you for inviting me to participate in this hearing on science, technology, engineering and mathematics (STEM) education. The National Science Foundation (NSF) is committed to promoting excellence in STEM education. We are fortunate to have that same level of commitment to excellence from you, as is evident from your legislative actions and your continued interest in inspiring our youth to pursue STEM careers.

The hearing today reflects three overarching concerns: (1) the conditions prompting student interest in and pursuit of careers in science and engineering; (2) the circumstances enhancing excellence in teaching and learning in STEM; and (3) the tools, resources, materials and technologies linked to effective STEM teaching and learning. Over the years, NSF has funded projects addressing all three areas. It has also aggregated information on STEM education, drawn from activities funded by other agencies and foundations as well as by NSF. That information provides a useful backdrop for this hearing on student interest, teacher enhancement, and high-quality resources. This testimony generally does not address the criteria laid out in the ACC.

What we think we know about students:

- Course-taking, not mere interest, contributes to STEM learning. The completion of challenging courses has links to performance, particularly on tests of achievement. The evidence is especially strong in the case of pre-college mathematics.
- Enrollment in advanced courses during the secondary school years influences the selection and completion of STEM majors during college.
- Nationally, the trend is toward greater participation of secondary school students in advanced mathematics and science courses.

What we think we know about teachers:

- Students learn more from mathematics and science teachers who have strong content knowledge and pedagogical skills than they do from teachers who lack these attributes. The skills are more often found among experienced than novice teachers.
- Most mathematics and science teachers in public middle and high schools participate in professional development activities.
- Teacher effectiveness rises with a less chaotic environment, greater support from administrators and colleagues, and more adequate teaching and learning resources.

Students

NSF's STEM education research and development portfolio underpins these overall general findings and offers insights into the processes under-girding them. The Longitudinal Study of American Youth (LSAY) is quite relevant to the issue of student interest, performance, and achievement. Launched in 1989, the LSAY has tracked pre-college students over time to determine their interest in mathematics and science and the subsequent choices they make. Table I is a summary of attitude changes among high school students. It shows that in general students are no more likely to like or dislike science and mathematics than they are other subjects, as evidenced by similar mean scores.

Table 1. Student Liking of Science, Mathematics, Social Studies and English Courses for selected grades.

Grade	Mean scores on liking the subject matter of each course			
	Science	Mathematics	Social Studies	English
8	2.7 (2217)	2.9 (2273)	2.7 (2224)	2.7 (2253)
10	2.7 (2072)	2.5 (2219)	2.7 (1296)	2.8 (1931)
12	2.8 (884)	2.5 (1063)	2.8 (1311)	2.8 (1494)
The standard error of the mean for each cell was .03				

Source: Jon D. Miller. 2007. "Student Interest in Science and Mathematics: Measures, Patterns, and Consequences." (The numbers in parentheses indicate sample size)

The LSAY results suggest a positive relationship between an individual's attitude toward science during high school and choice of a STEM major in college (see Table 2). The level of interest in science was assessed among students in grade 10, and their college major determined subsequently. Those expressing the highest level of interest (score: 4) were more likely to have chosen a STEM major than were students uninterested (score: 0) in science. It is worth noting that most students chose non-STEM majors, regardless of the evaluations of science they had made earlier. Attitudes alone do not shape career trajectories.

Table 2: Student Liking for Science Courses and Enrollment in a STEM Major.

Level of Science Interest	Four years after high school …		N
	Non-STEM major	STEM major	
Grade 10			
0	87%	13%	70
1	94	6	87
2	86	14	206
3	83	17	351
4	72	28	250
	Gamma = .32		

Source: Jon D. Miller. 2007. "Student Interest in Science and Mathematics: Measures, Patterns, and Consequences."

Based on our experience we believe that persistence in a STEM major is affected by:

- Bridge programs in the summer before the first year of college to enable at-risk students to gain the academic skills necessary to compete successfully at the college level;
- Changes in pedagogy and content of first-year STEM gateway courses that allow all students to master content and improve their ability to think critically and independently;
- Redesign of early mathematics sequences so that students deficient in mathematics can reach mastery levels;
- Opportunities for first- and second-year undergraduates to participate in authentic research;
- Initiatives that provide students with advice about the careers available to STEM majors, the kinds of interests and skills required in these careers, and the preparation necessary for the careers; and
- Mentoring programs involving both peer mentoring and faculty mentoring that encourage students to continue with their majors and that provide individualized guidance for navigating through these demanding STEM majors.

Teachers

NSF has invested heavily in research and development programs to improve the knowledge, skills, and performance of teachers at all levels. Initial NSF results show that others have picked up this research and have investigated at large scale such as ExxonMobil mentioned below. The investments are particularly noteworthy in reference to professional development.

Efforts to gauge the impacts of professional development have been constrained by a lack of instruments to measure teacher knowledge. Attempts to understand the relationship between teacher knowledge and student learning have been similarly limited. To address this need, the NSF's Math and Science Partnership program has funded many projects such as the examples below that have produced measures of knowledge that are being used widely.

The Assessing Teacher Learning About Science Teaching (ATLAST) project is such an example. The project developed a program on force and motion for high school teachers and a test (ATLAST) to measure teacher learning of the fundamental concepts. Subsequently, the teachers tested their ninth grade physics students before the students were taught the concepts and reassessed them following a unit of instruction. The outcome: the higher the teacher's score, the greater the change in the scores of their students.   ATLAST warrants attention not only because it fosters and measures learning by teachers, but also because it relates such learning to the performance of students.

On mathematics learning, the study, Learning Mathematics for Teaching (LMT), merits notice. The study developed an instrument called Mathematical Knowledge for Teaching (MKT) to measure the mathematical knowledge and skills of teachers. It then tested the performance of the students. The outcome revealed a positive relationship between the performance of the teacher on the MKT test and the performance of his or her students. This outcome was obtained even when the study took into account the performance of the students on prior tests and differences in the backgrounds of the teachers and their schools.   The LMT study later videotaped lessons from mathematics classrooms and scored the quality of the instruction, as evident in the absence of mathematical errors, the use of mathematical justifications and explanations, and the teachers' skill in representing the work of students.   The instruction judged to be of higher quality occurred among teachers with higher scores on mathematical knowledge for teaching.

The LMT study reinforces a result other research has uncovered: teaching effectiveness depends on an ability to translate knowledge into quality experiences for students. One such investigation comes from the Alliance for Improvement of Mathematics Skills, PreK-16, a partnership that includes Del Mar Community College, Texas A&M University-Kingsville, and nine independent school districts in South Texas. Over a two-year period, approximately 250 teachers participated in more than 30 hours of professional development, typically through mathematics-focused institutes. An observational study of teachers who participated in the institutes showed a sharp decrease in their use of "teacher-directed" instruction (lecture) in favor of a more "student-centered" learning environment. Such an environment related positively to measures of student engagement.

A project funded at the University of Miami offers possibilities for closing the gaps still found in achievement between population groups. The program provided teachers with professional development workshops, and new mathematics and science instructional materials designed for English language learners. Measures taken before and after the instruction showed changes in science achievement that reached statistical significance. Likewise, performance in mathematics, measured on a statewide mathematics test, indicated greater improvement for the students given the specialized instruction than for a comparison group. It should be noted that both groups consisted overwhelmingly of students from economically disadvantaged backgrounds.

Additional NSF programs designed to strengthen STEM teaching include Discovery Research K-12, with its emphasis on improving knowledge about teaching and learning; Geoscience Teacher Training (GEO-Teach), created to identify strategies of effective pre- and in-service preparation for Earth science teachers; and the Physics Teacher Education Coalition, a project focused on increasing the quality and numbers of teachers in physics and other physical sciences. Past investments by NSF in teacher preparation have led to new models, such as the UTeach program at the University of Texas, now being replicated with ExxonMobil support. This model gives center-stage to master K-12 teachers who take the lead in designing and teaching pre-service courses.

Tools

NSF funded research has produced materials and resources to accelerate student learning. Those materials in turn have been assessed in educational settings at various scales as noted below, to determine their viability as classroom tools. Among the tools NSF has supported are:

- *The Cognitive Tutor,* a software package that provides personalized instruction for the individual student. The development work on The Cognitive Tutor began in 1980 and continued into 2003 funded through more than 20 awards from programs across the Foundation. Tutors using the software are now reaching over 500,000 students in 2600 schools. Evaluations, using very rigorous designs to assess impact, have shown that the tutors do in fact improve learning. Indeed, the consistently replicated results have made *The Cognitive Tutor* one of only a few approaches the Department of Education includes in its *What Works Clearinghouse*. Importantly, the positive effects appear in rural as well as urban settings, in schools with at-risk students and more advantaged ones, and among honors students in addition to English language learners.

- *SimCalc Math World,* consists of text materials and software for computers, and calculators for teaching core algebra concepts. SimCalc has its roots in research funded by the Directorate for Computer and Information Sciences in 1980. The software development began with an award granted in 1993. In the summer of 2005, SRI International began a rigorously designed randomized controlled experiment with 151 7th and 8th grade teachers and thousands of students from all over Texas. The project compared a SimCalc replacement to existing 7th- and 8th-grade pre-algebra curricula. In both grades, the use of the SimCalc curriculum and technology resulted in greater student learning gains, especially for advanced aspects of proportionality, rates, and linear functions that are required for further STEM learning. The findings were robust across variations in regional demographics, school poverty levels, student ethnicity and gender, and with teachers having differing attitudes, beliefs, and backgrounds.

Students of teachers who implemented SimCalc's integrated curriculum and software materials learned more advanced mathematics than did students given other instructional materials. The project's findings demonstrate how society can harness the dynamic capabilities of technology to expand access to advanced mathematics, and accelerate students' progress towards STEM careers.

- *Engineering is Elementary*, a curriculum for elementary school students, was developed by the informal science community. The curriculum integrates engineering and technology concepts and skills with elementary science topics. In addition, it has connections with reading skills, mathematics, and social studies. Studies show that children using the *Engineering is Elementary* materials gain in their understanding of engineering and science topics, compared to children not using the materials. In addition, children in the experimental group come to know what engineers do and what technology entails.

  The curriculum and the research associated with it delve into an area explored only infrequently: how children at young ages think about engineering concepts. The body of work not only illuminates this area, but also outlines ways in which teachers can draw upon the knowledge and assumptions children possess. Initial research suggests that this approach has been successful in helping young children envision themselves as engineers.

I have presented thus far projects and outcomes centered on STEM learning in formal settings. But NSF recognizes and supports work in the informal sector as well. For example, a museum-based enrichment program tracked past participants who had completed at least one year of the program between 1992 and 1997, and found that for the people pursuing careers in health and other STEM fields, mentors and exposure to job skills were key elements to their job choice. With this finding in mind, 29 Innovative Technology Experiences for Students and Teachers (ITEST) projects currently match students with mentors, and all ITEST projects offer opportunities to develop job skills that students can take with them beyond the ITEST experience. Informal Science and Education (ISE) youth projects also use this strategy to build student exposure to STEM careers.

NSF takes pride in the work that it has supported and the gains in student and teacher learning that are a result of those investments. However, there is substantially more work to be undertaken. To ensure continued progress, NSF stands ready to act in partnership with other federal agencies, such as the Department of Education, business and industry, professional associations and of course, policymakers. The quality teaching and learning that the nation needs—that our youth need—depend on us all.