Insights

into

Research and Evaluation on Education in Science and Engineering

at the

National Science Foundation

Citizens well-educated in science, technology, engineering, and mathematics (STEM) are an essential foundation upon which sound economies are built. Education research at the National Science Foundation (NSF) is a catalyst for change – advancing theory, method, measurement, and innovation to help build the nation's next generation of scientists, mathematicians, and engineers. NSF's education research generates high quality findings that assist policymakers and practitioners in ensuring all students receive the STEM skills to participate in the science and technology-based economy of the 21st century.

Research and Evaluation on Education in Science and Engineering (REESE) is a program funded by NSF's Division of Research on Learning in Formal and Informal Settings (DRL). REESE supports an interdisciplinary portfolio focused on core scientific questions including: Where is the cutting edge in STEM education research? How can we best support it? What are the policy and practical implications of this work? Answers to these questions from REESE and other NSF programs are informing STEM learning and teaching in and out of the classroom, from early educational experiences through the workforce.

Over 300 projects are currently funded under the REESE program. The 11 projects described here provide insights into how educational research is advancing teaching and learning in STEM. Some of these projects have been in development for several years; others are newly funded. Together they demonstrate a wide range of methods and approaches for studying how to change and improve the nation's capacity and expertise in mathematics and science.

Mathematics Results

Researchers in California are studying the impact of technology on complex reasoning in mathematics. The SimCalc project uses animations of mathematical graphs in an integrated program of curriculum and teacher professional development to help middle school students learn concepts such as rate, proportionality, and linear function. Two randomized experiments using 7th- and 8th-grade students in more than 100 Texas schools showed that the integrated SimCalc approach increases student learning, in particular the development of advanced reasoning skills. These results hold regardless of student gender, race, or income and for teachers with different credentials, experience, and technical expertise. [#1]

Technology helps students develop complex reasoning skills

A REESE project in Tennessee is using new computer tools to help students think like statisticians. Four iterative studies involved 5th- and 6th-grade students who collected real-world data and developed statistical models to account for the patterns in their data. Quasi-experimental comparisons showed that these students were more adept than their peers at reasoning about probability, sample, and different visual representations of the same data. Assessments of this ability to think statistically are being adapted to inform classroom teaching. [#2]

Computers help middle school students think like statisticians

Testing the stereotype that boys are better at mathematics than girls, investigators in Wisconsin have been analyzing mathematics test results for over 7 million students from 2nd through 11th grade. Results across 10 states showed no significant difference in average mathematics performance by gender. Further analyses of data from the National Assessment of Educational Progress (NAEP) on 12th graders also showed no gender differences, even for difficult items requiring complex reasoning skills. [#3]

A gender stereotype dispelled

Researchers in Michigan used two tests to measure the impact of a program for teaching biological diversity that had already been shown to build scientific reasoning skills. Approximately 1,800 Detroit Public School 6th graders who used this program were assessed using both a standardized test and a complex reasoning test. Multilevel statistical analysis showed that the program was more effective than the standard curricula, regardless of which test was used to measure achievement. Long-term exposure to the program resulted in greater improvements in complex reasoning skills. [#4]

A collaborative project among researchers in Arizona, Nevada, and Michigan is uncovering factors that make teaching and learning about biological evolution difficult. Evolution Challenges has brought together more than 60 experts in biology, paleontology, science education, psychology, and other fields to identify developmental, cognitive, and cultural barriers to understanding evolution. The project is helping to overcome barriers to learning via teacher workshops, public symposia, and an edited volume. [#5]

Barriers to understanding evolution are present from an early age

How does spatial cognition affect STEM learning? Cognitive psychologists and geoscientists in Pennsylvania and New York are collaborating on a stream of NSF-funded research that explores how spatial concepts and skills affect students' perceptions and representations of their environments, factors crucial to STEM learning. For example, a recent study found that students who had not acquired certain basic spatial concepts before receiving elementary instruction in geology had considerable difficulty learning a new field geology skill. These studies also documented the strategies used by both successful and unsuccessful students. Findings suggest possible interventions for improving instruction and learning in a range of STEM fields. [#6]

Investigators in New Mexico are experimenting with virtual environments to see whether beginning teachers learn more from classroom cases presented in video or in text format. Using a random sample of students enrolled in a teacher education program, the researchers found that those who received "virtual" training were better able to remember and model best practices than students in the control group, who received training in text format. The research team also found that prior training in learner diversity helped beginning teachers solve dilemmas that they are likely to face in the inclusive classroom. [#7]

Researchers in Pennsylvania have analyzed national survey data to evaluate the nature of the mathematics and science teacher shortage. The data document that the supply of STEM teachers is sufficient to cover losses of teachers due to retirement. The analysis finds that pre-retirement turnover is the driving factor behind STEM teacher staffing problems. Results show that such turnover is best prevented by giving teachers more influence, improving school leadership, and providing adequate resources. [#8]

Shortage of STEM teachers is widely misunderstood

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The research summarized here was presented in an invitational poster reception at NSF in February 2009. To view the posters and for updates on REESE project findings, visit the Center for Advancing Research and Communication in STEM at NORC at the University of Chicago and Michigan State University at: http://arc.uchicago.edu

Novices in biology, astronomy, geology, and medicine need years of training to acquire perceptual skills critical for success in their fields. For example, radiologists must learn to visually distinguish tumors from other tissue in mammograms, and biologists need training to distinguish cell structures. Investigators in New York are exploring how insights from machine learning and multiple sensory experiences can be used to develop new STEM training methods and environments. A major goal of the project is to determine which training procedures elicit the largest learning effects and best prepare scientists for success. [#9]

New REESE work builds on a series of NSF-funded projects looking at the factors affecting STEM career pathways and the impact of curricular reforms. Earlier research with three cohorts of Florida public school graduates found that even high-achieving women and minorities were significantly less likely to take advanced STEM courses than white men. Another study used matched samples and advanced statistical techniques to find that Teaching Smart®, a professional development program, led to significant improvements in science instruction. Currently this research team is examining whether more advanced science and mathematics course offerings in high school has led to more STEM course-taking in college. [#10]

Advanced high school courses linked to STEM course-taking in college

Researchers in New York City and Nashville showed in previous work funded by NSF that the basic mathematics skills of elementary school children are closely related to individual differences in brain structure and activity. A new REESE project is expanding this work to see how early formal education in STEM affects these relationships. The research team will use a "natural experiment" that compares the progress of older kindergarteners to younger 1st graders in order to disentangle the impact of maturation versus curriculum. [#11]

Acknowledgments

1. Roschelle, Jeremy. *Working with Teachers and Leveraging Technology to Scale Opportunities to Learn More Complex and Conceptually Difficult Middle School Mathematics.* [NSF Award #0437861]
2. Lehrer, Richard. *Constructing Data, Modeling Worlds: Collaborative Investigation of Statistical Reasoning.* [NSF Award #0337675]
3. Hyde, Janet. *New Trends in Gender and Mathematics Performance: Meta-Analytic Synthesis.* [NSF Award #0635444]
4. Songer, Nancy. *DeepThink: Thinking Deeply about Biodiversity and Ecology.* [NSF Award #0628151]
5. Brem, Sarah. *Facing the Challenges of Learning and Teaching About Evolution: A Synthesis.* [NSF Award #0635629]
6. Liben, Lynn. *Collaborative Research: Constructing Mental Images of Geologic Structures from Field Observations.* [NSF Award #0411686]
7. Moreno, Roxana. *Bridging the Gap Between Theory and Practice in Teacher Education: Guided Interactive Virtual Environments (GIVEs) for Case-Based Learning.* [NSF Award #0238385]
8. Ingersoll, Richard. *The Effects of Accountability and Teacher Preparation on Mathematics and Science Teacher Retention.* [NSF Award #0814295]
9. Jacobs, Robert. *A Machine Learning Approach to Human Visual Learning.* [NSF Award #0817250]
10. Borman, Kathryn. *On-Track for STEM Careers: Access to Rigorous and Relevant STEM Courses in Florida's High Schools.* [NSF Award #0815250]
11. McCandliss, Bruce. *Brain Correlates of Early Math and Number Skills: Tracing Changes Related to Age and Instruction in a Natural Experiment.* [NSF Award #0816063]

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