

# Creating Futures

University of Colorado *Boulder*



*Transforming  
Math and Science  
Learning for  
Every Student:  
STEM Education*

# Why don't *more* American students like science and math?

Could it be that too often science is taught as rote memorization instead of as an exciting way to make sense of the world? And that math appears to be a set of procedures without any context for how these tools might be put to use?



*Shelly Belleau teaches science at the Mapleton Expeditionary School of the Arts; she discovered her love of teaching as a Learning Assistant at CU-Boulder.*

What would it take to transform how math and science are taught so that the excitement of deep understanding, of really getting how things work, could be accessible to every student—to future elite mathematicians and research scientists, to future teachers of math and science, and to every future citizen?

**CU-Boulder is a national leader in education reform in Science, Technology, Engineering, and Math (STEM)** because of its commitments, for more than a decade, to:

- use cognitive science research to transform undergraduate courses
- recruit the best math and science students into teaching and train them in unique and exciting ways
- conduct cutting-edge, discipline-based research on effective teaching practices and student learning



*High schoolers engage in a discussion about waves.*



## National Context, National Need

Every national report conveys the same lament. The United States is losing its preeminent position as the world's leader in technological and scientific innovation.

- U.S. students perform poorly on international assessments, especially at higher grade levels. For example, U.S. 15-year-olds ranked 36<sup>th</sup> in science achievement, out of 57 countries.
- Long-term trends show a steady decline in the completion of natural science and engineering baccalaureate degrees compared to other countries. In 2005, China graduated over 440,000 engineers while America graduated only 66,000 engineers.
- In Japan and Korea, only about 10 percent of 8<sup>th</sup> graders are taught science and math by teachers without a college degree in these fields, but in the U.S., 34 percent of 8<sup>th</sup> graders are taught science and math by teachers without specialized training.

*CU-Boulder's leadership in developing innovative STEM education programs was recognized in January 2010 when CU-Boulder Chancellor Philip DiStefano (left) visited President Barack Obama (right) at the White House—as one of four public research university leaders, representing 120 universities—and pledged to double by 2015 the number of new science and mathematics teachers prepared by the country's top research institutions.*

To regain international prominence in science and technology, national leaders have called for dramatic reforms of the STEM education system from prekindergarten through graduate school, and for high-priority efforts to recruit the best minds into challenging teaching careers.

# CU-Boulder: A Leader in Reforming STEM Education



*Former Learning Assistant and now a K-12 teacher, Cassandra Ly, helps middle school students conduct an experiment.*

CU-Boulder has earned an internationally recognized leadership position in STEM education because of its unique cross-campus collaborations that have brought together the very best math, science, and engineering faculty members with experts in research on teaching and learning. The College of Arts and Sciences, the School of Education, and the College of Engineering and Applied Science all collaborate on numerous STEM education programs and initiatives—some that have been operating for more than a decade.

In 2009, in recognition of its extensive cross-campus STEM collaborations, CU-Boulder was awarded one of only six NSF Innovation through Institutional Integration grants to build a Center for STEM Education, designed to further establish CU-Boulder as a national hub of STEM education research and reform.

*Graduate students present their research projects at a recent poster session.*



## IMPROVING UNDERGRADUATE AND GRADUATE STEM EDUCATION

At CU-Boulder, STEM initiatives touch students who are in kindergarten through those seeking postgraduate degrees.

### LEARNING ASSISTANT PROGRAM

Astrophysics professor Dick McCray and education professor Valerie Otero created the Learning Assistant program to help transform large lecture courses and to give outstanding undergraduate students, hired as LAs, an experience with teaching. In LA-transformed courses, the professor still lectures twice per week, but instead of going to “recitation” sections where graduate students work problems on the board, LAs and graduate students now lead “learning teams” where students are engaged in talking through their own reasoning about how to solve problems. LAs take an education course on learning research and meet regularly with the course professor.

- Students in courses with Learning Assistants dramatically outperform students in traditional courses on nationally standardized examinations.
- Begun in 2003 with only three departments, the Learning Assistant program now includes eight CU-Boulder departments and reaches 9,000 students per year.
- The American Physical Society is sponsoring the replication of the Colorado Learning Assistant model at 13 universities nationwide.



*College of Engineering and Applied Science Associate Dean Brian Agrow (left) presents at the 2010 STEM Symposium with Computer Science Professor Clayton Lewis (right).*

### SCIENCE EDUCATION INITIATIVE

Led by Nobel Laureate and CU-Boulder physics professor Carl Wieman, the goal of the Science Education Initiative (SEI) is to achieve highly effective, evidence-based science education for all postsecondary students by applying the latest advances in cognitive science and pedagogical and organizational excellence. To be a part of the SEI's "evidence-based" approach, department faculty agree to:

- develop explicit learning goals
- implement new teaching practices that require students to be more mentally engaged
- design new assessments to measure more challenging levels of science understanding



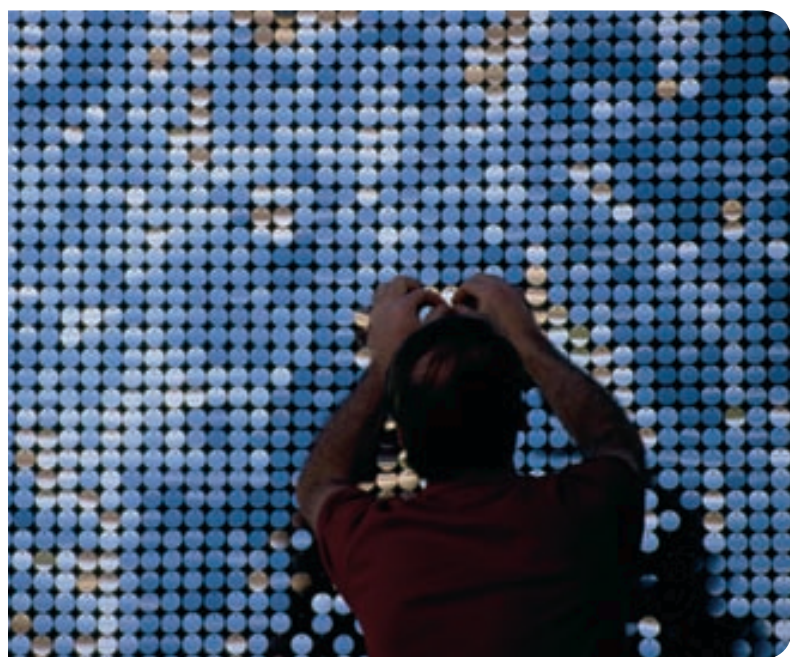
*CU Teach students learn to use interactive science kits.*

### INTEGRATED TEACHING AND LEARNING LABORATORY

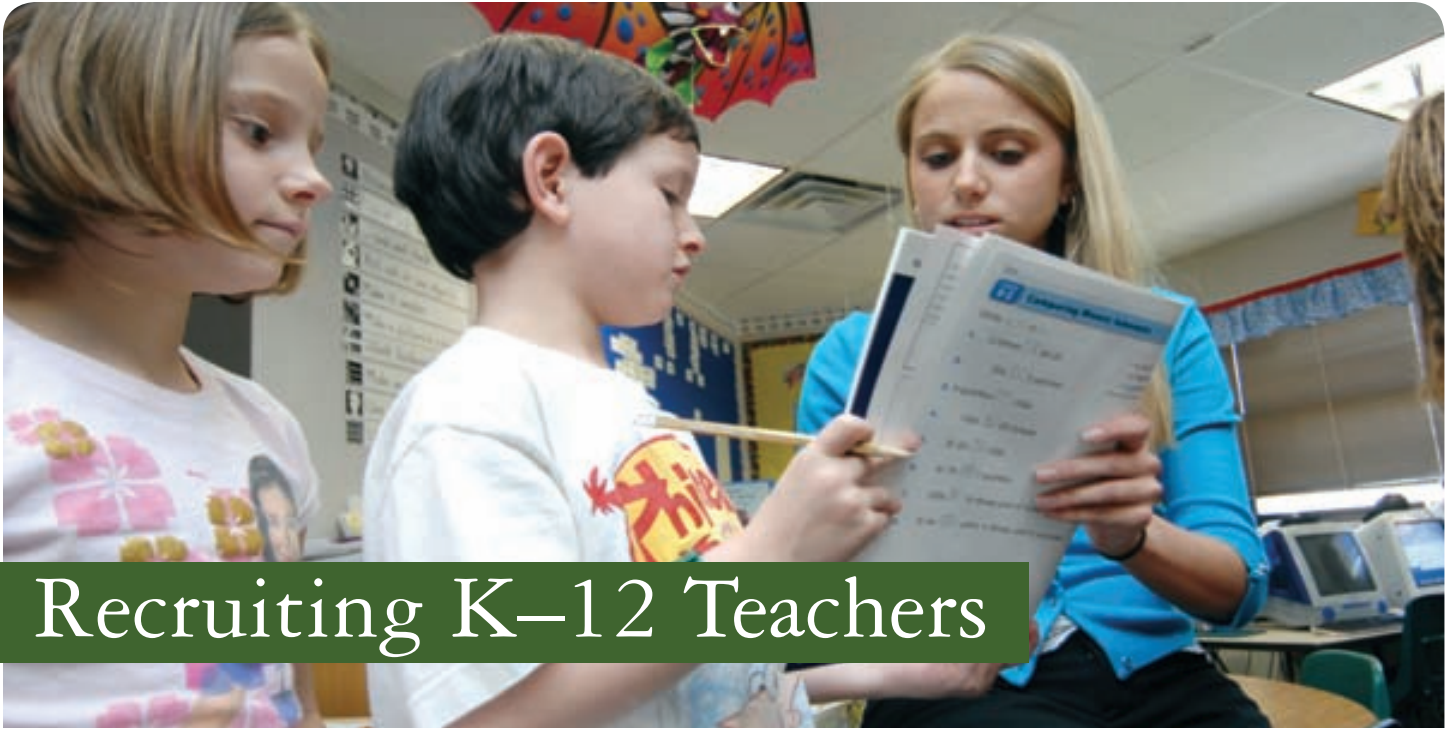
The Integrated Teaching and Learning Laboratory (ITLL), with its team meeting rooms and "building as a learning tool" systems, has been described by Hewlett-Packard as one of the "finer teaching environments on the planet."

### NSF GRADUATE STEM FELLOWS IN K-12 EDUCATION (GK-12) PROJECTS

The National Science Foundation (NSF) developed the GK-12 program because graduate students preparing for careers in research also need to be able to communicate about science and research to a wide variety of audiences. CU-Boulder has three GK-12 projects in partnership with local school districts. By bringing their science expertise into K-12 classrooms, graduate students become adept at explaining scientific phenomena, and help K-12 students develop deeper understandings and stimulate much greater interest in science and engineering careers.



*Students built this wind sculpture as part of the Integrated Teaching and Learning Laboratory.*



## Recruiting K–12 Teachers

When top-level research scientists turn their attention to teaching, it is no surprise that the quality of teaching and learning improves. But there is also an important cultural shift that occurs that increases faculty and student respect for the intellectual work of teaching. As Eric Stade, former chair of Mathematics, noted, “It changes the life of the mind in your department.”

If the most highly regarded faculty members believe that teaching is rocket science, then respect for teaching as a career is increased, which helps to address the national goal of recruiting the best minds into teaching.

### LEARNING ASSISTANT PROGRAM AS A PATHWAY INTO TEACHING

The Learning Assistant program is essential to improving undergraduate and graduate STEM education. This program is also key to recruiting the best and brightest math, science, and engineering students into teaching.

- In 2005, in the entire state of Colorado, only five physics majors were recruited into a teacher education program. In 2007, at CU-Boulder alone, 13 physics majors were recruited from the LA Program into teacher preparation.



*School of Education graduates outside of Old Main.*

In CU-Boulder’s School of Education, students who enter the teacher licensure program do not give up their academic major. Rather, the licensure program works like a “double major,” ensuring that future teachers have deep content knowledge in their major field as well as pedagogical clinical training.

- In 2007, 19 STEM teachers graduated from the teacher education program in the School of Education at CU-Boulder. By 2009, recruiting from the talented Learning Assistant pool, 30 STEM teachers completed their licensure program to go into K–12 teaching.

## CU TEACH

CU Teach is a program in the School of Education and College of Arts and Sciences modeled after the innovative and successful UTeach program at the University of Texas, Austin. Established in 2007, CU Teach recruits talented math and science students at CU-Boulder into teaching careers by giving them early, firsthand, real K–12 teaching opportunities. CU Teach allows students to experience how the teaching profession is an intellectual endeavor that is exciting and fulfilling.

CU Teach allows students to complete a major in math or science and earn a teaching license at the same time.

The ultimate goal of CU Teach is to rigorously prepare and license 50 math and science teachers every year, which is 10 times the number of teachers that were trained before starting CU Teach. The program will accomplish this by encouraging talented students to explore teaching, create content-specific education classes, share the wisdom of master teachers, and provide internship opportunities.

## RESEARCH ON STEM TEACHING AND LEARNING

After 40 years of cognitive science research, we now have a firm basis for developing more effective, interactive teaching strategies. For example, there is clear evidence that students gain deeper conceptual understanding—and over time better reasoning capabilities—if they regularly have to explain their reasoning to others in the course of learning.

CU-Boulder faculty in education, psychology, and the science disciplines, especially physics, biology, and engineering, have contributed to this body of work and, in turn, have used cognitive science and STEM education research as the basis for creating and studying CU's innovative STEM programs.

## Outreach to K–12 Schools

CU-Boulder has a long tradition of bringing hands-on science and engineering programs to K–12 students and teachers.

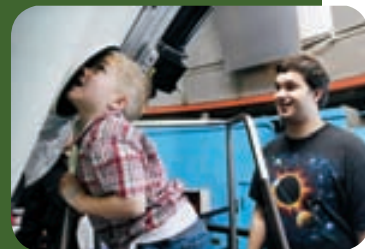
**CU WIZARDS** The CU Wizards Program began in the Physics Department in 1976, and provides an educational, entertaining, and interactive introduction to a variety of sciences, including a once-per-month Saturday show.

**SCIENCE DISCOVERY** Established in 1983, Science Discovery (SD) is a statewide K–12 outreach program serving 30,000 students and 1,500 teachers annually with five core programs.

**BSI SCIENCE SQUAD** With funding from the Howard Hughes Medical Institute, the Biological Sciences Initiative Science Squad sends teams of graduate-level scientists to K–12 classrooms to lead hands-on science activities.

## CIRES OUTREACH

These “Mr. Wizard-style” presentations for middle and high school students began in 1989 and today focus on earth-system science and inquiry-based pedagogy.



**K–12 ENGINEERING** The College of Engineering and Applied Science offers a variety of workshops for elementary through high-school students as well as support for K–12 teachers to help them bring science and engineering concepts into their classrooms.

*Students in a Science Discovery program learn about optics.*





*Richard (Dick) and Sandy McCray have deep ties to CU-Boulder. Dick is the George Gamow Distinguished Professor, Emeritus, Department of Astrophysical and Planetary Sciences and Sandy is a graduate of the CU-Boulder Law School. They understand the importance of STEM Education initiatives and are committed supporters of the Learning Assistant Program.*

## Help Strengthen STEM Education and Transform Math and Science Teaching and Learning

**You can make a critical difference in the education of the next generation of K–12 students, K–12 teachers,** and future research scientists and engineers by investing in CU-Boulder's signature STEM education programs. These programs, begun with grant funding, need your support to be sustained and to grow.

- **Endowed Chairs and Professorships** would help reward and retain outstanding faculty and enhance the visibility and importance of STEM education initiatives.
- **Graduate Fellowships** provide funds and recognition that can be awarded either to further STEM education research as a career or to provide a one-year teaching-focused experience during the PhD training of a research scientist.
- **Postdoctoral Fellowships and Department Grants** continue the work of the Science Education Initiative by supporting course transformations, implementing new teaching technologies, and developing more challenging assessments.
- **Undergraduate Scholarships and STEM Stipends** support outstanding students in the Learning Assistant and CU Teach programs and in Engineering's Earn-Learn Program.
- **Enhancements to K–12 Outreach** will impact local schools, teachers, and students through small curriculum-development grants (linking CU-Boulder's cutting-edge science to K–12 standards) and through scholarships for K–12 teachers and students.
- **STEM Education Permanent Funding** ensures the continued contributions of the Learning Assistant program, CU Teach, and the Science Education Initiative.

### Help Us Seize the Moment.

To learn about the many ways you can make a gift, contact

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