Investing in the Future for Colorado and the Nation

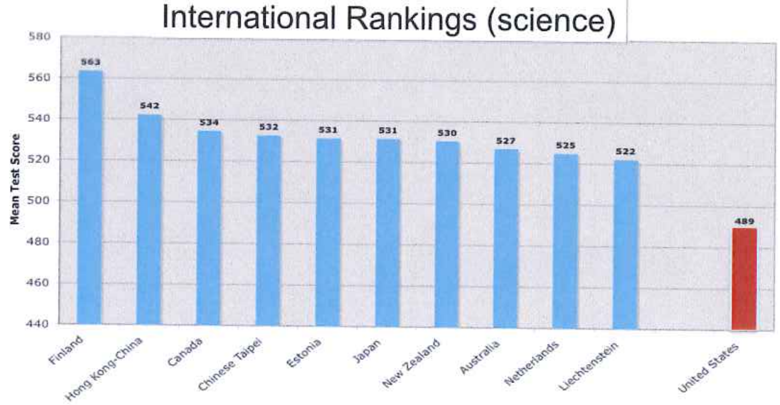
Science, Technology, Engineering, Mathematics (STEM) at the University of Colorado Boulder

Grand Challenges in US Education

Better education
More and better teachers
More STEM Grads Needed
More Higher education & research

U.S. ranks:
21 out of 30 in science
25 out of 30 in math
- PISA 2006

International Rankings (science)



Area of National Attention

Congressional charge (2005):

10 priority recommendations for American competitiveness in the 21st century

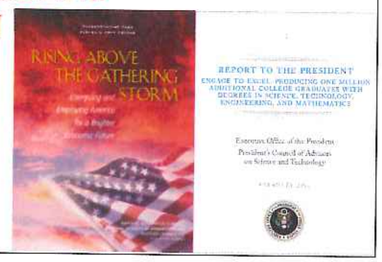
4 Recommendations (2006) & US Law 2007, 2001:

#1: 10,000 TEACHERS, 10 MILLION MINDS,

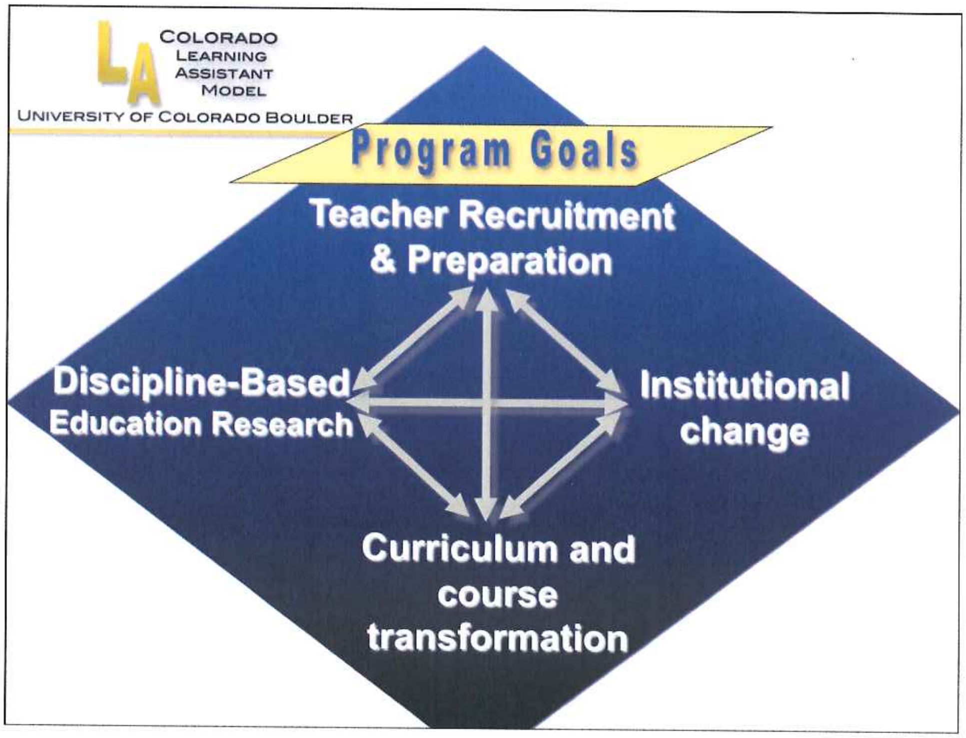
#2: SCIENCE AND ENGINEERING RESEARCH

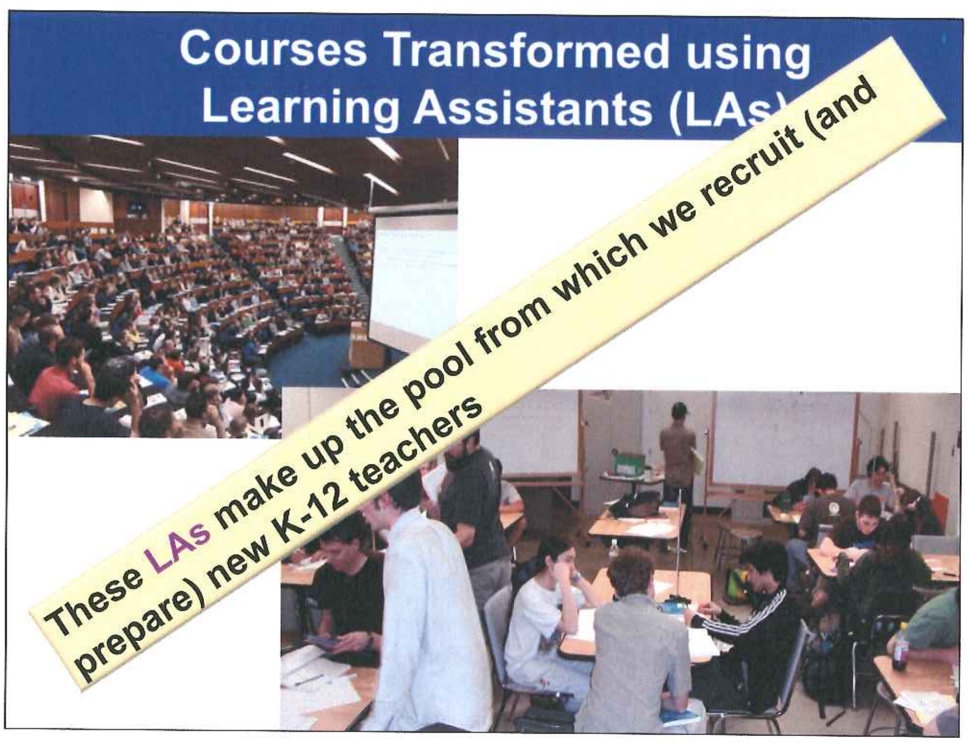
#3: BEST AND BRIGHTEST IN SCIENCE AND ENGINEERING HIGHER EDUCATION

#4: INCENTIVES FOR INNOVATION

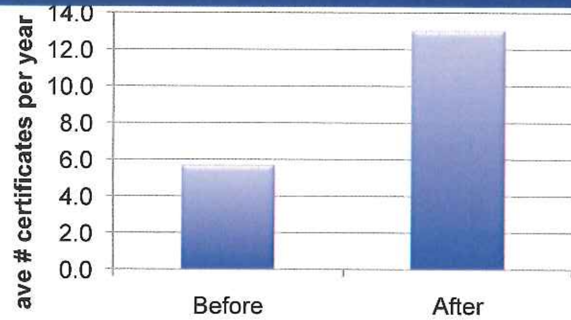


University of Colorado Programs Emulated Throughout the Nation

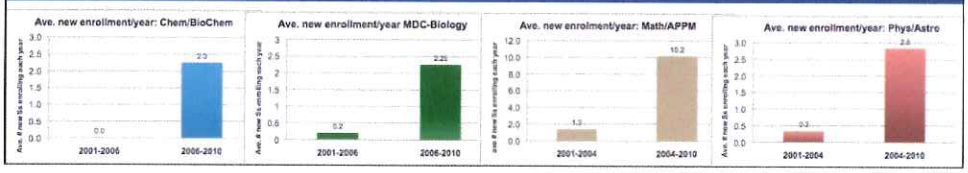

COLORADO
LEARNING
ASSISTANT
MODEL
UNIVERSITY OF COLORADO BOULDER
Program Goals
Teacher Recruitment & Preparation
Discipline-Based Education Research
Institutional change
Curriculum and course transformation


Courses Transformed using Learning Assistants (LAs)
These LAs make up the pool from which we recruit (and prepare) new K-12 teachers

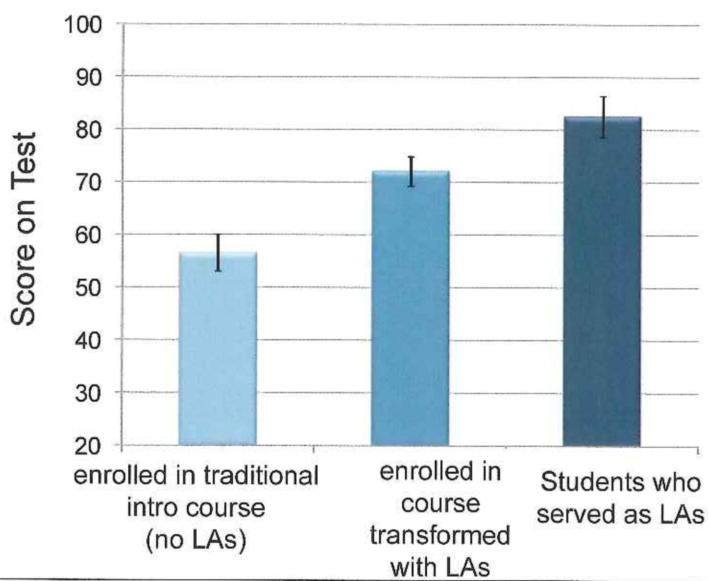
LA Program Impacts Teacher Recruitment



Specifically in Areas of Need

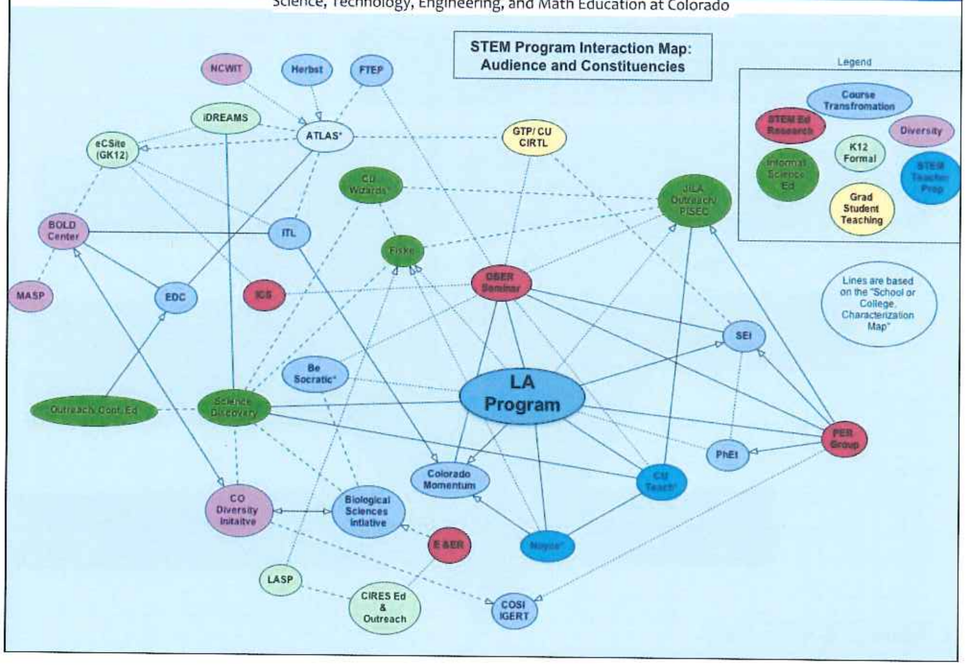


Students Learn More in Transformed Courses



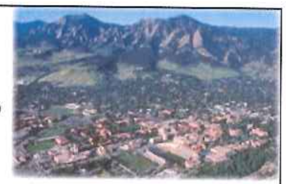
LA is part of a broad network on campus

Science, Technology, Engineering, and Math Education at Colorado



INTEGRATING **STEM**

Science, Technology, Engineering, and Math Education at Colorado

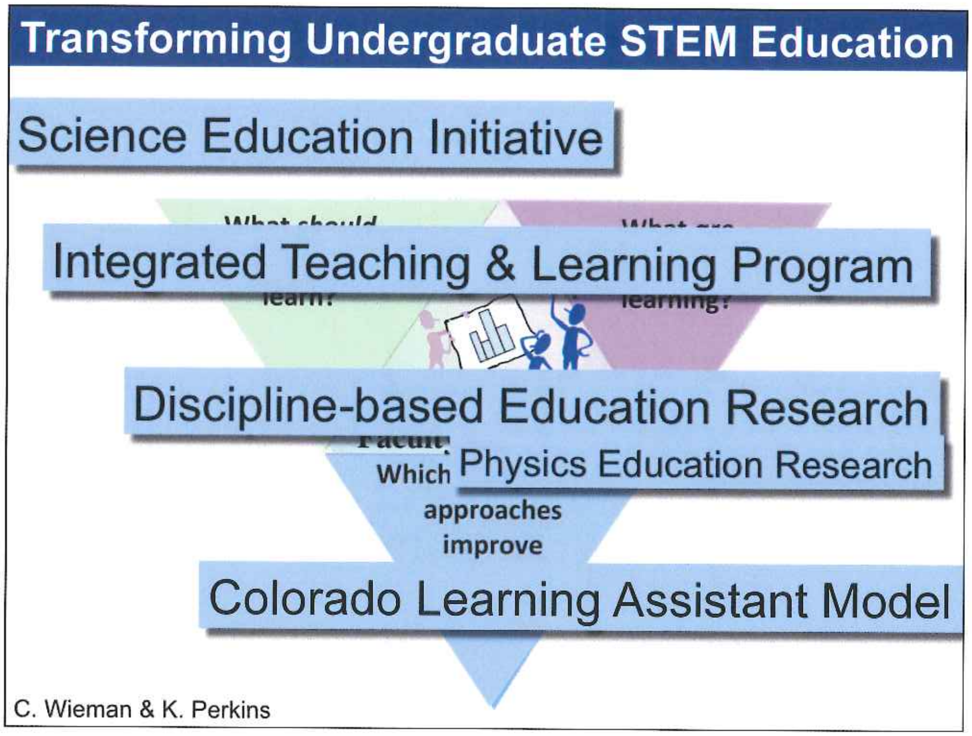


The University of Colorado as a national hub of STEM education research and reform

University of Colorado is a national center for:

- **Education in STEM disciplines**
- **Research on STEM education**
- **STEM teacher preparation**

PI: Chancellor DiStefano
Co-Pis include: Provost Moore,
Deans Argrow (engineering), Gleeson (arts & sciences), Shepard (education), Stevenson (graduate school)



Broad Faculty Participation

Applied Math
Jim Curry (Chair)
Mary Nelson
Anne Dougherty
Harvey Segur,
Tiejun Tong
Adam Norris

Astronomy
Dick McCray
Doug Duncan
Nick Schneider
John Stocke
Fran Bagenal
Seth Hornstein

Chemistry
Tom Cech
Robert Parson
Veronica Bierbaum
Margaret Asirvatham
Laurie Langdon
Susan Hendrickson

Education
Valerie Otero
David Webb
Derek Briggs
Laura Moin
Vicky Hand
Erin Furtak
Jeff Frykholm

MCD Biology
Mike Klymkowsky
Jennifer Knight
Jia Shi
Tom Blumenthal (chair)
Nancy Guild
Bill Wood
Sylvia Fromherz
Michelle Smith

Physics
Steve Pollock
Kathy Perkins
Carl Wieman
Carl Rogers
Murray Holland
Noah Finklestein
Mike Dubson
Ed Kinney
Jim Shepard
James Nagle
John Cumulat (Chair
Paul Beale (Chair)
Steve Wagner
Shijie Zhong
Stephanie Chastine

K-12 Teachers
Steve Iona
Mike Fuchs
Roberta Tanner
Craig Schneider

Graduate Students
Kim Geil
Kara Gray
Heidi Iverson
Chandra Turpen
May Lee
Bud Talbot
Stephanie Barr
Deb Morrison
Ben Spike
Danielle Harlow

Mathematics
Eric Stade (Chair)
Rob Tubbs
Evelyn Puaa

Engineering
Brian Argrow
Derek Reamon
Daria Kotes-Schwartz

Community Partnerships, Outreach & Service

Science Discovery

Biological Sciences Initiative

CIRES Outreach | JILA PISEC | NCWIT

LASP | ITLL | PhET Simulations | Fiske

GK12s | Engineering for Develop Communities

Office for University Outreach

30 years COLORADO MESA Mathematics Engineering Science Achievement

cde Improving Academic Achievement

CU as a National Leader / National Reputation

National Organizations Promoting CU Models:

Association of American Universities 1900 AAU

Association of Public and Land-Grant Universities

APS physics

National Math + Science Initiative

Multiplying Success

Serving the Nation:

Chancellors DiStefano & Shockley-Zalabak at the White House
Educate to Innovate

Finkelstein congressional testimony for America COMPETES Act

Otero advises National Governor's Association Race to the Top

Natural Synergies investing in the future

COLORADO INITIATIVE IN MOLECULAR BIOTECHNOLOGY

Renewable and Sustainable energy institute
A Joint Institute of the University of Colorado at Boulder & the National Renewable Energy Laboratory

INTEGRATING STEM
Science, Technology, Engineering, and Math Education at Colorado

Serving Colorado, Engaged in the World

Flagship 2030

What is Integrating STEM Education?

Integrating STEM Education (iSTEM) is a 5-year initiative to create a center that will integrate:

- superior STEM education
- innovative approaches to discipline-based education research
- the recruitment of top-tier STEM students as K20 educators

Through the integration of these three strands, we are helping to address today's educational challenges:

- Our nation is lagging in STEM performance relative to other countries.
- Higher education is being overlooked in national discussions about STEM education.
- There are too few qualified math/science teachers nationwide.

iSTEM is committed to and strives for diversity, access, and inclusion of all people in STEM disciplines.

iSTEM is addressing local, state and national calls for reform through policy work.

A signature program of the University of Colorado Boulder, iSTEM is also a National Science Foundation Innovation through Institutional Integration (I^3) program.

Sample STEM Programs:

- Chancellor's Award Program
  www.coloado.edu/istem/ChancellorAward.html
- CU Learning Assistant (LA) Program
  laprogram.colorado.edu
- CU Teach
  cuteach.colorado.edu
- Discipline-Based Edcation Research Seminar Series
  www.colorado.edu/istem/DBER.html
- Integrated Teaching and Learning Program & Lab
  itll.colorado.edu
- Science Discovery
  www.colorado.edu/sciencediscovery
- Science Education Initiative (SEI):
  www.colorado.edu/sei

www.colorado.edu/istem

Principal Investigator: Chancellor Phil DiStefano

Co-PIs: Provost Moore, Dean Gleeson, Dean Shepard, Assoc. Dean Argrow, Associate Professor Finkelstein

Project Directors:

Noah Finkelstein
noah.finkelstein@colorado.edu

Michael Klymkowsky
michael.klymkowsky@colorado.edu

Daria Kotys-Schwartz
daria.kotys@colorado.edu

Valerie Otero
valerie.otero@colorado.edu

Derek Reamon
derek.reamon@colorado.edu

Eric Stade
eric.stade@colorado.edu

Project Administrator:

Kate Kidder
kate.kidder@colorado.edu

With Support From:

University of Colorado Boulder

PhysTEC

HHMI Howard Hughes Medical Institute

National Math + Science Initiative

The William and Flora Hewlett Foundation

SEI

Be part of the transformation:
For more information on supporting excellence at CU-Boulder, contact margot.neufeld@cufund.org

Integrating STEM Education
UNIVERSITY OF COLORADO BOULDER

Serving Colorado and the nation through STEM education

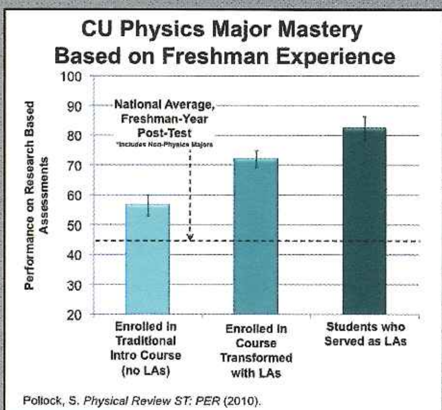
CU-Boulder's collaborative STEM education efforts are advancing K20 STEM education by transforming the way we teach, discover, and share knowledge.

TRANSFORMING STEM EDUCATION

through innovative, research-based courses and programs that produce proven advances.

- We make science education a science.
- We build on a base of proven research.
- We emphasize interactive engagement.
- We assess student learning objectively.

Already, physicists have successfully improved CU-Boulder's introductory physics sequence by introducing interactive engagement (IE) techniques such as small group work, clicker questions, and active discussion. Research demonstrates that these students consistently learn two to three times the national average of those taking traditional lecture-based courses.



Pollock, S. *Physical Review ST: PER* (2010).

Physics majors who have been LAs or who were in an introductory physics class with LAs outperform those who were in a traditional introductory class on research-based assessments.

Impacts:
At CU-Boulder, more than 35 undergraduate courses in 8 departments have been transformed, affecting more than 9,000 students (>25%) per year.

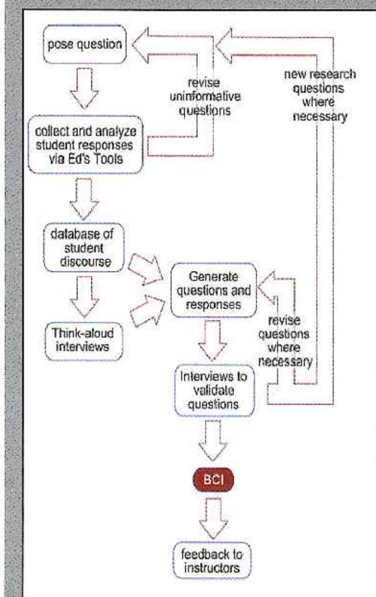
"I view the University of Colorado Boulder as the national leader in driving improvements in STEM education..."

—Dr. Bruce Alberts, editor-in-chief of Science

RESEARCHING STEM EDUCATION

as part of an internal, discipline-based education research community that includes faculty and students.

- We treat STEM education as a scholarly endeavor.
- We conduct fundamental studies on learning.
- We enhance tools, practices, and assessment for course transformation and improved learning.
- We apply research findings to STEM classrooms.



CU-Boulder biologists have developed a validated instrument for measuring student learning. The Biology Concept Inventory is becoming a staple tool for research on learning and evaluating student understanding in biology.

Klymkowsky & Garvin-Doxas. 2008. PLoS Biology, 6(1): e3

Impacts:
More than 50 faculty from 14 disciplinary departments, including multiple Nobel laureates and National Academy members, are actively engaged in STEM education research. Their work has been published in leading journals, like *Science* & *Physical Review*.

www.colorado.edu/istem
iSTEM@colorado.edu
(303) 492-6963

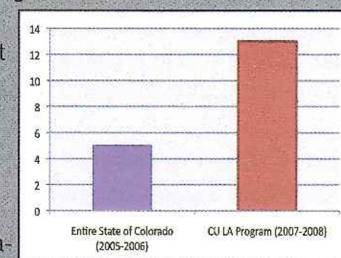
RECRUITING STEM TEACHERS

by preparing top-tier STEM students for the intellectually challenging careers of K12 and college teaching.

- We recruit the best and brightest into teaching.
- We tailor teacher preparation to the STEM disciplines.
- We couple teacher preparation with course transformation and research on learning.

CU Teach:
Through new courses designed to provide early field experiences in the classroom and partnerships between the School of Education and STEM departments, CU Teach is transforming teacher certification.

Colorado Learning Assistant (LA) Program:
High performing undergraduate STEM majors are recruited from introductory courses and encouraged to consider teaching as a career. LAs facilitate small-group interaction in large-enrollment courses, supporting course transformation. Their experience includes a School of Education pedagogy course and weekly disciplinary preparation.



No. of Physics/Astrophysics. Majors Recruited into Cert. Programs
Otero et al, Science. 313(5786), 445-446 (2006).

Impacts:
The number of undergraduate STEM students considering teaching as a career had dramatically increased, resulting in double the number of discipline-trained high school science and math teachers in Colorado. Students recognize teaching as a challenging and intellectually rewarding career.

"Strengthening STEM education is vital... we need to recruit and train math and science teachers to support our nation's students."

—President Barack Obama

The Learning Assistant (LA) Model

The LA Model is an experiential learning program of the University of Colorado at Boulder

Courses Transformed

Undergraduate students are hired as Learning Assistants to help transform courses to be responsive to research on how students learn.

Over 35 math and science courses have been transformed using Learning Assistants.

Teachers Recruited

Over 40 talented mathematics, science, and engineering majors have been recruited to become K-12 teachers through the Learning Assistant program. Just under 20 are currently teaching in high needs school districts in subject such as physics and chemistry

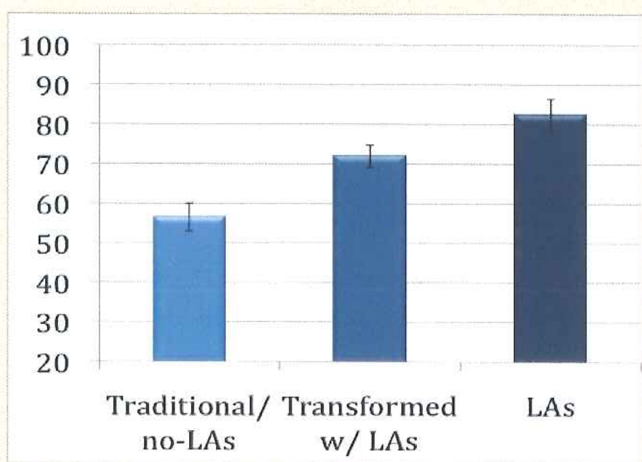
National Model

- Universities throughout the nation received significant funding to replicate the Colorado Learning Assistant model
- Addresses our Nation's critical shortage of highly qualified math and science teachers
- 21st century educational program, a signature program at CU Boulder

Multi-disciplinary — High Impact

- Aligned with several institutional priorities outlined in the University's strategic plan, Flagship 2030
- Approximately 160 mathematics, science, and engineering majors hired each year to serve as Learning Assistants in 8 departments
- Over 9000 students are impacted each year at a cost of under $50 per student

Students Learn More



Students in courses transformed with Learning Assistants outperform those in traditional courses. Learning Assistants outperform all of their peers.

CU's Science Education Initiative

Departments and Faculty Take Action to Improve Science Learning

INTEGRATING STEM — Science, Technology, Engineering, and Math Education at Colorado

CU's Science Education Initiative (SEI) is a 5-year, $5M investment by President Benson and Chancellor DiStefano to catalyze and support significant, sustainable improvements in undergraduate science education. Directed by Nobel Laureate Carl Wieman and Kathy Perkins, the SEI funds departments to take a four-step, scientific approach to undergraduate education:

1) Establish what students should learn;
2) Scientifically measure what students are actually learning;
3) Use instructional approaches guided by research on learning and data on student thinking and learning;
4) Disseminate and adopt what works.

SEI Supports

Departments	Faculty	Students
5 funded: IPHY, PHYS, MDCB, GEOL, CHEM	>100 faculty use SEI-funded resources <75 faculty modified thier teaching	Changes in >50 courses Impacts >10,000 students/yr

Faculty partner with Science Teaching Fellows to Transform Courses

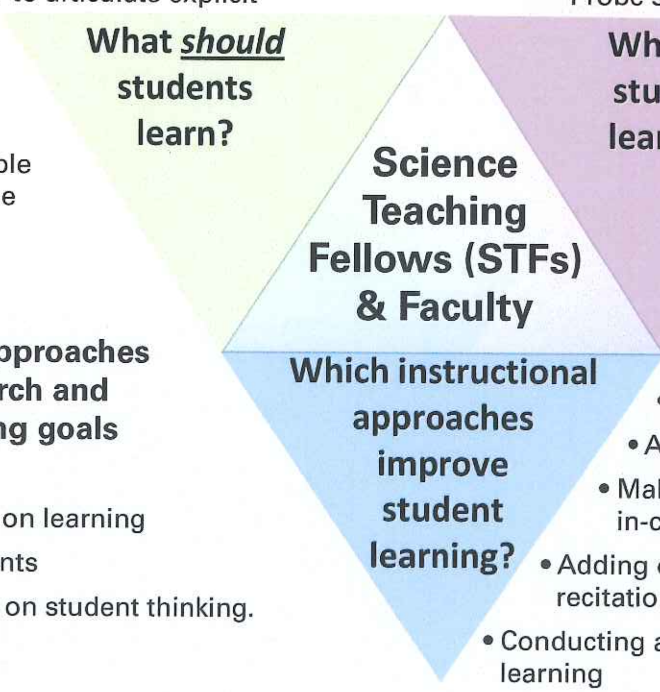
Develop consensus learning goals

- Faculty work together to articulate explicit learning goals for courses.
- Shift from topics to outcomes: "What students should be able to DO at the end of the course?"

Use data to support & guide faculty efforts

Probe student thinking and learning with:

- Student Interviews
- Observations
- Surveys
- Analysis of student work
- Conceptual pre/post assessments



Develop or adapt approaches supported by research and aligned with learning goals

These are:

- Aligned with research on learning
- Actively engage students
- Guided by knowledge on student thinking.

Faculty are...

- Communicating explicit learning goals
- Attending to motivation
- Making lecture interactive with concetp tests, in-class activities, and classroom discussion
- Adding or modifying homework, labs, and recitations
- Conducting and publishing research on student learning

Reference:
Transforming Science Education at Large Research Universities: A Case Study in Progress.
By Carl Wieman, Katherine Perkins, and Sarah Gilbert, Change Magazine, 2010.

For more information visit:
www.colorado.edu/sei

PhET Interactive Simulations

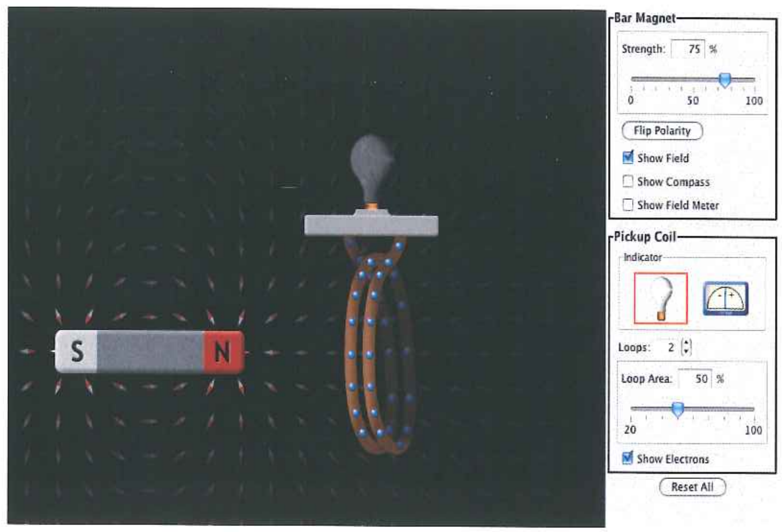
INTEGRATING STEM
Science, Technology, Engineering, and Math Education at Colorado

PhET Interactive Simulations are a suite of free, research-based tools that improve the way that physics, chemistry, biology, earth science and math are taught and learned. These interactive tools enable students to make connections between real life phenomena and the underlying science which explains such phenomena. Our team of scientists, software engineers and science educators use a research-based approach to create simulations that support student engagement with and understanding of scientific concepts. All simulations are free and easily down-loadable or can be run live from the web.

Interactive & Engaging: PhET simulations animate what is invisible to the eye through the use of graphics and intuitive controls such as click-and-drag manipulation, sliders and radio buttons. In order to further encourage quantitative exploration, the simulations also offer measurement instruments including rulers, stop-watches, voltmeters and thermometers. As the user manipulates these interactive tools, responses are immediately animated thus effectively illustrating cause-and-effects relationships as well as multiple linked representations (motion of the objects, graphs, number readouts, etc...).

Research Based: To ensure educational effectiveness and usability, all of the simulations are extensively tested and evaluated. These tests include student interviews in addition to actual utilization of the simulations in a variety of settings, including lectures, group work, homework and lab work. Our rating system indicates what level of testing has been completed on each simulation.

For more information or to use PhET Sims, visit:
www.phet.colorado.edu



PhET Sims: Reaching the World

- **84 total sims** available
- **Over 400 activities for teachers** using sims
- Available in **44 languages** and counting
- **8.4 million:** Number of sims run online in 2009

How do I get PhET Sims?

All simulations are completely free and can be accessed from the PhET website in three ways:

- Download individual sims
- Download the entire website
- Run them live from the web

PhET is generously supported by:

THE WILLIAM AND FLORA HEWLETT FOUNDATION

Committed to Excellence in STEM Education for Colorado | www.colorado.edu/istem

Physics Education Research Group @ Colorado

INTEGRATING STEM
Science, Technology, Engineering, and Math Education at Colorado

What is PER@C?

The Physics Education Research Group at Colorado (PER@C) is one of the newest and largest research programs in PER in the nation. Our research group develops and studies: uses of technology in physics education, assessments (conceptual, epistemological, and belief oriented), theoretical models of students learning physics, social and contextual foundations of student learning, examination of successful educational reforms and replication studies of such reforms, and student problem-solving in physics. We sponsor a number of educational reforms in physics, which range from pre-college to post-doctoral. The research group includes faculty, staff, and students from both the Department of Physics and the School of Education.

PER@C Successes:

- Six faculty, including Nobel Laureate Carl Wieman, and six researchers and post-docs make PER@C the largest PER group in the nation
- With over $12 million in external funding, PER@C is one of the best-funded programs of it's kind in the nation.
- PER@C is one of the most published PER groups in the nation with papers appearing in Science, Nature: Physics, Physics Today, American Journal of Physics, and Physical Review.
- PER@C faculty lead corner-stone efforts in science education at CU, including nationally recognized programs.

PER@C: *Leading the way in understanding how science is learned and transforming the teaching of science.*

per.colorado.edu
www.colorado.edu/istem

PER@C Highlights:

The PhET Interactive Simulations Project: Developing, testing, and researching online simulations in physics, and now, chemistry, biology, geology and math.

Lower Division Course Transformation: Developing materials, implementing, evaluating and conducing research on transformation in Physics 1, 2 and 3.

Upper Division Course Transformation: Transforming junior Electricity and Magnetism & Quantum Mechanics, and use of PER-based tools in courses as advanced as the graduate level.

Assessments: The development of research-based instruments for evaluation of student learning including: attitudes and beliefs, quantum mechanics, and upper division E/M.

Theoretical Work: Developing theories of student learning in physics, including student use of representations, analogies, simulations; student development of epistemic and ontological commitments in physics; the development of future teachers, graduate students and faculty.

Areas of focus include **Institutional change** in physics and science, **gender studies,** and **informal science education.**

The Learning Assistant Program: Research on the nationally recognized effort that couples course transformation with teacher recruitment and preparation.

APS physics · PhysTEC · National Math + Science Initiative · University of Colorado 1876 · NSF · AAPT Physics Education · The William and Flora Hewlett Foundation · American Institute of Physics

Discipline-Based Education Research Group (DBER)

INTEGRATING STEM
Science, Technology, Engineering, and Math Education at Colorado

The Discipline-based Education Research (DBER) group began in 2004 as a forum through which faculty in science, technology, engineering and mathematics (STEM) departments could engage in conversations about effective education. It is based on the premise that the various STEM disciplines face both common and distinct pedagogical challenges. These issues are critical to effective university teaching, but no mechanism existed for sharing successes and challenges across departments.

Through a weekly seminar series, faculty and research students present their ideas, observations, and conclusions relating to particular problems and issues associated with promoting effective learning in STEM disciplines. Typically the group consists of faculty and students from a wide range of departments, including applied mathematics, astrophysics, chemistry & biochemistry, computer science, cognitive science, engineering, geology, mathematics, molecular, cellular & developmental biology, physics, and the school of education.

The DBER group meetings also serve as a forum within which iSTEM grant recipients describe the design of their projects, their observations and conclusions. DBER has also taken on broader challenges, such as: examining the proposed Colorado State Science Standards for coherence and "teachability"; working with CU Teach in the design of Functions and Modeling and Research Methods courses (part of the STEM teacher certification program), as well as considering the conceptual coherence of foundation courses in various disciplines.

For current topics and information visit:
www.colorado.edu/istem/DBER

Recent DBER seminar topics:

- Transforming upper division physics
- Learning through computer modeling
- Faculty attitudes to pedagogical techniques
- Learning through design in engineering
- Identification of conceptually difficult topics in specific STEM disciplines
- Approaches to integrating math and modeling into biology education
- An approach to improving the scientific thinking of students in an introductory class for non-science majors
- Course transformation through the use of learning assistants and pedagogically-based instruction

Committed to Excellence in STEM Education for Colorado | www.colorado.edu/istem

Integrating STEM Education is supported by the University of Colorado and the National Science Foundation through I3

References & Resources: Powell, K. 2003. Science Education: Spare me the lecture. Nature 425: 234-236
Klymkowky, M.W. & E.M. Furtak. 2009. Incoherent Science and Mathematics Education Undermines Biological Literacy. http://coloradohigherednews.com/Pages/Archive.php?id=1460

Advancing Colorado and the Nation

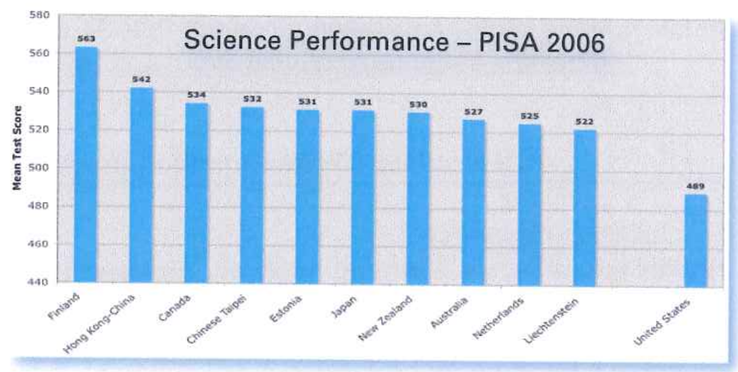
Science, Technology, Engineering, Mathematics (STEM) Education at the University of Colorado at Boulder

Noah Finkelstein and Valerie Otero
http://www.colorado.edu/istem

STEM: an Area of National Need

➢ ***We need investment in K12 education***

The U.S. ranks 21st out of 30 in science and 25th out of 30 in math achievement in recent international surveys of 15-year-old students (PISA 2006). On national assessments in science (NAEP 2005), only about 1/3rd of 8th grade students in Colorado rated as proficient, and our 12th graders have gotten worse since 1996. Simultaneously, we maintain a longstanding gap between majority and underrepresented minority students.

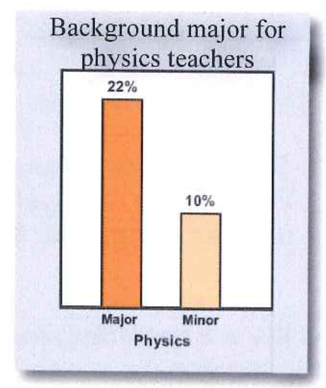


More at:
http://www.oecd.org/dataoecd/15/13/39725224.pdf, http://nationsreportcard.gov/science_2005/ and http://www.whitehouse.gov/issues/education/educate-innovate

➢ ***We need more K12 teachers in STEM***

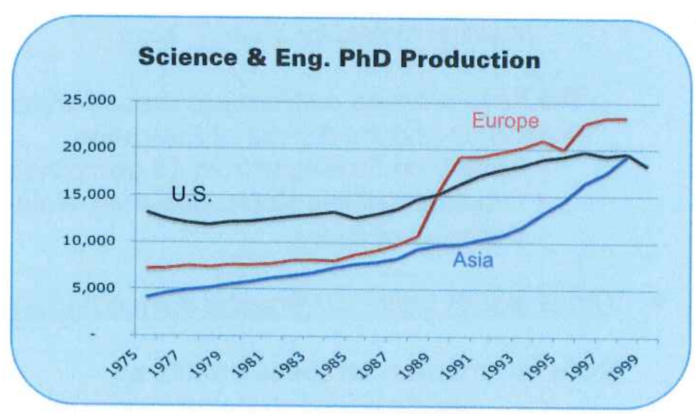
- In 2009, only 46% of teachers who taught physics held a major or a minor in physics or physics education. (Only about 1/3rd were in held majors or minors in physics).
- Retention of quality teachers is a major problem.
- Areas of national need include, math, physics, chemistry, molecular biology, and engineering.

More at: http://www.ptec.org and http://www.aaee.org



➢ ***We need investment in higher education & research:***

- In 2008, about 5 million first university degrees were awarded in S&E worldwide. Students in China earned about 23%, those in the European Union earned about 19%, and those in the United States earned about 10% of these degrees.
- In 2007, China overtook the United States as the world leader in the number of doctoral degrees awarded in the natural sciences and engineering
  - NSF Science & Engineering Indicators 2012



More at:
http://www.nsf.gov/statistics/seind12/c2/c2h.htm

STEM Education: An Area of National Focus

The National Academy of Sciences, National Research Council Report, (2006), *Rising Above the Gathering Storm* (RAGS) recommends *four priorities* for investing in a competitive and secure country: 1) 10,000 teachers, 10 million minds (more STEM teachers in K12); 2) fundamental investment in science and engineering research; 3) supporting the best and brightest in undergraduate and graduate students in STEM; and 4) incentives for innovation in business. More at: http://www.nap.edu/openbook.php?record_id=11463

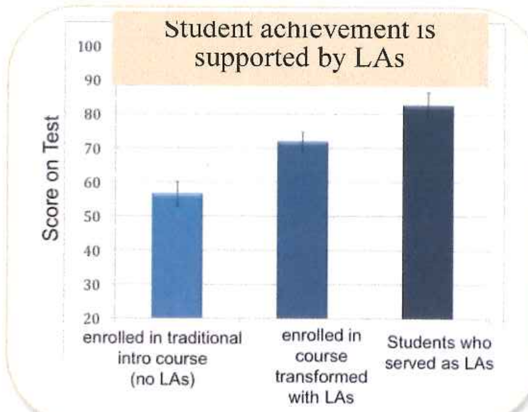
The U.S. America COMPETES Act writes this into law and passes (2007), and Reauthorized, increasing funding to NSF and NSF Education efforts (Jan 4, 2011).
STEM undergraduate Education: focus of PCAST recommendations to White House (Feb 13, 2012)
http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-executive-report-final_2-13-12.pdf

CU-Boulder STEM education programs directly address the Calls for Action

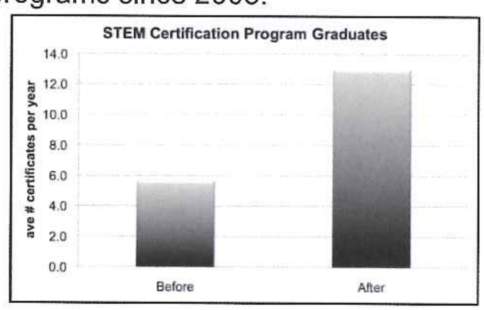
➢ *Colorado Response:*
Higher education is a critical linchpin, perhaps *the* critical linchpin in our educational system. In addition to providing undergraduate and graduate education, higher education is where STEM disciplines are defined and practiced; it is the destination of students in our pre-college system; it is where teachers are educated and return for professional development; it is where we produce materials, assessments, and standards for the broader system; it is where leading research on student learning occurs.
Higher education is too often overlooked in national discussions about STEM education.

➢ *A Sample of the Results at University of Colorado at Boulder*

Through programs such as the Colorado Learning Assistant (LA) Model, the Science Education Initiative, and CU Teach, we are addressing the national challenges.



- ***CU-Boulder students learn more*** in STEM education. courses. For instance, in physics, students learn two to three times the national average for traditionally taught courses.
- ***We are recruiting more and better teachers*** into K12 STEM education.
  - We have more than doubled the number of STEM teachers in our programs since 2003.
  - We have more than tripled in areas of high-need (e.g., math, physics, molecular biology, etc.).



- ***We have a broad coalition of faculty*** within STEM education disciplines and the School of Education.
  - More than 50 faculty from 14 disciplines
  - Includes multiple Nobel laureates, National Academy members, department chairs

➢ *These results make CU-Boulder unique and a model for other universities across Colorado & the country.*

More information on these efforts at:

http://www.colorado.edu/istem (the integrating STEM education effort)
http://laprogram.colorado.edu (the Learning Assistant Program at Colorado)
http://www.colorado.edu/news/reports/stemeducation (CU-Boulder news special reports)

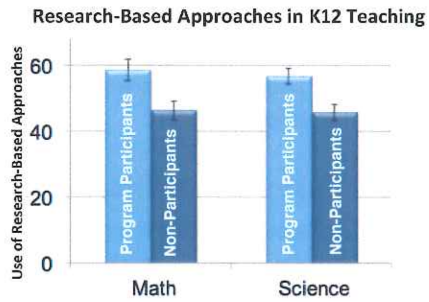
University of Colorado Boulder – National Efforts in STEM Education

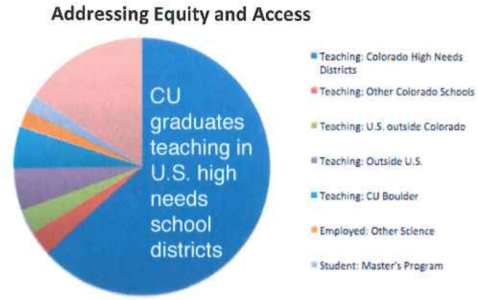
Noah Finkelstein and Valerie Otero

Improved K-20 Education ● More and Better K-12 Teachers ● Discipline-Based Education Research

National Model for Recruiting More STEM Teachers and Improving Teaching Quality

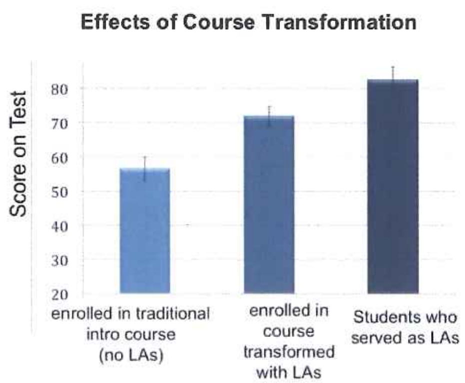
- Doubled the number of STEM Teacher Certification Graduates (triple in high needs areas)
- K-12 Classroom practice or program graduates better than that of their colleagues
- Addressing Equity & Access: graduates in high-needs schools, continue to partner with CU

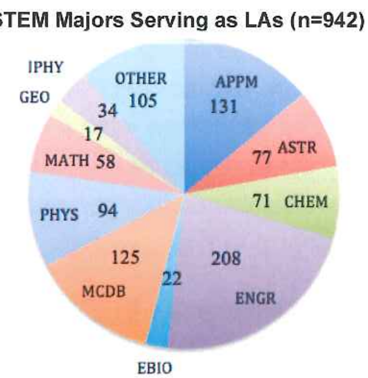




National Model for Transforming the Experiences and Outcomes of STEM Education

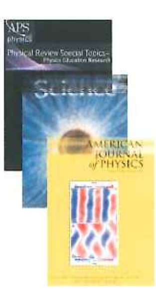
- Colorado Learning Assistant Program is Nationally Emulated at over 30 Universities
- At CU Boulder 14 STEM departments from 3 Colleges and Schools Participate
- Program impacts approximately 9000 students annually with over 45 courses transformed





Scientific Approach: Leaders in STEM Education Research

- Applied Research: Material Development, Learning Outcomes and Assessments
- Basic (theoretical) Research: Nature of Learning, Nature of Disciplinary Knowledge
- Advising the National Governors Association, U.S. Congress, and the U.S. President



Otero, V., Pollock, S., & Finkelstein, N. (2010). A Physics Department's Role in Preparing Physics Teachers: The Colorado Learning Assistant Model. *American J. of Physics,* 78(11), 1218.

Pollock, S. (2009). Longitudinal Study of Student Conceptual Understanding in Electricity and Magnetism, *PhysRev: ST Phys Ed. Rsrch,* **5**, 020110.

Otero, V., Finkelstein, N., McCray, R., & Pollock, S. (2006). Who is responsible for preparing science teachers? *Science, 313*(5786), 445-446.

Finkelstein, N. & Pollock, S. (2005). Replicating and Understanding Successful Innovations: Implementing Tutorials in Introductory Physics, *PhysRev: ST Phys Ed. Rsrch,* **1**, 010101.

A national Center for STEM Learning, redefining the future of higher education, producing leading resources and models, and building capacity across the country.

CU Boulder is a recognized national leader in STEM education, positioned to succeed.

Higher education is a critical linchpin, perhaps *the* critical linchpin in our educational system. In addition to providing undergraduate and graduate education, higher education is where STEM disciplines are defined and practiced; it is the destination of students in our pre-college system; it is where teachers are educated and return for professional development; it is where we produce materials, assessments, and standards for the broader system; it is where leading research on student learning occurs. **In the last decade, CU has created the infrastructure to succeed in making essential contributions to transforming STEM education.** We are a research university involving those generating STEM knowledge, as well as those deeply involved in studies of diversity, equity, and access. CU brings a long history of attention to and leadership in STEM education. **Cited as an exemplary program by APLU, we provide models and practices that make CU an essential higher education component in national efforts in STEM education.**

University of Colorado Boulder brings a breadth of integrated resources.

- More than 50 active faculty members collaboratively transforming STEM education,
- Working across 14 different departments and programs (physics, chem., math, bio., engineering, ...),
- Spanning Colleges of Arts& Sciences, Engineering and Applied Sciences, and Education,
- Linking Undergraduates, graduates, postdocs, faculty, administrators,
- And including children, family, teachers, non-profits, and schools across Colorado,
- Led by the University Chancellor, Provost, sr. Administration, and internationally renowned faculty.
- We have developed and support nationally replicated programs in educational transformation.

University of Colorado Boulder brings a depth of resources.

- CU has decades of experience with dedicated initiatives to transforming K-20 STEM education.
- We host faculty within disciplinary departments along with scholars in the school of education, conducting foundational research (published in *Science*) that provide resources for transformation.
- More than a dozen graduate PhDs in STEM education *within disciplines* focusing on student learning.
- One of the largest Discipline-based education research communities, working *within and across STEM fields*, addressing longstanding and new challenges in inter-disciplinary work (e.g. health and energy).
- The largest physics education research group in the country.

A Trusted Partner, Promoted in National Networks in STEM Education.

As higher education deeply engages in STEM education transformation, two critical components are being aligned – work within disciplinary societies and work by university systems. We are helping align these efforts:

- CU Boulder provides model programs, advising and capacity building for national disciplinary societies (such as the American Physical Society, Am. Chemical Society, Am. Society for Engineering Education)
- CU supports, shapes, develops and disseminates efforts through professional societies of universities (such as Assoc. of American Universities, and the Assoc. of Public & Land-grant Universities)

More information at:

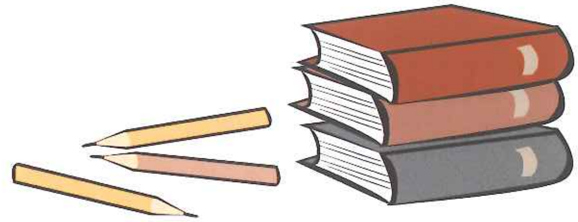
http://www.colorado.edu/istem (the Integrating STEM education effort building a national Center)
http://laprogram.colorado.edu (the Learning Assistant Program at Colorado)
http://cuteach.colorado.edu/ (a leading national model in teacher preparation and support)

Contacts:

Prof. Noah Finkelstein, Physics, Dir. Integrating STEM Education: Noah.Finkelstein@colorado.edu
Prof. Valerie Otero, Education, Dir. Learning Assistant Program & CU Teach. Valerie.Otero@colorado.edu

PROFESSIONAL DEVELOPMENT

Who Is Responsible for Preparing Science Teachers?



Valerie Otero,[1*] Noah Finkelstein,[2] Richard McCray,[3] Steven Pollock[2]

At the University of Colorado at Boulder, involving students in the transformation of science courses raises the visibility of science teaching as a career and produces K–12 teachers well-versed in science.

Teachers knowledgeable in both science and pedagogy are critical for successful math and science education in primary and secondary schools. However, at U.S. universities, too many undergraduates are not learning the science (*1–3*), and our highest performing students are choosing fields other than teaching (*4*). With a few exceptions [such as (*5*, *6*)], universities convey that teaching kindergarten to 12th grade (K–12) is not a career worthy of a talented student (*7*). Two out of three high school physics teachers have neither a major nor a minor in the discipline (*8*), and the greatest teacher shortages are in math, physics, and chemistry. The shortages of teachers with these majors have likely contributed to the poor current outcomes (*9*) for math and science education [supporting online material (SOM) text].

Enhanced online at www.sciencemag.org/cgi/content/full/313/5786/445

The first of four recommendations by the National Academies for ensuring American competitiveness in the 21st century was to "increase America's talent pool by vastly improving K–12 science and mathematics education" (*9*). Teacher preparation is not solely the responsibility of schools of education. Content knowledge is one of the main factors positively correlated with teacher quality (*10*), yet the science faculty members directly responsible for teaching undergraduate science are rarely involved in teacher recruitment and preparation.

The Learning Assistant Model

At the University of Colorado (CU) at Boulder, we have developed a program that engages both science and education faculty in addressing national challenges in education. Undergraduate learning assistants are hired to assist science faculty in making their courses student centered, interactive, and collaborative—factors that have been shown to improve student performance (*1–3*). The program also recruits these learning assistants to become K–12 teachers. Thus, efforts to improve undergraduate education are integrated with efforts to recruit and prepare future K–12 science teachers.

Since the program began in 2003, we have transformed 21 courses (table S1) with the participation of 28 science and math faculty members, 4 education faculty members, and 125 learning assistants. The learning assistants support and sustain course transformation—characterized by actively engaged learning processes—by facilitating collaboration in the large-enrollment science courses (fig. S1). The program also increases the teacher-to-student ratio by a factor of 2 to 3 (SOM text). Without learning assistant participation, such courses tend to be dominated by the lecture format. Faculty members new to course transformation are supported by faculty that have experience working with learning assistants (SOM text).

About 50 learning assistants have been hired each semester for courses in six departments: physics; astrophysical and planetary sciences; molecular, cellular, and developmental biology (MCD biology); applied mathematics; chemistry; and geological sciences. The learning assistants are selected through an application and interview process according to three criteria: (i) high performance as students in the course; (ii) interpersonal and leadership skills; and (iii) evidence of interest in teaching. Learning assistants participate as early as the second semester of freshman year and as late as senior year. Learning assistants differ from traditional teaching assistants (TAs) in that learning assistants receive preparation and support for facilitating collaborative learning.

Learning assistants receive a modest stipend for working 10 hours per week in three aspects of course transformation. First, learning assistants lead learning teams of 4 to 20 students that meet at least once per week. Learning assistant–led learning teams work on collaborative activities ranging from group problem-solving with real astronomical data to inquiry-based physics activities. Second, learning assistants meet weekly with the faculty instructor to plan for the upcoming week, to reflect on the previous week, and to provide feedback on the transformation process. Finally, learning assistants are required to take a course on Mathematics and Science Education that complements their teaching experiences. In this course, cotaught by a faculty member from the School of Education and a K–12 teacher, learning assistants reflect on their own teaching, evaluate the transformations of courses, and investigate practical techniques and learning theory (SOM text).

Through the collective experiences of teaching as a learning assistant, instructional planning with a science faculty member, and working with education faculty, learning assistants develop pedagogical content knowledge, which is characteristic of effective teachers (*11*). The skills that learning assistants develop are valuable for teaching at all levels and in many environments. Those learning assistants who consider K–12 teaching as a career are encouraged to continue and are eligible for NSF-funded Noyce Teaching Fellowships (fig. S2).

Undergraduates enrolled in science teacher certification programs

Major	All of Colorado (2004–2005) LAs not included	CU Boulder (2004–2005) LAs not included	CU Boulder (2005–2006) LAs recruited
Physics and astrophysics	2	1	7
MCD biology	0	0	4
Chemistry	14	0	N.A.
Geoscience	11	0	N.A.

More students enticed into teaching. The learning assistant (LA) program at CU Boulder improved recruitment of undergraduate students into K–12 teacher certification programs relative to the undergraduate recruitment rates noted for 2004 to 2005 without the learning assistant program. Chemistry and geoscience joined the program in 2006, and so have not yet recruited students into teaching certification programs. N.A., not applicable.

Results of the Learning Assistant Program

The learning assistant program has successfully increased the number and quality of future science teachers, improved student understanding of science content, and engaged a broad range of science faculty in course transformation and teacher education.

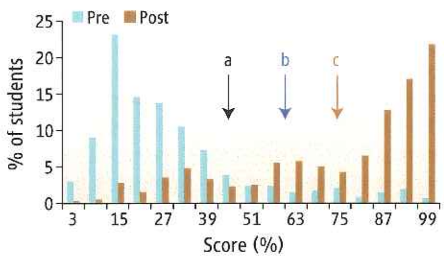
To date, 125 math and science majors have participated as learning assistants and 18 of

[1]School of Education, [2]Department of Physics, [3]Department of Astrophysical and Planetary Sciences, University of Colorado, Boulder, CO 80309, USA.

*To whom correspondence should be addressed. E-mail: valerie.otero@colorado.edu

them (6 math and 12 science) have joined teacher certification programs. These learning assistants have an average cumulative grade point average (GPA) of 3.4, higher than the typical 2.9 GPA for math and science majors who express interest in teaching (*12*). In physics at CU Boulder, the average GPA for majors is 3.0, and it is 3.75 for learning assistants.

The learning assistant program improved recruitment rates to science teacher certification programs over preexisting rates (see table on page 445). Before the learning assistant program, about two students per year from our targeted science majors enrolled in certification programs. Nationwide, about 300 physics majors each year are certified to teach (*13*). Thus, even small improvements in recruitment rates could have an impact on the pool of available teachers, particularly in the state of Colorado (*14*). Most of the learning assistants who decided to become teachers report that they had not explored teaching as a career until participating as learning assistants. Factors that led to decisions to become teachers include recognition of teaching as intellectually challenging and positive attitudes among participating faculty (*7*).



Learning assistants improve student learning. Pretest and posttest FMCE results for CU students in a transformed course with learning assistants. The pretest median is 24% (±1%) (n = 467); the posttest median is 85% (±1%) (n = 399). Arrows indicate posttest average (mean) scores for (a) students nationwide in traditional courses with pretest scores matching those of CU students, (b) students in a CU course that features educational reforms but no learning assistants, and (c) students in the CU course transformed with learning assistants (arrow shows the mean of the brown bars).

Development of Content Knowledge

Each of the participating departments demonstrates improved student achievement as a result of the learning assistant program (*15–17*). The transformation of the introductory calculus-based physics sequence provides an example. These courses are large (500 to 600 students), with three lectures per week implementing peer instruction and personal response systems (*17, 18*). The learning assistant program has provided enough staff to implement student-centered tutorials with small-group activities (*19*). Learning assistants and TAs train together weekly to circulate among student groups and ask guiding questions. The number of applicants for learning assistant positions in physics is currently 50 to 60 per term for 15 to 20 positions.

We assessed student learning with the Force and Motion Concept Evaluation (FMCE) (*20*) and the Brief Electricity and Magnetism Assessment (BEMA) (*21*). In transformed courses, students had an average normalized improvement of 66% (±2% SEM) for the FMCE test (see chart, left), nearly triple national average gains found for traditional courses (*3, 22*). With the BEMA exam, the average normalized learning gains for students in the transformed courses ranged from 33 to 45%. National averages are not yet available for this new BEMA exam. The normalized learning gains for the learning assistants themselves average just below 50%, with their average posttest score exceeding average scores for incoming physics graduate students. In a different model, students enrolled in a physics education course can opt to participate as learning assistants for additional credit (*23*). These students make gains twice that of their peers who do not opt to participate as learning assistants. Students who engage in teaching also demonstrate increased understanding of the nature of teaching and improved abilities to reflect on their understanding of teaching and learning (*23*) (table S2).

Impact on Faculty

Faculty members participating in the learning assistant program have started to focus on educational issues not previously considered. Faculty members report increased attention to what and how students learn. In a study of faculty response to this program, all 11 faculty members interviewed reported that collaborative work is essential, and learning assistants are instrumental to change (*7*). One faculty member notes: "I've taught [this course] a million times. I could do it in my sleep without preparing a lesson. But [now] I'm spending a lot of time preparing lessons for [students], trying to think 'Okay, first of all, what is the main concept that I'm trying to get across here? What is it I want them to go away knowing?' Which I have to admit, I haven't spent a lot of time in the past thinking about." This type of statement is common among those who engage in course transformation for the first time (SOM text).

Sustaining Successful Programs

The learning assistant model can be sustained and modified for a variety of institutional environments. Another longstanding successful model, the UTeach program at the University of Texas (*5*) has demonstrated that it is possible to internally sustain educational programs for science majors. These and other model programs bring together partners who each have a vested interest in increasing the number of high-quality teachers and the number of math and science majors, as well as improving undergraduate courses.

Implementation of a learning assistant program requires local interest from faculty in the sciences and education, as well as administrative backing and funding of a few thousand dollars per learning assistant per year (SOM text). The cost of a learning assistant is less than one-fifth that of a graduate TA. Learning assistants may also receive credit in lieu of pay. Another model is to fund learning assistant stipends from student fees.

With collective commitment, education can be brought to greater visibility and status, both for students considering teaching careers and for faculty teaching these students (SOM text). As scientists, we can address the critical shortfall of K–12 science teachers by improving our undergraduate programs and supporting interest in education.

References and Notes

1. J. Handelsman *et al.*, *Science* **304**, 521 (2004).
2. J. Handelsman *et al.*, *Science* **306**, 229 (2004).
3. R. Hake, *Am. J. Phys.* **66**, 64 (1998).
4. National Science Board, *Science and Engineering Indicators 2006* [National Science Foundation (NSF), Arlington, VA, 2006], vol. 1, NSB 06-01; vol. 2, NSB 06-01A.
5. UTeach (https://uteach.utexas.edu).
6. Physics Teacher Education Coalition (www.ptec.org).
7. V. Otero, paper presented at the AAAS Annual Meeting, Washington, DC, 17 to 21 February 2005.
8. M. Neuschatz, M. McFarling, *Broadening the Base: High School Physics Education at the Turn of the New Century* (American Institute of Physics, College Park, MD, 2003).
9. NRC, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Future* (National Research Council, Washington, DC, 2005).
10. U.S. Department of Education, Office of Policy Planning and Innovation, *Meeting the Highly Qualified Teachers Challenge: The Secretary's Second Annual Report on Teacher Quality* (Editorial Publications Center, Washington, DC, 2002).
11. L. S. Shulman, *Educ. Res.* **15**, 4 (1986).
12. L. Moin *et al.*, *Sci. Educ.* **89**, 980 (2005).
13. M. Neuschatz, personal communication.
14. Colorado Commission of Higher Education, *Report to Governor and General Assembly on Teacher Education* (CCHE, Denver, CO, 2006).
15. J. K. Knight, W. B. Wood, *Cell Bio. Educ.* **4**, 298 (2005).
16. M. Nelson, doctoral dissertation, University of Colorado, Boulder, CO (2005).
17. N. D. Finkelstein, S. J. Pollock, *Phys. Rev. ST Phys. Educ. Res.* 1, 010101 (2005).
18. E. Mazur, *Peer Instruction: A User's Manual* (Prentice-Hall, Englewood Cliffs, NJ, 1997).
19. L. McDermott, P. Shaffer, *Physics Education Group, Tutorials in Introductory Physics* (Prentice-Hall, Saddle River, NJ, 2002).
20. R. K. Thornton, D. R. Sokoloff, *Am. J. Phys.* **66**, 338 (1998).
21. L. Ding, R. Chabay, B. Sherwood, R. Beichner, *Phys. Rev. ST Phys. Educ. Res.* **2**, 010105 (2006).
22. The student normalized improvement is defined as (posttest – pretest)/(100 – pretest).
23. N. D. Finkelstein, *J. Sch. Teach. Learn.* **4**, 1 (2004).
24. This work is supported by the NSF, the American Institute of Physics, the American Physical Society, the American Association of Physics Teachers, and the University of Colorado. We thank the STEM Colorado team and the PER group at the CU Boulder for helping develop and maintain this effort.

10.1126/science.1129648

Supporting Online Material
www.sciencemag.org/cgi/content/full/313/5786/445/DC1

Strengthening Undergraduate and Graduate STEM Education

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

Summary of Oral Testimony
Feb 4, 2010

Noah Finkelstein
Department of Physics, University of Colorado at Boulder

Education is society's fundamental form of investment in its future.

As a result, we are now deciding among a variety of **possible futures** for our nation. Will we depend on other countries for technological innovation? Or for essential technological infrastructure, such as energy? Will our children grow up to be leading innovators and scientists? The current outlook is somewhat pessimistic.

While, education is a fundamental form of investment in our future, **A critical, perhaps the critical linchpin in our educational system is in Higher Education**. In addition to housing undergraduate and graduate education, it is where STEM disciplines are defined and practiced; it is the destination of students in our pre-college system; it is where teachers are educated and return for professional development; it is where we produce materials, assessments, and standards for the broader system; it is where leading research on student learning occurs. **It is also all too often overlooked in the national discussions in STEM education.**

I make 3 points in this testimony:

1) **We know what to do but not how to do it broadly.** Through DBER we have shifted our understanding of teaching and learning. We shift from the teacher-centered model of information delivery to student-centered, inquiry-oriented environments that focus on knowledge generation. Application of these ideas, such as Colorado Learning Assistant Program, **have led to improved learning**, where students perform 2 to 3 times better. Yet, despite knowing what to do, **such educational practices not widespread.** Research shows that **we are not taking a scholarly and scientific approach to promoting <u>change</u> in STEM education** on a broad scale.

2) The **challenges in our STEM educational system are complex and intertwined, and so, too, should be our solutions**. We can effect sustained change by coupling, efforts in undergraduate and graduate education, teacher preparation and research in STEM education. Through the Colorado Learning Assistant program, we focus on course transformation, k12 teacher recruitment and preparation, faculty development, and research. The **results lead to increased learning by all students, improved faculty practices, a dramatic increase in teacher recruitment, and fundamental research**. There are plenty of other examples, such as the Science Education Initiative, Informal Science Education and CIRTL that all run on our campus. All of these efforts indicate that **we need to work across levels of the system.**

3) **Key seed-funding from the Federal Government can potentially stimulate and unlock $100's B in latent infrastructure of the higher educational system.** We need to ensure that faculty practices at the university are aligned with our understanding of student learning. We need to establish institutional resources that support faculty engagement in meaningful educational experiences. We need to build on and support discipline based education research in STEM. The **National Science Foundation (NSF)** provides an excellent model in providing both funding and prestige (imprimatur) to effect change. Key NSF programs support individuals, such as **Distinguished Teaching Scholars (DTS)** program, **CAREER, PFSMETE, GRF's.** Similarly, programmatic work supported by **CCLI, REESE, DR-K12,** recent education efforts within NSF's **STEM directorates,** and **Noyce** have led individuals and localized programs to create effective models of educational practice. These are the NSF programs that support the high risk, high reward research that is the hallmark of American innovation.

Meanwhile **sustained Federal support** is necessary and a characteristic of other Federal Departments.

What is needed is a cultural shift – within science, technology, engineering and math:

- for STEM **departments** to take up the mantle of educational reform and assume leading roles in STEM education challenges across all levels,
- for **institutions** to integrate efforts across STEM disciplines and teacher education programs,
- for **professional organizations** and societies to assume leadership in endorsing, enabling, and connecting efforts across the nation in reform. National societies play an essential role. In physics and at the University of Colorado, the commitment of the Am. Assoc. of Physics Teachers, Am. Inst. of Physics, Am. Physical Society, and the Assoc. of Public and Land-grant Universities have been critical in supported sustained transforation.

and for this **Committee to catalyze and to endorse both in name and in action (funding) these key stakeholders** in improving STEM education at the undergraduate and at all levels.

Through targeted Federal funding (in the $1B's) we can engage university resources ($100B's) that reside, largely inert, to improve STEM education.

Such cultural shift can be the result of a Grand Challenge, where all Americans realize their identity and agency in STEM education reform.

As such, we can return to our roots as a Democracy based on an educated citizenry.

Thank you for your dedication to this critical issue.

Written testimony, transcripts and video of the hearing is available at:
http://science.house.gov/Publications/hearings_markups_details.aspx?NewsID=2723

EDUCATION NEWS COLORADO
http://www.ednewscolorado.org/

CU a leader in preparing STEM teachers

Posted by Julie Poppen on Jan 29th, 2010

CUTeach co-director Valerie Otero works with student Learning Assistants

After years breaking down the often impenetrable walls between colleges and departments in academia, the University of Colorado is finally getting attention for its comprehensive and groundbreaking efforts to recruit future teachers in math, science, technology and engineering.

An array of quieter honors culminated recently with CU-Boulder Chancellor Phil DiStefano shaking hands with President Obama in the White House during an event aimed at letting the president know what universities are doing to address the national shortage of science and math teachers. CU was among the 41 public research institutions that pledged to double the number of teacher recruits in these hard-to-fill areas by 2015.

"We are fast on the train to teacher recruitment, preparation and support – particularly at the K-12 level," said Noah Finkelstein, an associate professor of physics and one of the directors of the university's iSTEM (Integrating Science, Technology, Engineering, & Math Education) program. "We believe we're just at the beginning of establishing CU-Boulder, in particular, as a national hub for STEM education."

Nationwide, the goal is for 121 public research universities to increase the number of new science and math teachers to more than 10,000 annually by 2015, meaning there will be an additional 7,500 new teachers pumped out of the schools over the next five years. For CU, it means doubling the 28 STEM graduates who now qualify each year for teacher licensure in math or science.

Rising above the storm

Finkelstein said CU's initiatives stem from a 2007 report called "Rising Above the Gathering Storm," in which The National Academies argued that the U.S.'s weak standing in science and engineering would "degrade its social and economic conditions and in particular erode the ability of its citizens to compete for high-quality jobs."

The report's top recommendation was to improve K-12 science and math education. The ambitious goal was to recruit 10,000 science and math teachers every year to educate 10 million students. CU jumped to meet the challenge.

According to a news release issued by the Science and Mathematics Teacher Imperative, an agenda sponsored by the Association of Public and Land-grant Universities (APLU), CU-Boulder "stands alone in the breadth of its integrated campus-wide STEM initiatives that transform the way undergraduate courses are taught."

As another symbol of its growing eminence in the field, CU was selected to host the APLU's Science and Math Teacher Imperative's inaugural conference last spring.

The overarching goal is simple, said Michael Klymkowsky, a professor in molecular, cellular and developmental biology and co-director of CU Teach, a program created to allow students pursuing STEM subject areas to attain a degree and a teaching certificate in four years.

"We want to recruit people early in their career so they see teaching as a positive thing rather than a fallback position," Klymkowsky said.

Achieving the goal is not so simple, but CU has several programs underway that complement one another, and campus leaders are seeing results.

A coveted program

For starters, CU-Boulder was one of 13 teacher education programs in the nation to be awarded a grant in 2007 by the National Math and Science Initiative to model its CUTeach program after the nationally known UTeach program.

CUTeach represents innovative collaboration between the College of Arts and Sciences and the School of Education. The program allows math and science students to earn a degree in a math or science major and simultaneously pick up a secondary math or science Colorado teaching license without forcing the student to stay in school longer than necessary.

The first CUTeach course taken by freshmen and sophomores gets them into real elementary school classrooms to see if they like teaching. The second phase of the program places CU students in middle school classrooms. Presently, 170 students are enrolled in CUTeach. And a brand new CUTeach program is also under way on CU's Colorado Springs campus.

"The thing that makes CUTeach different from other teacher education programs is that we place teacher recruits into the classrooms of real teachers," said program co-director Valerie Otero. "Those teachers play a real role in the teacher preparation of our students."

Another program that has garnered attention nationwide is CU's Learning Assistants program, which has been around since 2003.

The innovative program places selected Learning Assistants from STEM majors into large, introductory (often dull) STEM courses. The Learning Assistants evaluate how well students are learning the material – based upon pedagogy learned through education courses. They help struggling students overcome their barriers to learning through small group activities.

The program has now been emulated at 13 other institutions, including Cornell University.

LAs – sometimes six or more in one lecture class – are assigned to 35 courses covering topics in chemistry, physics, astrophysical and planetary sciences, molecular, cellular and development biology, mathematics and applied mathematics.

The LAs meet weekly with faculty to plan for the upcoming week, reflect on the previous week, and analyze assessment data. They facilitate collaboration among learning teams by assessing student understanding and asking guiding questions. They attend a special Mathematics and Science Education seminar where they reflect on their own teaching and learning and make connections to relevant education literature.

Otero said "teaching leads to learning" and that the undergraduate LAs are often confused with doctoral candidates because of their breadth of knowledge and ability to defend concepts.

"Learning is embodied in the experience of serving as a Learning Assistant," Otero said.

The program was launched with a National Science Foundation grant but is now covered by funds from various university units, including the provost and deans of engineering, arts and sciences and education.

CU science teaching fellow Laurie Langdon, who works with the LA program, said synergy is building between CUTeach and the LA program. A growing number of LA applicants have participated in CUTeach and know they want to become teachers.

"Hiring LAs has evolved a bit from being totally focused on trying to recruit students who might not otherwise consider teaching as a career to one in which we're balancing recruitment with support of students who have made decisions to go into teaching," Langdon said. "It is very exciting to see such a critical mass of future STEM teachers build up over the last several years, and I don't see it slowing down yet."

Senior Cassandra Ly, 21, is one student who had an inkling she'd want to teach even though she started at CU on a pre-med track. Working as an LA for two great faculty members, including the Nobel Prize winning chemist Tom Cech, sealed the deal. She graduates this spring with the goal of becoming a middle school science teacher in her home district, Adams 12.

As for the national shortage of math and science teachers, Ly said many of her friends and peers aren't so interested in science because it's "one of hardest things to learn." She said the quality of teaching isn't always great, although she sees that beginning to change as professors seek to understand what makes students tick.

"A lot of professors put an emphasis on research vs. teaching," Ly said.

Other CU programs

A few other programs are putting CU on the STEM map.

Distinguished Professor and Nobel laureate Carl Wieman launched the Physics Education Technology project, or PhET, at CU in 2002. The globally renowned education tool uses interactive web-based simulations for physics instruction.

In 2009, 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 as a national hub of STEM education research and reform.

All told, more than $30 million in grants are funneled toward the many STEM endeavors at CU.

Through its programs, the Boulder campus has increased the number of STEM majors completing secondary math and science teacher certification from an average of six per year a decade ago to 13 today. The number of physics and chemistry majors enrolling in teacher certification has more than tripled in the past three years.

Finkelstein said there were only five physics majors statewide enrolled in teacher certification programs seven years ago. Now, CU recruits that many every year.

The big picture

Few would deny the inherent importance of having well-trained scientists, engineers and mathematicians in the nation's classrooms. Obama has pointed out the fact that American 15-year-olds now rank 21st in science and 25th in math when compared their peers around the world.

A study by the National Math and Science Initiative found that about 30 percent of high school math students and 60 percent of those enrolled in physical science classes had teachers who did not major in the subject or were not certified to teach it.

Finkelstein cited one study showing that two of three high school physics teachers have neither a major nor minor in physics.

However, the root of the problem may not be an inadequate number of STEM graduates with teaching certificates, but rather a steady drain of qualified teachers from the nation's schools, according to a study cited by Education Week last spring.

Richard M. Ingersoll, a professor of education and sociology at the University of Pennsylvania, admitted being "heretical" when he released his finding that colleges and universities are producing 2½ times more math and science teachers than schools require to replace those who are retiring. Ingersoll said policymakers ought to focus on retaining the much larger pool of science and math teachers who are already in schools.

Otero, a professor in the School of Education, said there are programs addressing that side of the issue as well.

Broadly speaking, there may not be a crushing demand for more scientists or mathematicians, but there is a need for an educated populace, said CUTeach co-director Klymkowsky, noting that an under-educated public leads to bad public policy on important issues, such as climate change.

Klymkowsky, who inhabits a cluttered office strung with holiday lights and all manner of biological images and artifacts, said we live in an era when "politicians can say really stupid things scientifically, and not be labeled stupid, ignorant people." Klymkowsky said he would like to see that trend reversed.

"There is a lack of understanding about how science works," he said. "We're not trying to generate more scientists, we're trying to create a population that gets the value of science."

He blames the present state of scientific illiteracy on entrenched systems that serve to eliminate those with a passing interest in science but who may not want to become career scientists or professors.

"Our system is so designed to sort people – who wants to go to this school or that school – when the important thing is, can you understand basic ideas of science? Literacy has to do with how people think, not just the recitation of stupid facts."

Others at CU, though, including Finkelstein, believe the U.S. will need more highly skilled scientists, mathematicians and engineers down the line. While the university's STEM initiatives are critical to address the national teacher shortage, they're also vital to the nation's economic health.

"Our economy is driven by science and technology," Finkelstein said. "Eighty-percent of jobs that are going to exist in five to 10 years haven't been created yet. We need to create people who know how to use technology and learn on the job."

CU Learning Assistant Program stats

- 27 former LAs are now working as teachers
- 25 former LAs who were recruited to teaching careers are either finishing teacher certification requirements or have decided not to teach
- About 85 Learning Assistants are hired each semester
- Each assistant costs $3,000 per year
- 444 STEM majors have participated in the program
- 8,000 STEM students per year demonstrate a higher level of learning due to LAs having been in their large, introductory courses
- 15 percent of LAs – representing the top students – are recruited to become teachers
- LAs are paid $1,500 per semester to work about 10 hours per week
- LAs who decide to pursue a K-12 teaching license are eligible for a $6,000 to $10,000 Hach or Noyce scholarship

Education emergency's first responders

As the 'gathering storm' in science and math education approaches 'Category 5' and imperils American competitiveness, CU students rush in

By Clint Talbott

Ryan O'Block had been considering a career in K-12 teaching since high school, but when he signed up to become an undergraduate "learning assistant" in an introductory physics course at the University of Colorado, he expected the experience to be daunting.

He signed up to teach three sections and assumed he'd be exhausted by the end of each day. Instead, "I found myself more energized."

"A light bulb clicked on for me," O'Block recalls. "This is what I want to do."

As a learning assistant, he didn't deliver monologues or lectures. He would help small groups of students grappling with concepts. "What was energizing about that was these students would be wrestling with their own ideas," O'Block recalls.

"My job was not to tell them this is the way it is." His role was akin to leaving a trail of educational bread crumbs.

"It's kind of a fun game to play. Anybody can sit there with a textbook and say F=ma" (which stands for "the force acting on an object is equal to its mass times its acceleration," Newton's second law of motion).

Helping students figure out problems on their own can be more difficult than delivering lectures by rote. It also requires a level of conceptual mastery that many teachers simply lack, statistics show.

O'Block, a good student pursuing a major in physics and a minor in mathematics, is in a program in which he has committed to teaching in a high-needs K-12 school district.

Traditionally, the brightest students in science, math and engineering were shunted away from teaching at the K-12 level. They were told, explicitly or implicitly, that the best scientists and mathematicians should be in higher education or doing private-sector R&D.

It is not that way at CU any more. Here, teaching effectively is recognized as a legitimate, scholarly activity for faculty and their students.

When he was in high school and mentioned his interest in teaching, he saw that bias firsthand.

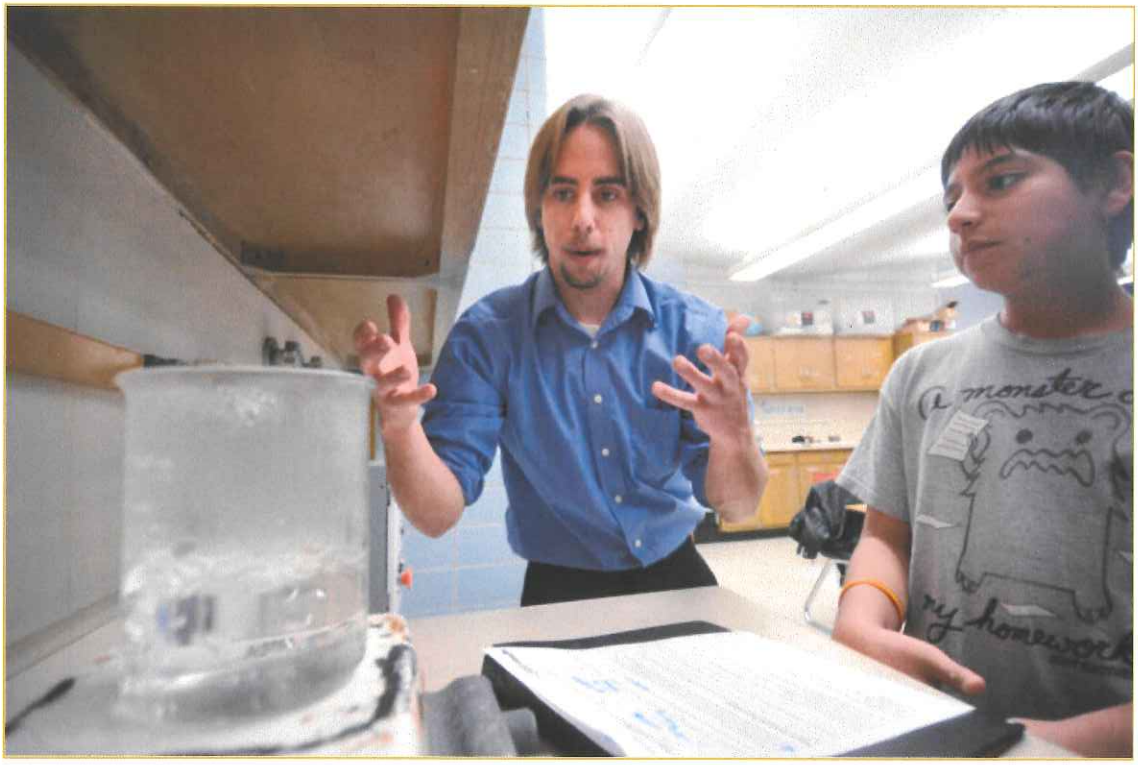
"I had teachers say, 'Ryan, don't go into teaching. You're too smart,'" O'Block recalls, noting that such statements shocked him. He believes the best and brightest should also teach.

He used to ask: "Why aren't we recruiting the most gifted people to teach the next generation? Why is teaching looked down upon? Why is it reserved as a backup plan?"

The National Academies have pondered the same questions for years.

As the National Academies note, 93 percent of U.S. public-school students in fifth through eighth grades are taught physical sciences by teachers with no degree in the physical sciences. When teachers don't really understand the science and math they teach, students won't, either.

'Rapidly approaching Category 5'



Noyce Fellow Ryan O'Block works with a middle-school student in Thornton. CU Photo by Casey A. Cass

That is an educational shortcoming. It is also a matter of national concern and, as the National Academies contends, a threat to America's prosperity. This case is made in a 2010 National Academies report, "Rising Above the Gathering Storm, Revisited: Rapidly Approaching Category 5," which noted the lack of progress on U.S. competitiveness investments in the five years since the academies' last report.

As the National Academies argues, students who are ill-taught science in middle school or high school will be less-prepared for the rigors of higher education—and less likely to realize their full intellectual capacity.

Hence, these ill-prepared students will make comparatively fewer groundbreaking discoveries, secure relatively fewer important patents and ultimately help generate fewer American exports and jobs.

America's ability to compete in the global economy has deteriorated in the last five years, and it must invest in science education and research—as its global competitors have—to keep from slipping further, the National Academies argued.

O'Block is one of many CU students who take this challenge seriously, accepting scholarships in exchange for a promise to dedicate years of their lives to teach science in high-needs K-12 school districts.

If, as the National Academies argue, this is an emergency, these students and their CU professors are the first responders. The university is their training ground.

O'Block is the recipient of a Noyce Fellowship. Noyce fellows receive up to $15,000 per year. They must teach for two years in a K-12 high-needs school district for each year of scholarship they receive.

The Noyce Scholarship Program, funded by the National Science Foundation, began at CU in 2005, and 51 CU students have become Noyce fellows since then.

To be a Noyce fellow at CU, a student must have already served as an undergraduate "Learning Assistant," facilitating small-group interaction in large-enrollment courses or participated in CU-Teach courses where CU students work with K-12 students in local science classrooms.

Committed to K-12 teaching

Since 2003, CU's nationally emulated LA Program has been enhancing large-enrollment science courses for three purposes: 1) to recruit and prepare talented K-12 science teachers, 2) to encourage faculty to participate in the preparation of future science teachers and, 3) to improve science education for all students.

The LA Program has transformed more than 35 courses. CU hires about 180 learning assistants per year and it costs about $3,000 per year per LA, who help teach about 8,000 students annually.

Learning assistants do more than work with other undergraduates toward an understanding of central scientific concepts. In the process of coaching others, LAs learn the material better themselves, which is one factor that helps them become better teachers.

The LA Program administers assessments before and after selected science and math courses. Courses that are supported by LAs score higher—and students learn more—than those not supported by LAs.

Learning assistants themselves score even higher than those they coach. Such data indicate that learning assistants know their stuff, which will help them—and the nation—regardless of whether they become research professors or high-school physics teachers.

Both the LA Program and the Noyce Fellowship Program are part of CU's ground-breaking work in education and research advancing Science, Technology, Engineering and Mathematics—or STEM.

It is from the pool of LAs, who have already demonstrated learning and teaching prowess, that most Noyce fellows are picked. While LAs might—and many do—choose to teach in a K-12 school, Noyce fellows promise to teach in a high-needs school district.

Such districts are legion. In Colorado, only one district is not classified as "high needs."

Noyce fellows at CU are required to engage in disciplined-based research with a science, mathematics or education faculty member. They also work with local K-12 math and science teachers.

The Karate Kid and Mr. Miyagi

Noyce Fellow Hunter Cuchiaro, center, works as a class facilitator in a Northglenn High School physics course. CU Photo by Glenn Asakawa.

Noyce fellow Hunter Cuchiaro did not come to college planning to become a middle-school science teacher. "No," he emphasizes. "Absolutely not."

But things changed when the CU student who had been focused on ornithology, theatre and language "happened upon chemistry" and then took an education class.

Cuchiaro acts as a physics class facilitator at Northglenn High School. The teacher is currently employing an LA program herself, in which high school students work with elementary school students to learn science. Cuchario is helping collect data on the effects of this program. "My role is I'm the Karate Kid, and she's Mr. Miyagi," Cuchiaro quips.

Good teaching is not only cognizant of the concepts and how to bring content alive, Cuchiaro says, "It's also a matter of engaging with students as people."

And those people don't always see the value of science and math. K-12 science and math teachers are sometimes asked a tough question. "Why do I need to learn this if I'm not going to be a scientist?"

Not wanting to give a half-formed response, Cuchiaro says, "My first response will be, 'I need to think about that.'"

It's not that the student is saying, "This is stupid." The student might be asking for a reason to learn science and math. The student might be telling the teacher, in essence, "You're not making this relevant."

To meet that challenge, Cuchiaro might return to class the next day and say, "If your interests lie somewhere else, this is how it applies. I would try to make it relevant."

Further, if students don't see the value of a course, "I need to be aware of the cultural nuances that I'm dealing with."

He adds: "Going into science might not be for everyone, but thinking through problems and resolving a best approach to your task is for everyone. Regardless of your background or where you end up, your ability to address the world you live in depends on your ethic in overcoming obstacles. You have the tools, and my science classroom will give you the opportunity to practice with them—what will you (the student) decide?"

As Cuchiaro notes, he loves chemistry and loves science. Additionally, "I love the kids. I love the idea that every day you go into a classroom and you're doing work, but you're doing it in a creative way ... I think it's a wonderful gift that you could do that as a profession."

Conveying 'how cool this is'

Noyce Fellow Sam Sherman says he didn't come to CU planning to be a teacher. He planned to be an engineer. But students inspired him to be a teacher. CU Photo by Noah Larsen.

Sam Sherman is also a Noyce fellow this year. Like Cuchiaro, he didn't come to CU thinking he'd be a teacher. He liked physics and figured he'd become an engineer, which he thought was a good way to make a living while using physics.

There was just one problem with engineering. "I wasn't that into it," Sherman says.

He became a learning assistant and realized that he loved to teach. He also realized that he had much to learn.

"What I thought I knew about physics was not anywhere close to what I ended up learning as a teacher," Sherman says.

Before becoming a teacher, Sherman tended to view science as a collection of equations and memorizable facts. When he had to teach science, students asked him to explain why it was relevant.

Part of the answer, regardless of the students' long-term goals, Sherman emphasized, was conveying "how cool this is." In some science classes, students are given variables such as X, Y and Z and asked to find an answer.

"But the real world is not like that. It doesn't always give you these nice, little facts that you can plug into it," Sherman says.

Learning science means learning the scientific method, which involves critical-thinking skills that are helpful in any human endeavor.

Sherman recognizes that the National Academies, the President's Council of Advisors on Science and Technology and many others see STEM education and research as critical to the nation's economic competitiveness. But that's not why he's going to teach.

"The individual students were what inspired me," he says. And to those who suggest that good scientists should be in higher education, he adds, "You're still doing science with students."

Though he is similarly eager to teach, O'Block harbors no illusions about the life of a teacher. "It's going to be extremely frustrating," O'Block says.

"Many teachers go out and think, 'We're going to change the world.' But you have to come to terms with the fact that it's not going to happen, and especially not in the first couple of years."

Similar Posts:
Education: society's investment in the future
Workshop aims to help K-12 faculty teach evolution
CU joins White House pledge on science, math ed
Turning students on to science and math
Science-education symposium aims for change