Penn State College of Education

Report on the Status of Science, Technology, Engineering, and Mathematics Education in the United States

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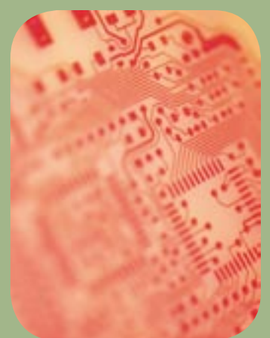

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Dean's Message

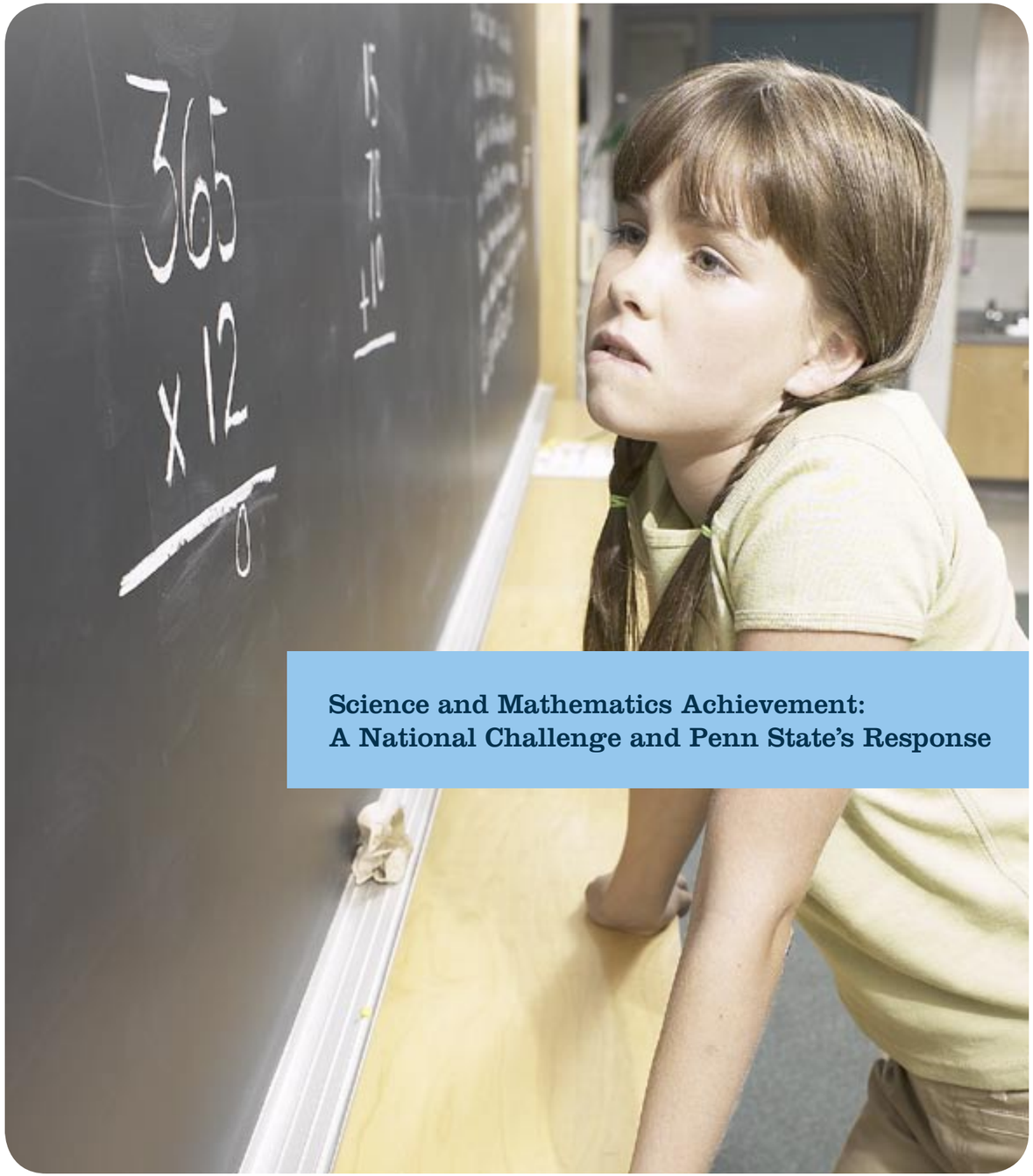
I am pleased to welcome you to a new publication series wherein we will periodically address a timely topic in the field of education and provide both a critical overview of the relevant issues and a report on what the Penn State College of Education is doing to respond. Our goal is to bring our alumni and friends up to speed with respect to critical issues in the field and to help you learn more about the modern college and its growing strengths.

Our topic for 2006 is the state of science, technology, engineering, and mathematics education, or what has come to be known as STEM education. It is hard to escape the sometimes quite dire pronouncements in the media about the crisis the nation is facing in our efforts to maintain preeminence in STEM-related fields. There are serious concerns about the lack of interest of the nation's youth, particularly young women and persons of color, in studying the STEM disciplines. And there are parallel concerns about the nature of instruction in these fields along with sometimes quite striking differences in points of view about the preferred approach. These concerns are not limited to K–12 schools, but extend into higher education, where there is much debate about how best to teach science, mathematics, and technology to young adults.

It is perhaps worth noting that these are not new concerns. We are coming up on the fiftieth anniversary of the passage of the National Defense Education Act, which you may recall, was motivated by concerns about the Soviet Union surpassing the United States in the race into space. Nor is the current debate without its share of irony. I can remember attending a national meeting at the start of the first Gulf War where there was much criticism about the teaching of mathematics and science in the schools. We all hurried from the meeting to learn the latest about the war and were dazzled by the spectacle of "smart" bombs traveling down chimneys of chosen targets with remarkable precision—all courtesy of technologies that were presumably designed by persons trained in conventional ways using the very methods that were prompting our criticisms at the meeting.

This is a complex area of the field with numerous interconnected issues. I think you will be impressed with the comprehensive nature of the College of Education's response. In line with our responsibility as a professional college in a research-oriented university, we are placing emphasis on research and the implications it has for the improvement of practice in the field. We are also working collaboratively with the STEM colleges at Penn State to bring the expertise we can offer about teaching and learning phenomena to the content expertise offered by our colleagues in mathematics and the sciences. It is through the kinds of partnerships that we describe in this report that we will truly make progress at resolving these longstanding issues.

I welcome your interest and your questions. If you would like to learn more, please visit our Web site (**www.ed.psu.edu**), and I invite you to contact the faculty members whose work we highlight in the report. Their contact information can be easily found on our Web site. In addition, please feel free to contact me or any of the members of the college's administrative leadership team. We are very proud of what we are accomplishing as a college, and we are always interested in hearing from you.



Science and Mathematics Achievement: A National Challenge and Penn State's Response

Science and Mathematics Achievement: A National Challenge and Penn State's Response

The U.S. education system faces a daunting problem: Its students are not grasping math and science.

Contributing factors include public apathy regarding math proficiency, less-than-effective instruction in these areas, and a lack of qualified educators at all levels. This predicament potentially will become more critical as technologies advance and the world demands higher proficiency in these fields.

Penn State is in a position to develop a strong coordinated response to this challenge. From its research into these issues, the College of Education recognizes that the key to building a technology-based workforce is an integrated K-through-university, problem-based approach to teaching and learning in the science, technology, engineering, and mathematics (STEM) disciplines.

Throughout the College of Education, faculty are investigating the scope of this problem and working to understand its underlying factors. Based on this research, they have developed programs to improve how students learn—and how teachers teach—mathematics and science.

Problem: American Students Are Trailing their Global Peers

Published reports show that American students are falling behind their foreign counterparts in STEM disciplines. In standardized testing over the past several decades, students in other industrialized countries have been raising the bar in math and science, while the scores of American students have remained flat. America's troubles are revealed in the numbers:

—In 1995, U.S. twelfth graders performed below the international average for twenty-one countries on a test of general knowledge in mathematics and science.

—In 2003, American 15-year-olds ranked twenty-fourth out of the forty countries participating in the Program for International Student Assessment (PISA) examination, which assessed students' ability to apply mathematical concepts to real-world problems.

—Just 7 percent of America's fourth- and eighth-graders achieved the advanced level on the Third International Mathematics and Science Study (TIMSS) test. In Singapore, 38 percent of fourth-graders and 44 percent of eighth-graders scored at the advanced level.

Obviously, a disconnect is occurring between the instruction and the average student's grasp of the subject matter. A number of reasons can account for this. Some argue that traditional instruction methods fail to grab students' attention. Others point to the struggles of teachers to improve classroom instruction while facing a lack of technology resources.

Penn State's Response: Improve Classroom Instruction

Prepare Teachers More Effectively

One way to improve classroom instruction is to teach developing teachers how to make the classroom an interesting place. Teaching Elementary School Science as Argument (TESSA) is one among many programs in the college focused on doing that. This research project, funded by the National Science Foundation, aims to develop electronic resources for supporting beginning teachers as they learn to give priority to evidence and explanation in their science teaching.

Carla Zembal-Saul, associate professor of science education, formed the TESSA research group to investigate how beginning elementary teachers learn to teach science in ways that emphasize evidence and argument. TESSA targets preservice teachers in their science content and methods courses and tracks their development into the first years of teaching.

As part of their science methods course, preservice teachers log in to the TESSA Web site, view video-based cases of science teaching, and respond to questions. Each of the online TESSA cases provides a set of instructional materials to help preservice teachers develop an understanding of the role of argumentation in school science. These online cases include videos of classroom teaching, reflection questions, teacher reflection videos, peer responses, lesson plans, and other teaching resources.

Zembal-Saul says of the program, "The TESSA resources are intended to support teacher learning by bridging the gap between education majors being learners of science to teachers of science. We have become quite effective at engaging preservice teachers in learning science in ways that are consistent with contemporary ideas about meaningful learning and science as inquiry. However, they rarely have opportunities to see science taught this way in real classrooms with real teachers and students prior to being asked to teach themselves. TESSA cases are designed to extend the kinds of issues about teaching and learning we take up in class to authentic classroom contexts."

The response from preservice teachers has been overwhelmingly positive. They recognize the immediate benefit of having access to these "visions of the possible." When interviewed during student teaching about important influences on their teaching practice, preservice teachers often make references to details from particular cases as having helped them work though problems of practice that they encounter.

Learn more about TESSA: **tessa.ed.psu.edu**

Empower Current Educators

The College of Education is committed to working with current K–12 teachers to help them learn how to utilize new methods in the classroom to make STEM subjects interesting and accessible to their students.

The Center for Science and the Schools (CSATS), based in the College of Education, is a University-wide initiative to develop collaborations between Penn State scientists and K–12 educators. Educators have access to a variety of resources through CSATS and its sponsored programs, a number of which are featured below.

E21 or Energy Education for the 21st Century, a collaboration between CSATS and Penn State Public Broadcasting, brings together curriculum specialists from Penn State with teacher consultants, multimedia specialists, and instructional designers to develop an innovative curriculum focusing on clean energy.

Utilizing a multimedia delivery model that is aligned with Pennsylvania state science standards, the E21 program offers online lesson plans, curriculum guides, and other teacher resources. Technology-rich lesson plans provide students with hands-on, inquiry-driven activities while instructional tools allow teachers to assess how much students know about science concepts.

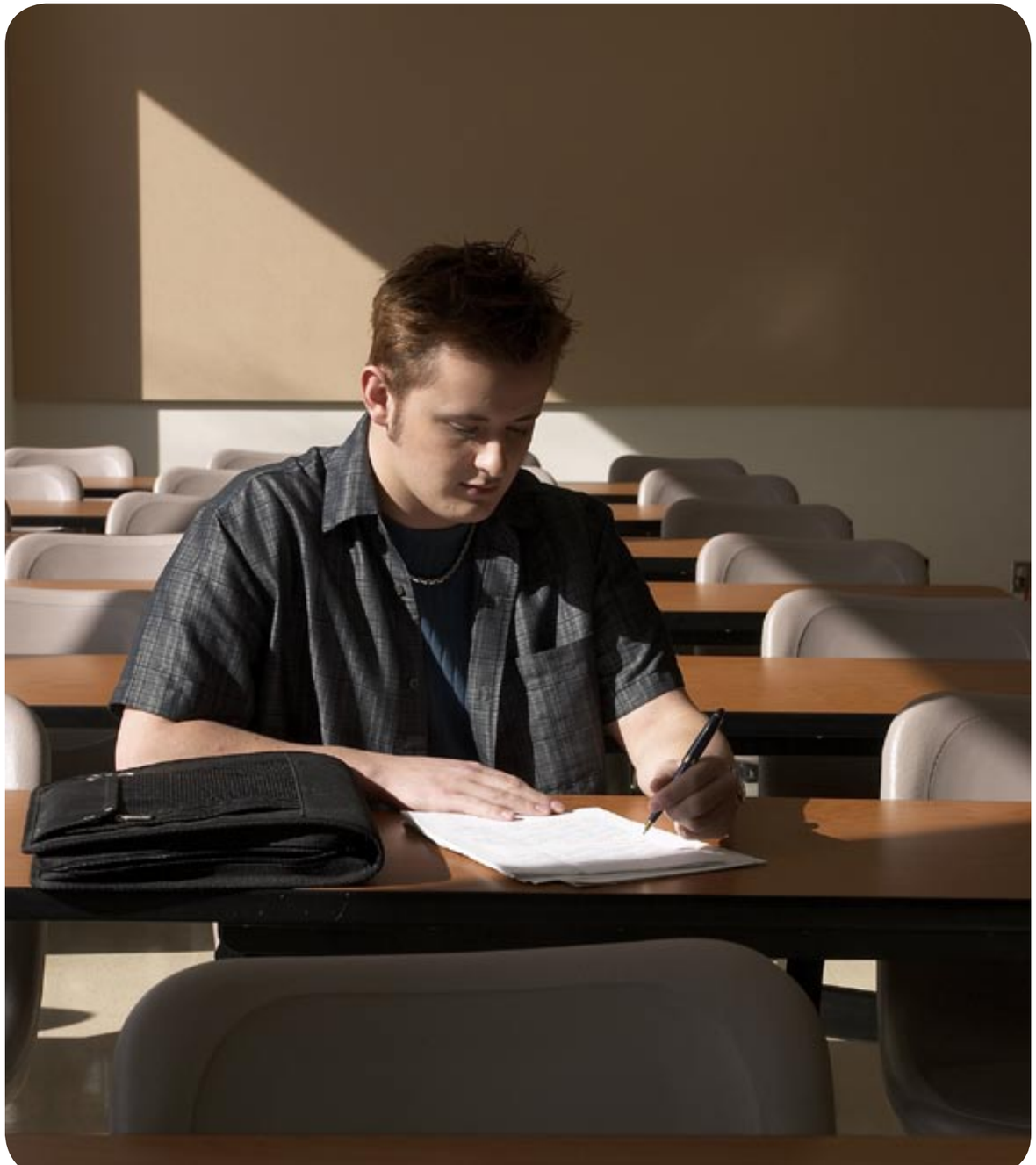
Another CSATS project is the Boeing–Penn State Research Sabbatical Fellowships for Teachers. With corporate philanthropic support from Boeing, this program brings science teachers to University Park to participate in research projects directed by Penn State scientists and engineers. Focusing on high-need urban schools, the program provides fellowships for middle school and high school teachers to conduct research in cutting-edge fields.

"The teachers will be making a professional contribution to science as well as learning new skills," says **William Carlsen**, professor of science education and director of CSATS. "This is a chance for science teachers and research scientists to collaborate and gain greater mutual respect for each other's endeavors."

CSATS also offers Saturday Science Workshops in which Penn State scientists share their research with elementary and middle school teachers and preservice teachers. "One Saturday a month, teachers and Penn State scientists come together in a relaxing professional atmosphere to share and learn," says **Karen Eklund**, professional development coordinator at CSATS.

Eklund and the presenters develop age-appropriate lessons that are aligned with the Pennsylvania Science and Technology/Environment and Ecology Educational Standards. The teacher participants become students for a day as they work through the inquiry-based lessons. They earn Act 48 (professional development) credit for their participation. "At the end of the workshop, teachers leave with lesson plans, science background information, and materials to use in their classrooms," says Eklund.

Learn more about CSATS: **csats.psu.edu**



Develop New Instructional Methods

Rose Mary Zbiek ’92 Ph.D., associate professor of mathematics education, and **Elizabeth Kisenwether** ’79 Eng, assistant professor in the College of Engineering, are investigating new instructional approaches for math education in “Math Excellence: Math Achievement in a ‘New Technology’ Context,” a collaboration between Penn State’s Colleges of Education and Engineering funded by the GE Foundation.

Middle school students in the Steelton-Highspire (Pennsylvania) School District are getting a better appreciation of how mathematics is applied to real-world engineering, information technology, and business settings. Zbiek and Kisenwether are engaging themes of interest to the students to foster interest in math and to improve standardized test scores for both Pennsylvania System of School Assessment (PSSA) and yearly TerraNova tests.

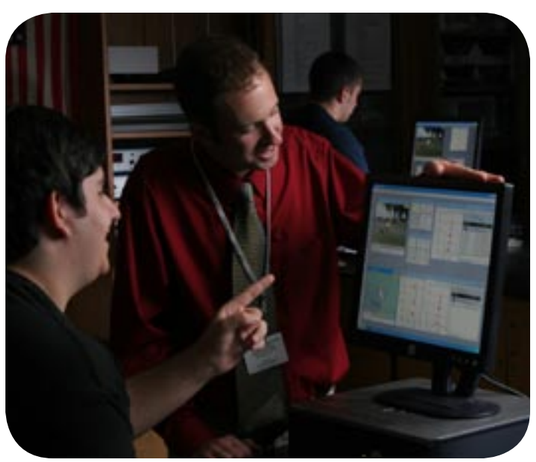
The students are learning the mathematical implications of using practical electronic devices (e.g., cell phones and warehouse inventory tags). “Students simply cannot hold back their surprise and enthusiasm when they see the cell phones and clothes they love appear as part of their math lessons,” says Zbiek. “They ask questions about mathematical ideas because knowing math helps them see their world in a new light.”

Others in the college are developing new instructional methods in the sciences. The Invisible College for Inquiry Science Study (ICISS) was formed last year as a research-oriented professional development group focusing on science instruction in secondary classrooms. **Scott McDonald**, assistant professor of science education, created the group by gathering practicing science teachers from across Pennsylvania. Forming the nucleus of the group, the teachers videotape exemplary inquiry science lessons that the group analyzes for professional development and academic dissemination.

In fall 2005, ICISS took the next step in its development by adding student teachers to its group. With ICISS teachers serving as mentors, the student teachers spent a semester learning to teach science using inquiry.

Reflecting on her unique student teaching experience, **Jessie Krautbauer** '05 B.S. commented, "Using inquiry requires the students to develop their own ideas and really think at a different level than the way that they're thinking in a traditional classroom. They're not just being given the information, they really have to find it out for themselves and that gives them such a solid foundation to be able to use those skills to build them up in the classroom and then be able to use them later on in their lives."

Krautbauer noted that, "At first many students were quite reluctant about learning in this manner simply because they were not familiar with it, and it required a much greater amount of work on their part. However, once they became used to it and began to realize how much information they were learning at such a deep conceptual level, they actually began to look forward to it and enjoyed the challenge that it posed."



Although the ICISS group is distributed in school districts across the state, technology helps the group communicate with one another and collaborate on projects. Utilizing online tools such as video, discussion boards, and blogs, the group supports the student teachers' development and develops models of inquiry instruction based on practice.

Utilize Technological Resources

A related effort to improve classroom instruction provides developing teachers with cutting-edge tools for instruction, lesson design, communication, and collaboration. At the start of the 2005–06 school year, Penn State's College of Education and Apple Computer, Inc., established a three-year partnership equipping prospective teachers in the award-winning Elementary Professional Development School (PDS) program and Secondary English PDS with laptop computers to use during their internship year. A central goal of this one-to-one computing is to transform learning and teaching at all levels, from students to beginning and veteran teachers to teacher educators.

Todd Roth '01 M.Ed., an intern teacher in the PDS program, explains: "The laptop has enabled me to think differently about the classroom and what it means to be a teacher. It's helped me make connections between several facets of teaching, including planning, instruction, and assessment, as everything is contained in one mobile educational tool. It's helped me create a new vision of what teaching can be with the capability of using and implementing various types of technology into the classroom and beyond."

Empowering Educators with Technology

Faculty in the college's Instructional Systems program are recognizing how vital technology has become for today's classrooms. With this knowledge, the program has just launched a new online Master of Education in Instructional Systems—Educational Technology program. This program will help teachers learn not only how to use the technology, but also how to measure the impact of the use of technology on student learning.

The program will have an immediate impact for the educators and their classrooms, as many of the courses require projects to be implemented and evaluated in working classrooms. The first cohort began in summer 2006.

This master's program and other Instructional Systems programs build directly on the active research of the Instructional Systems faculty. Instructional Systems faculty are currently investigating areas such as how to design effective technology-based learning environments and how to create online communities of learners using Weblogs and other communication tools.

For example, **Christopher Hoadley**, associate professor of education and information sciences and technology, is especially interested in designing and investigating communities supported by technology. He has been an active research partner with the Center for Technology Enhanced Learning in Science (TELS) since its inception.

TELS brings university researchers together with middle school and high school educators to improve instruction in science. Established by the National Science Foundation as a national Center for Learning and Teaching, TELS is headquartered at the University of California, Berkeley, and has partners from universities and school districts worldwide in addition to Penn State.

The collaboration between universities and school districts is central to the work of TELS, allowing researchers to work directly with classroom teachers to test and refine curricular activities and provide professional development to help teachers customize their materials and the methods they use for coaching their students. The experiences of the participating teachers help to inform university research, which can be studied and distributed to a larger audience.

Hoadley has been especially interested in the community created by the TELS research itself. "Studying how we work together makes TELS more than just another science unit. Our goal is to conduct quality learning research, professional development research, and, finally, partnership research. Since I have been able to document how the TELS community has worked together, we actually have something to say about what makes it successful."

Learn more about the Master of Education degree in Educational Technology: **www.worldcampus.psu.edu/MasterinEducationalTechnology.shtml**

Learn more about TELS: **www.telscenter.org**

Problem: Public Attitudes

American society seems to accept underperformance in the STEM disciplines. It's okay in our culture not to excel in math or science. A person can openly state, "I'm not good in math," and not feel the same stigma as admitting, "I'm not good at reading."

Not enough K–12 students in the United States take an interest in the STEM disciplines. A strikingly small percentage of American high school students are pursuing high-quality curricula that would prepare them to be tomorrow's leading scientists, engineers, and mathematicians.

—Only 15 percent of all undergraduates in the United States receive their degrees in natural science or engineering; in China, the number exceeds 50 percent.

—About 34 percent of doctoral degrees in natural sciences and 56 percent of engineering doctorates in the United States are awarded to foreign-born students.

Furthermore, a majority of parents believe that the current state of math and science education is fine. They see no need for educational reform. Such indifference raises the hurdle that the education system must overcome. "People must come to understand that mathematics can be very powerful, that it can be exciting," says **M. Kathleen Heid**, distinguished professor of mathematics education. "Today, mathematics is about teaching concepts and ideas that underpin procedures and problem solving."

Penn State's Response: Educate the Rising Generation

To help change these public attitudes, educators in the College of Education are reaching out to the rising generation of parents and educators by improving the math and science education they receive in college. The Center for the Integration of Research, Teaching and Learning (CIRTL) is helping graduate students and faculty in the STEM areas develop strong teaching skills that help them teach others. The result will be a national science, engineering, and mathematics faculty that will enable all college students to be scientifically literate.

"We want to reach all students," says CIRTL investigator **Carol Colbeck**, associate professor and director of Penn State's Center for the Study of Higher Education (CSHE). "Our goal is the improvement of teaching to assure that the STEM disciplines are taught well, not only to the select few pursuing these degrees, but also to all students who need to take only a minimum of STEM course work."

Colbeck works with a core group of STEM faculty who are recognized for the excellence of their disciplinary research as well as their commitment to undergraduate student learning. Together, they are initiating improvements in the ways doctoral students are educated as future teachers as well as researchers.

Colbeck compares the CIRTL focus on educating doctoral students to apply research skills in their teaching to a 4-H model. More than 100 years ago, the rural youth program helped land grant universities educate the children of farmers who resisted government interventions. Thanks to the positive impact of 4-H on youngsters, institutions were also able to reach and win over the farmers. Says Colbeck, "Current STEM faculty who see their doctoral students succeed in applying research methods to implement teaching practices that improve undergraduates' learning experiences and outcomes are more likely to try new practices themselves. The interest in integrating teaching with research to enhance learning becomes infectious."

CIRTL is a collaboration of five universities (Penn State, the University of Wisconsin—Madison, Michigan State University, Howard University, and the University of Colorado) as part of a five-year, $10 million project funded by the National Science Foundation. CIRTL's groundwork is cemented on three pillars—teaching as research, a learning community, and learning through diversity—that the center's doctoral students can incorporate into their courses, programs, and informal activities.

Learn more about CIRTL: **cirtl.wceruw.org**

Problem: A Shortage of Qualified Educators

An infrastructure problem exists in the American education system. Both secondary schools and universities have a striking shortage of qualified instructors.

A great percentage of the nation's high school mathematics and science teachers are not adequately prepared to teach in their subject area. About 30 percent of U.S. public high school mathematics teachers do not have a major or minor in mathematics; some 45 percent of biology teachers are teaching outside of their field.

U.S. universities have a shortage of faculty holding doctorates. Consequently, thousands of mathematics and science education majors are not getting the full benefit of advanced instruction in their college classrooms. "If our graduate schools could award enough doctorates, our universities would be better able to understand how mathematics and science are taught, rather than drilling the same, ineffective materials," says Heid.

Not nearly enough educators are earning doctoral degrees in mathematics and science to fill the existing faculty openings at universities and colleges. Each year around 300 positions in mathematics education become available on campuses, while only 70 to 100 doctorates are awarded.

The shortage could get worse. Nearly 80 percent of today's mathematics education faculty are eligible to retire within the next ten years.

The problem is compounded because so many bright educators are comfortably settled into their careers, earning solid incomes, and are thus hesitant to pursue a doctorate. Returning to school is not economically feasible for many and few financial rewards await students upon completing their doctoral degrees.

Penn State's Response: Graduate More Doctoral Candidates

The college is adding depth and breadth to its doctoral programs to accommodate more graduate students and increase the volume of research conducted in the college. These new doctoral candidates will pursue research that will help us learn more about STEM teaching and learning. They will also become the next generation of teacher educators who will be preparing future K–12 teachers.

Journal editorships held by our faculty is one example of this increased research capacity in the college. In May 2006 **Gregory Kelly**, professor of science education, assumed editorship of ***Science Education,*** an authoritative journal now in its ninetieth year.

Early in 2007, **M. Kathleen Heid**, distinguished professor of education, will become editor-elect of the ***Journal for Research in Mathematics Education.*** Two other Penn State senior faculty members, **Glen Blume**, professor of education, and **Rose Zbiek**, associate professor of education, will serve as associate editors.

In addition to expanding its research programs, the college has acquired additional scholarships to specifically support new doctoral students who wish to pursue science or mathematics education.

The Mid-Atlantic Center for Mathematics Teaching and Learning (MAC-MTL) is attracting high-quality students who could not otherwise afford to commit to full-time graduate study. Funded through the National Science Foundation, the center is now in its second five-year funding cycle and is beginning to see the double results of both graduating more professors and advancing research. ***(See "Mid-Atlantic Center for Mathematics Teaching and Learning," page 15.)***

"We have an excellent group of doctoral students," says Heid, co-principal investigator of MAC-MTL. "Because of the support we are receiving from the National Science Foundation, we've been able to attract some of the very best educators." MAC-MTL hopes that these doctoral candidates, when they move on to become university faculty members, will transmit their proficiency to their students—themselves future educators.

Debbie McCullough, who recently completed her course work through the Mid-Atlantic Center, said, "I'm actively seeking a position at a university that will allow me to do some professional development and research." She feels fortunate to have been part of the center. "The opportunities to work with math education researchers have been incredible," she said. "It has created a new world of research for me that I hadn't thought of before."

The college is also increasing opportunities for students pursuing graduate studies in science education. For example, the Geraldine Brush Graduate Assistantship in Education annually supports the research and education of two full-time science education graduate students in the college.

Mid-Atlantic Center for Mathematics Teaching and Learning

For every three openings in mathematics education at universities in the United States, only one candidate holds a doctoral degree. "There are not enough people with doctorates teaching mathematics education at the universities," says **M. Kathleen Heid**, distinguished professor of mathematics education.

Heid is co-principal investigator of the Mid-Atlantic Center for Mathematics Teaching and Learning (MAC-MTL), a joint initiative between Penn State, the University of Maryland, the University of Delaware and three school districts. The center, one of several funded by the National Science Foundation, has just received a second five-year, $3.25 million contract to continue its mathematics education research. It is the only one of the NSF-funded centers to receive a second contract.

A primary goal of the center is conducting research into how mathematics teachers learn mathematics and how they use that knowledge in their teaching. "Our work focuses on understanding the development of mathematical knowledge in teachers and the relationship of that knowledge to classroom practice and student achievement," Heid says. "We expect that our center's findings will yield better ways to prepare mathematics teachers."

MAC-MTL is also working toward improving the preparation of mathematics education professors. The improvement would have a multiplier effect that will strengthen teaching in high schools throughout the nation. "A major activity of the center is finding ways to enhance teachers' mathematical understanding," says Heid. "Teachers who can use the mathematics they learn in college to deepen the way they understand school mathematics can encourage more students to pursue careers that require mathematics."

Heid believes that it takes a certain kind of teacher knowledge to help students achieve. "We want high school teachers to know mathematics deeply enough to handle the various ways that their students think about the subject," she says. "If a teacher's understanding relies only on memorization, his/her teaching style may not be flexible enough to help students really understand mathematics. And that kind of approach results in young adults who neither understand nor pursue mathematics."

Problem: Workplace Demands Are Increasing

As technology develops, the face of the workplace is changing dramatically. In the future, the manufacturing industry will no longer employ millions of people in low-skill jobs. Individuals will need a strong STEM background to prepare for careers in highly technical fields.

"The pace of technological and scientific change is incredible," says Colbeck. "We need specialists in these areas who are ready to take the science and math further."

The demand for employees who have first-rate math and science skills is global. Some of the best job opportunities are now being sent overseas—and not simply because of a cheaper workforce. The truth is that countries such as China, India, and Singapore have employees who are better educated in math and science. "We're outsourcing jobs to India," says Colbeck. "At the same time, fewer undergraduate and graduate students are coming to the United States than in previous decades."

Penn State's Response: Refine Accreditation Standards

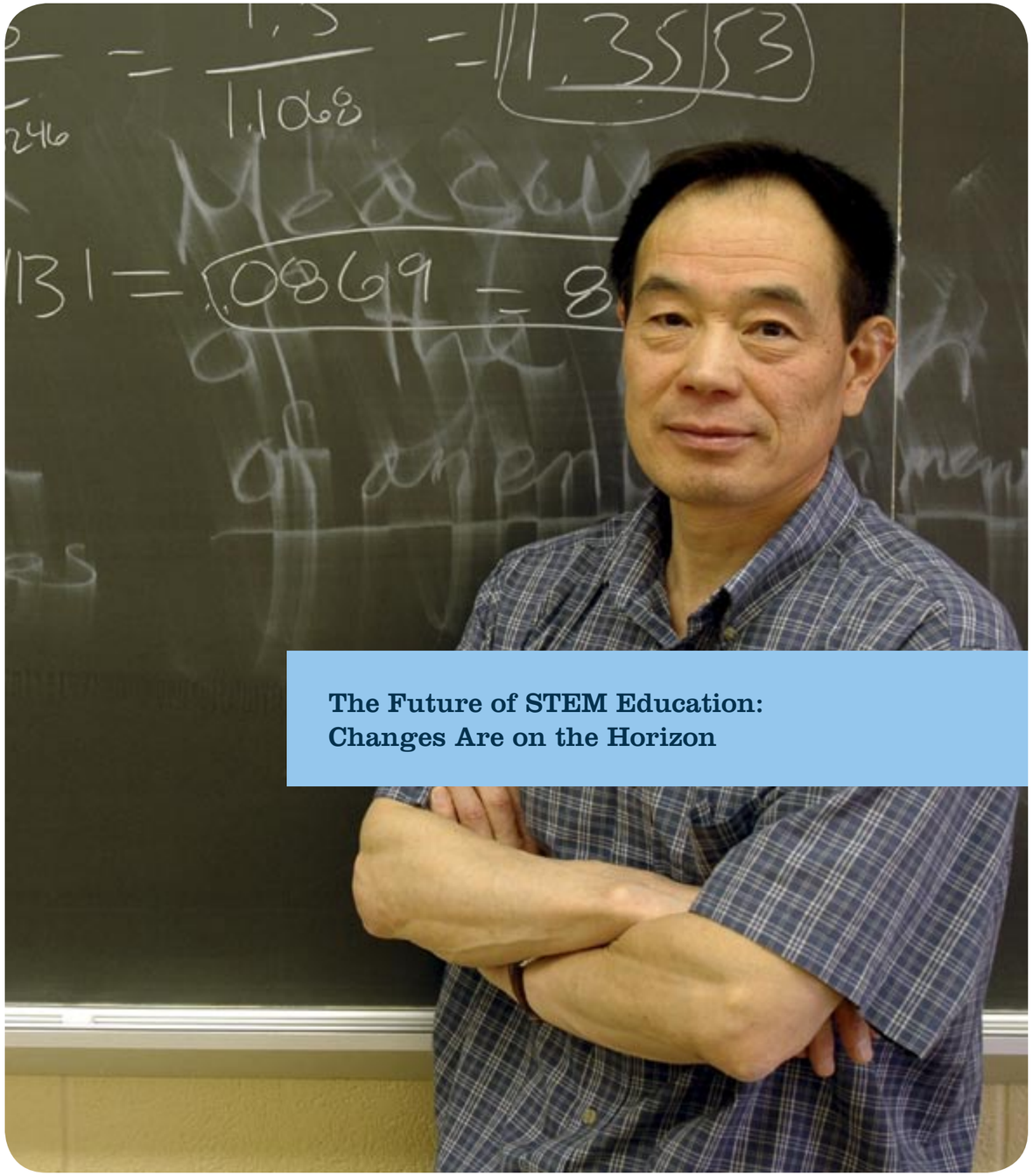
Some good news related to the current state of STEM education: Effective higher education accreditation standards may improve student preparedness for industry. Research recently completed in the Center for the Study of Higher Education (CSHE) in the College of Education revealed that students who earned undergraduate engineering degrees in 2004 are better prepared to enter their profession than were engineering students a decade earlier.

The study examined the impact of new accreditation standards in engineering. The Accreditation Board for Engineering and Technology (ABET), the accrediting body for college and university programs in applied science, computing, engineering, and technology, felt that its own standards needed to be evaluated to determine if its goals were being achieved. The skills examined included basic math and science, design and problem solving, experimental skills, engineering science applications, and technical and interpersonal communications.

The finding that the 2004 graduates scored well in foundational math and science was especially good news for America's colleges of engineering. **Lisa R. Lattuca**, co-director of the study and associate professor and senior research associate of CSHE, noted, "Some faculty members had feared that the curricular and instructional changes needed to meet the accreditation guidelines might come at the expense of instructors' attention to and student performance in basic science and math skills. The evidence indicates that has not happened."

Lattuca is set to begin work on a related study. She and **Patrick T. Terenzini**, distinguished professor and senior scientist with CSHE, began work in summer 2006 on a three-year study to assess the current capacity of undergraduate engineering programs to prepare engineers ready to meet the demands of a constantly changing global workplace. A national survey will map the landscape of undergraduate engineering education to reveal the extent to which programs are poised to educate engineers with strong analytical skills and professional skills, practical ingenuity, creativity, leadership abilities, and high ethical and professional standards.

The study will also scan an understudied sector of the engineering pipeline, surveying students in two-year colleges that prepare students for transfer to bachelor's programs. These colleges enroll many low-income, nontraditional, and minority students—groups that are currently underrepresented in engineering programs. Studying both two- and four-year student populations will enable researchers to focus on students at different points in the pipeline and to explore if and how different aspects of engineering education influence students based on their gender, race/ethnicity, age, and socioeconomic status.



The Future of STEM Education:
Changes Are on the Horizon

The Future of STEM Education: Changes Are on the Horizon

In the years ahead, the American education system will benefit from ongoing research as educators integrate technologies into classrooms to improve student math and science performance. Initiatives are being announced in federal and state budgets that should advance student learning in these fields. The schools of the future will have a new look.

Develop Strong Relationships with Schools

Penn State's College of Education is committed to field-based research to clearly understand what is happening in STEM classrooms. **Robert Hendrickson**, associate dean for graduate studies, research, and faculty development, says, "We are focused on developing stronger relationships with school districts to allow greater access to the classrooms and data. With these much-needed data, we will be better able to analyze and realize the impact of different STEM-based programs."

A greater presence in the classroom will lead to more opportunities to influence the classroom experience now. "We understand that there is a strong symbiotic relationship between research and practice. During the course of our field-based research, we are researching how teachers teach and how students learn, and at the same time we are doing outreach," says Hendrickson.

Make Research Available to Educators in the Field Now

In the very near future, educators in K–12 settings in the Mid-Atlantic region will be able to easily reach out to researchers for quick answers about instruction and learning.

Earlier this year, Penn State, in collaboration with Rutgers University and three consulting entities, entered into a $34 million contract with the U.S. Department of Education to establish the new Mid-Atlantic Regional Education Laboratory. The regional lab, housed in Penn State's College of Education, will help educators answer their questions about how to improve student learning.

Q & A with Skip Fennell, NCTM President and Penn State Alumnus

Francis (Skip) Fennell graduated from the College of Education with a Ph.D. in Curriculum and Instruction—Mathematics Education in 1972. He has been professor of education at McDaniel College in Maryland since 1976. In 2006, he became president of the National Council of Teachers of Mathematics (NCTM) and will serve two years in this position, with another year following that as past-president. President Bush recently appointed him to the National Math Panel, and he also serves as chair of the United States National Commission of Mathematics Instruction (USNCMI).

College of Education: Do you think the United States is falling behind in mathematics?

Fennell: I do think this really is an issue. On the National Assessment of Educational Progress the math scores of elementary age kids in this country are higher than they have ever been, and the gap between the majority and minority populations is decreasing. When we analyze international comparisons, we find that our fourth graders are comparable. You see a dip at the eighth-grade level, and the scores are quite low by high school. We really need to understand what is happening across these grade level comparisons, but particularly at the high school level.

College of Education: How does NCTM plan to address these issues?

Fennell: There really are three goals that we are working on:

1. We certainly need to be more competitive as a nation.

2. We need more undergraduate math majors who will be the next generation of engineers, mathematicians, and most important, math teachers.

3. We need to develop the next generation of teachers and parents in this nation who will value mathematics as a major, a career option, and as, frankly, just a really important subject.

College of Education: How can we attract more math teachers?

Fennell: We need to connect with education students when they consider math as an option. Education students in math and science often see their buddies blowing off evenings and weekends while they have to study. Then after graduation, they often see their friends making more money.

We also need to stick with these new teachers through the early years, offering professional development opportunities, and helping them deal with issues such as classroom management and the varying needs of their students. Half of all the teachers in the United States leave the profession in the first five years, with 30 percent leaving in the first three. Math and science teachers are leaving at greater rates, because they can easily be hired elsewhere and make more money.

We need to pay teachers more, but it's not all about money. Historically, we have underpaid our teachers; it is a part of our culture. Teachers were paid in the harvest and were offered lodging in someone's home. In other areas of the world, teachers are revered.

College of Education: What can colleges of education do to address these issues?

Fennell: Colleges of education are the entities that prepare our teachers. They should be current, provide expectations early on, and create opportunities for candidates to engage with students from the beginning. But we need to be careful not to shortchange the content background of the teacher just to get them with and around children in classrooms.

Colleges of education should also fully address the issues of the content background and pedagogical background of the student, making sure that the depth in both areas is sound and deep.

Colleges of education must also provide professional development for teachers from preservice years throughout their career. Many universities are already involved in just that. Both my institution, McDaniel College, and Penn State have very successful programs involving professional development schools (PDS). Not only do we work with preservice teachers, but we also provide development opportunities for the mentor teachers through these schools.

The regional lab enlists laboratory extension specialists living throughout a four-state region to gather questions directly from teachers and administrators. These specialists will relay the schools' priorities and needs to the lab's researchers. "The needs felt in schools will drive our research," says the lab's director, **Kyle Peck**, associate dean of outreach, technology, and international programs. "We'll focus on providing quick, high-quality responses when the questions can be answered through existing research."

The lab will also conduct experimental research to answer important questions for which the research does not exist. One of its projects is to study teachers and students in Algebra I classes in fifty classrooms in twenty-five schools to determine whether teachers who develop more rigorous and real-life assignments do, in fact, successfully engage student interest and improve students' learning.

Cutting-Edge Uses of Technology

A laptop on every high school student's desk by 2009 is the vision of Pennsylvania Governor Ed Rendell. In his "Classrooms for the Future" proposal to the state legislature in early 2006, Rendell promised that a one-to-one computing initiative would extend to every math, science, English, and history public school classroom in the Commonwealth.

Also, Rendell promised that every teacher in those classrooms would possess a multimedia computer, a Smartboard, a Web cam, and other equipment, along with professional development training for the technologies.

"This signals the inevitability of one-to-one student–computer ratios in Pennsylvania, and I know that this has significant implications for the preparation of the preservice teachers in our Penn State teacher education programs," says Peck.

The education system is certain to step up its use of technologies as an outreach tool to teachers in the field. The Center for Science and Technology in the Schools (CSATS) has already started utilizing distance education in its outreach to teachers for professional development. The center has been conducting Web-based seminars and has produced a video of curricular materials for public broadcasting. “We must keep integrating technology to maximize the number of people we can reach,” says **William Carlsen**, director of CSATS, “particularly with our strong interest in schools serving needy populations.”

The National Effort

In his 2006 State of the Union Address, President Bush proposed his America’s Competitiveness Initiative “to encourage innovation throughout the economy and to give our nation’s children a firm grounding in math and science.” The Bush administration is looking to provide funding for new fellowships for math and science teachers, for the creation of math and science specialty schools, and for a national clearinghouse for math and science teaching materials. The budget also establishes scholarships, fellowships, and internships to encourage students to pursue STEM careers.

The National Research Council estimates that during the next decade, some 200,000 teaching positions in secondary science and mathematics will become available. These positions, like STEM professions in the business and research sector, have traditionally been dominated by the white male demographic. Women and minorities are underrepresented in the STEM fields; they must be recruited to help fill the growing need.

In 2007–08, standardized testing in science will begin as part of the No Child Left Behind legislation. Because testing in mathematics and reading was instituted two years earlier, those two subjects have been the focus of school districts attempting to meet their Annual Yearly Progress (AYP) goals. It remains to be seen whether the schools’ attention to improving student performance in math and reading has adversely impacted proficiency in science.

"Schools have been so preoccupied with reading and math preparations that now there is increased pressure to improve the study of science in the elementary schools," says Carlsen. "Ignoring science is no longer an option. Administrators must be attentive to proper science instruction, rather than to test preparation."

Facing the Future with Open Arms

The future will not stand at arm's length. The American education system, across all subject areas, must adjust to the dictates of ever-changing technologies. But the subject areas of science, technology, engineering, and mathematics are at a disadvantage. The first challenge in STEM education is to gain ground already lost. And then the challenge will be to keep up with the quickening pace of subsequent technological changes.

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