

Science, Technology, Engineering and Mathematics (STEM) Education Initiatives at Penn State

David H. Monk
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Good morning, and thank you Chairman Hayes for this opportunity to provide an update on STEM Education at Penn State.

STEM has become a popular term in recent years, and STEM education is an important topic for the nation as well as for Penn State. President Obama recently addressed the topic at a speech he made at the National Academy of Sciences where he announced a renewed commitment to education in mathematics and science and noted that the progress and prosperity of future generations will depend on what we do now to educate the next generation. He went on to cite some worrisome statistics such as the finding that more than 60% of high school students are taught chemistry and physics by teachers without expertise in these fields.

The president challenged all of us to do better and commended states like Pennsylvania that have joined a National Governors Association effort to make STEM education a top priority. President Obama announced in his speech that Gov. Ed Rendell will be leading this effort, and he expressed his hope that all 50 states will participate.

I'm pleased to report that Penn State is actively involved in STEM Education and is playing a leadership role for the nation and beyond. We have a wealth of talent at the University in this area and we've been working to build partnerships throughout Penn State as well as with relevant constituency groups like the Pennsylvania Department of Education and the K-12 schools in the Commonwealth. The College of Education is well positioned to facilitate the development of these partnerships, and I'll be sharing some examples of what we're doing in my remarks this morning.

I'd like to begin by setting the context and describe what are known as pipeline issues for the field.

These pipeline issues exist at two, interconnected levels. We have pipeline issues involving students and we have pipeline issues involving teachers and teacher educators.

Student Pipeline Issues

- Small Numbers of U.S. High School Students Entering STEM Majors
- Frustrating Differences Across Gender and Racial/Ethnic Groups



Let's start with students where there are two significant challenges:

First, there are small numbers of domestic students who are pursuing interests in STEM and who are developing the skills they need to succeed in the STEM disciplines in higher education.

Second, there are stubborn and frustrating differences across gender and other social and economic groupings. We continue to struggle in our efforts to attract women and persons of color into the STEM fields.

US Degrees Conferred by Field of Study, 2002-2003

All Fields	2,540,084	
STEM Fields	399,465	15.7%
Non-STEM Fields	2,140,619	84.3%

(Source: Digest of Education Statistics, 2004)

You can get some sense of the relevant magnitudes by considering differences across fields in the numbers of degrees being earned in U.S. colleges and universities. You can see in this slide that for 2002–2003, just under 16% of the 2.5 million degrees that were awarded in the U.S. were in the STEM fields.

Pennsylvania Completions by Field of Study, 2007-2008

	All Completions	STEM Completions	% STEM
Penn State	9,442	2,811	29.8
All State Related	18,561	4,280	23.1
PASSHE	17,446	1,938	11.1

At Penn State, the percentage of completions is higher and is in the 30% range rather than the 16% we saw in the national data, although I should note that some of this difference may be related to differences across these studies in how degrees are being counted. The 30% for Penn State compares favorably with 11% for the State System schools and the 23% for all of the state-related schools in Pennsylvania.

Penn State First-Time Students in STEM Colleges by Type of Student (Fall 2008)

	Fall 1990	Fall 2008	% Change
Total	3,664	4,564	25%
Female	870	1,299	49%
Minority	285	674	136%

Penn State's percentage has also been increasing and we can see this by looking at the numbers of first time students entering the STEM Colleges at Penn State. You can see some impressive growth in the numbers of students entering these colleges at Penn State, and I think we can feel good about this progress.

But the growth percentages look good in part because the numbers remain relatively low, and we need to keep in mind that these are counts of students entering STEM programs. Not all of these students complete the programs they begin, and it's also clear that more needs to be done to recruit larger numbers of women and students from minority groups.

Need for Balance

- Stimulating student interest in STEM
- Sustaining student interest in STEM

Historically I'd say we've done a better job at stimulating students' interests in science than we've done at sustaining it. Many of you will remember the *Mr. Wizard* show on television. The more modern version is the *Bill Nye the Science Guy* show. These television programs frame science as being fun, which certainly is true, but not much is done as follow-up to build capacity to succeed with science curricula. There's also some truth to the assertion that the way we approach science at the upper levels in schools is more burdensome than necessary and that we lose good students along the way.

Even outside the world of television, you can find evidence of efforts to make science seem like fun without the necessary follow-through. I'll be telling you later about a major education initiative from NASA that has now moved to the College of Education at Penn State. In the old program, the emphasis was on having NASA education specialists visit schools around the nation and hold assemblies where they'd show young people things like space suits and models of spacecraft. Penn State's approach to this project is to move away from the one-shot, show and tell kind of assembly and toward a much more comprehensive effort to build the capacity of teachers in the schools to stimulate and sustain student interests in the sciences. We see this as a significant step forward.

Teacher and Teacher Educator Pipeline Issues

- Small Numbers of College Students Preparing to be STEM Teachers

Pipeline issues also arise when we think about the supply of teachers and teacher educators.

The basic reality is that only small numbers of people are preparing to be STEM teachers, particularly in the physical sciences. These small numbers translate very quickly into challenges for school districts when they compete to hire qualified teachers. Many school administrators struggle to hire these teachers and do not have the luxury of cancelling the classes if they can't find a qualified teacher. One result is the presence of teachers with less than ideal credentials in these classrooms, and one suspects that this does not help us as we try to stimulate and sustain student interest in the sciences.

Penn State Endorsed Applications for Professional Certification in PA (selected subject areas)

	2001-2002	2005-2006	2007-2008
All Certificates	1006	1050	1069
Elementary	274	350	366
Biology	15	14	21
Chemistry	5	5	2
English	55	50	51
Math	31	31	41
Physics	3	8	8
Social Studies	42	45	57

Here are some data showing the numbers of certificates Penn State is endorsing in selected certain subject areas. You can see how lopsided the numbers are with very small numbers showing for key fields like physics and chemistry.

We do better in mathematics at Penn State, but for the nation mathematics remains an area of chronic shortage.

Teacher and Teacher Educator Pipeline Issues

- Small Numbers of College Students Preparing to be STEM Teachers
- Challenges Retaining Teachers in STEM Fields
- Challenges Doing Justice to STEM Topics in Preparation Programs for Elementary Teachers
- Challenges Hiring Faculty in STEM Education

The schools also face retention challenges since well-prepared STEM teachers have many career options. One of the things we know is that a well-prepared teacher with a solid understanding of content is very attractive to employers. We lose a disturbing number of STEM teachers to alternative pursuits every year.

The turbulent economic times and uncertainties in the business world these days may actually work to the advantage of a sector like K–12 education. In the face of this turmoil, highly qualified teachers may be less inclined to leave the security of a school district position and we may also succeed at attracting more students who initially saw themselves majoring in a content area and staying away from teaching as a career.

At the elementary school level, the challenge is perhaps less obvious but no less real. The nation's elementary schools are populated with large numbers of teachers with limited backgrounds and interests in mathematics and science. We need to be building strong foundations at the elementary level and there is room for improvement.

And finally, there's the shortage of teacher educators. Teacher educators in the STEM fields also tend to exist in small numbers. We're fortunate at Penn State because of the strong reputation of our programs and we actually do pretty well in recruiting and retaining top teacher educators, but this is not true throughout the field and the overall result is an adverse effect on the quality of teacher education for the nation.

What we have is a chain of events that for the nation is problematic in the STEM fields. When weak teacher preparation occurs, it gives rise to weak teachers and weak teachers give rise to substandard teaching in the schools and this chokes off the supply of talent into the STEM fields. There are elements of a downward spiral here that need to be turned around.

So, that's a pretty sobering message, but there is some positive news to report, and I think we can be proud of how Penn State is responding to these challenges. There really is a good story to tell.

Building Capacity in STEM Education

2008-09

Science and Mathematics Education Faculty

Frank Arbaugh, B.S., M.Ed., Ph.D. (Indiana University)

Associate Professor of Education (Mathematics Education) (hires in 2005)

Interests: design and implementation of teacher development programs (both preservice and in-service); how and what teachers learn from these programs

Glendon W. Blume, A.B., M.A., Ph.D. (University of Wisconsin)

Professor of Education (Mathematics Education)

Interests: the mathematical understandings of secondary mathematics teachers; the impact of technology on mathematics teaching and learning

James Bohanago, B.S., M.Ed., Ph.D. (Purdue State)

Assistant Professor of Education (Mathematics Education)

Interests: professional development of secondary mathematics student teachers

Ann Brungart, B.S., M.Ed., Ph.D. (Purdue State)

Assistant Professor of Education (Mathematics Education)

Interests: elementary mathematics methods

William Carlson, A.B., Ph.D. (Stanford University)

Professor of Education (Science Education) and Director, Center for Science and the Schools

Interests: teacher knowledge; classroom investigations; collaborative curriculum design using technology tools

Richard A. Danchi, B.S., M.A.T., Ph.D. (University of Maryland)

History/Chemical Professor in Secondary Education (Science Education)

Interests: establishing science assessment learning environments that focus on the role of students' epistemic reasoning and representation processes

M. Kathleen Heid, B.A., M.A., Ph.D. (University of Maryland)

Distinguished Professor of Education (Mathematics Education)

Interests: the mathematical understandings of secondary mathematics teachers; mathematical thinking; the impact of technology on the teaching and learning of mathematics; technology-intensive mathematics curricula

Gregory J. Kelly, B.S., Ph.D. (Cornell University)

Professor of Education (Science Education)

Interests: knowledge and discourse in science education settings; classroom discourse; use of organizational analysis for assessing students; construction of epistemic practices in science learning

Greenelyle M. Lloyd, A.B., M.A., Ph.D. (University of Michigan)

Professor of Education (Mathematics Education) (hires in 2007)

Interests: teacher learning, particularly as it relates to teachers' connections with mathematics methods and curriculum materials

Andrea McCluskey, B.S., M.A.T., Ph.D. (Indiana University)

Assistant Professor of Education (Mathematics Education)

Interests: teacher learning; professional development models that provide opportunities for teachers to learn from their students' mathematics

Scott McDonald, B.S., M.A.T., M.S., Ph.D. (University of Michigan)

Assistant Professor of Education (Science Education)

Interests: professional pedagogical vision; inquiry-based science teaching grounded in practice; the use of video analysis software; in both research and teacher education, the integration of disruptive technologies with teaching and learning environments

Tom Musielmann, B.S., M.S. (Indiana University of Pennsylvania)

Instructor of Education (Science Education)

Interests: secondary science teaching methods; supervision of both preservice and student teachers; supervision of instructional student teachers; professional development for teachers; and volunteer coaching with high school athletes

Patricia A. Radaba, B.S., M.A., Ed.D. (Indiana University)

Professor of Education (Science Education)

Interests: strategies for integrating science-technology-society issues into middle school and high school science instruction and science teacher professional development

Kathleen Silliman, B.S., M.S., Ph.D. (Purdue State)

Assistant Professor of Education (Science Education)

Interests: elementary science methods; supervision of preservice teachers; science professional development for teachers

Deborah Smith, B.A., M.A.T., Ph.D. (University of Delaware)

Assistant Professor of Education (Science Education)

Interests: how teachers and young children build conceptions of scientific discovery and practice in the early years of schooling; research-based teaching practices and professional development; preservice elementary teachers' development

R. Timothy Smith, B.A., M.A., Ph.D. (University of Delaware)

Assistant Professor of Education (Science Education)

Interests: development of elementary science teachers; elementary science methods

Annamarie R. Ward, B.S., M.A., Ph.D. (Purdue State)

Instructor of Education (Science Education) and

Associate Director, Center for Science and the Schools

Interests: elementary teachers' science content knowledge and inquiry-based science teaching; specialized science content courses for preservice elementary teachers; professional development for teachers; evaluation of Ph.D. programs

Rose Mary Zwick, B.S.Ed., M.S.Ed., Ph.D. (Purdue State)

Professor of Education (Mathematics Education)

Interests: teachers' and students' mathematical reasoning and representations in technology-intensive environments at the secondary and college levels

Carla Zumbal-Saul, B.S., M.S., Ph.D. (University of Michigan)

Assistant Professor of Education (Science Education) and

Holder of the Rubin Professorship in STEM Education

Interests: teaching practices that support K-6 children's participation in scientific discovery and practices; school-science partnerships; the purposeful integration of technology tools

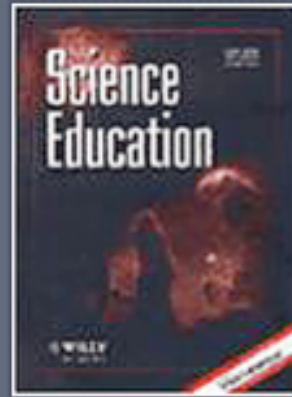
Within the College of Education, we've been placing a great deal of emphasis on capacity building in STEM. In particular, we've been adding to the strength of our STEM Education faculty, particularly in the areas of science and mathematics education. We've made seven tenure-line hires in mathematics and science education in the past five years and this has resulted in a net increase in our tenure-line faculty in both areas. In the ten years that I've been dean, the tenure-line faculty in both our math and science programs has grown by 50%. Without exception these have been phenomenal hires that build on the existing strengths of the faculty.

We've also been adding fixed term faculty to the mix and the slide gives you a sense of the current roster of talent and the scale of the operation.

Editorships of Major STEM Education Journals



Editor: M. Kathleen Heid



Editor: Gregory J. Kelly

We've also succeeded at being awarded the editorships of two preeminent journals in STEM education—the *Journal for Research in Mathematics Education*, which is being edited by Dr. Kathy Heid; and *Science Education*, which is being edited by Dr. Greg Kelly. These journals significantly enhance Penn State's visibility in a very competitive field. They are a lot of work, but they also offer the opportunity to shape the entire field.

Faculty Endowments Earmarked for STEM Education

- Waterbury Chaired Professor in Secondary Education ~
Richard A. Duschl



- Kahn Professorship in STEM Education ~
Carla Zembal-Saul



We've also earmarked two faculty endowments for STEM education. The Waterbury Chair in Secondary Education is now focused on STEM, and the holder is Dr. Richard Duschl, who is an internationally known science educator with a background in geology. Rick is the president-elect of the National Association for Research in Science Teaching and is a very visible figure in the field. We also recently named Dr. Carla Zembal-Saul as the inaugural holder of the Kahn Professorship in STEM Education. Carla is a very accomplished science educator who previously received an NSF Early Career Award.

Growing Commitment to the Use of Technology in Teacher Preparation

- EDUCATE Initiative
 - Exploring Directions in Ubiquitous Computing And Teacher Education
- Innovation Studio

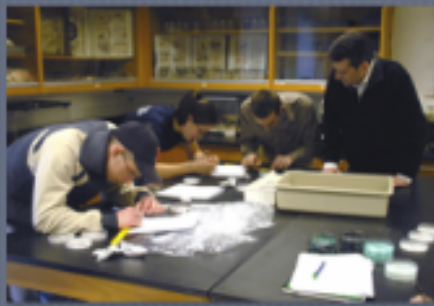


The College, through its strategic planning process, has also embraced the role of technology in teacher education. EDUCATE is an acronym that stands for Exploring Directions in Ubiquitous Computing and Teacher Education. It's a two-year-old initiative that is infusing the use of modern computing and telecommunication technologies into the day-to-day lives of our preservice teachers. These Penn State students are making cutting-edge use of these technologies in their own classes as well as in the classes they are teaching as part of their clinical experiences in the schools.

We're also launching an Innovation Studio, which will serve all faculty in the College who are working to harness technology and to develop teaching skills in online environments.

Working Collaboratively to Reduce Barriers in Teacher Preparation

- Undergraduate Students
- Early and Mid-career Transfers
- Career and Technical Education



One of the things we know about STEM Education is that it cuts across many parts of the University. Things work best when we're working in partnership with the various STEM colleges at University Park as well as with the campuses. We have some longstanding collaborative programs with the College of Engineering and more recently we've been working more closely with our colleagues in the Eberly College of Science to break down barriers in teacher preparation.

Undergraduates at Penn State can prepare to be secondary science or mathematics teachers by completing a major in Eberly or by completing the secondary education major in the College of Education. The number of content courses a student takes is not materially affected by the path that is chosen, and we're closely connected to these students regardless of the path they select. What we're finding is that a key variable in the equation is to help the Eberly students become knowledgeable about a teaching career early in their time at Penn State. Some of the best students in STEM education started out thinking they'd like to be bench scientists only to discover that they're more interested in combining an interest in science with opportunities to

work with young minds. Teaching is a good option for these students, and we're working closely with the faculty in Eberly to identify more students with these kinds of interests.

We also work with people pursuing careers in STEM fields who are interested in shifting into a teaching career. We handle these on a case-by-case basis since there is great variation these individuals' backgrounds. We work hard to help these men and women achieve certification as quickly as possible.

Finally, there is the area of career and technical education. Much of the STEM Education debate is focused on getting students ready to complete four-year baccalaureate degree programs and this overlooks what's going on in postsecondary career and technical education. At Penn State, we have a graduate program that's focused on Workforce Education and Development, and we prepare teachers who work in vocational education at both the secondary and postsecondary levels. The science and mathematics dimensions of technical education warrant attention, and Penn State is uniquely positioned to lead in this area.

I'd like to close by giving you a quick tour of some of the major research and outreach initiatives going on at Penn State in the area of STEM Education. You'll see that this is a rich portfolio of activity that demonstrates the leadership Penn State is providing for the field.

Working Collaboratively on Research

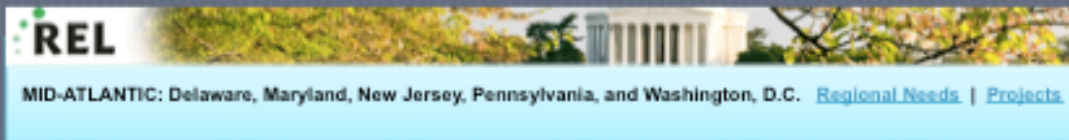
- NSF Funded Mid-Atlantic Center for Mathematics Teaching and Learning
 - Penn State
 - University of Maryland
 - University of Delaware



The Mid-Atlantic Center for Mathematics Teaching and Learning is an NSF-funded center that has been in operation now for close to ten years. It's a collaborative effort involving mathematicians and mathematics educators at Penn State, the University of Maryland, and the University of Delaware. The Center has a research focus and also a doctoral education focus and one of the center's great claims to fame is the number of doctoral students it has trained in mathematics education.

Working Collaboratively on Research

- Mid-Atlantic Regional Education Laboratory
 - U.S. Department of Education
 - 5-year, \$34 Million Contract
 - Randomized Control Trial Focused on the Connected Mathematics Program



The Mid-Atlantic Regional Education Laboratory is a five-year, \$34 million effort that is based in the College of Education at Penn State. The Regional Lab is deeply engaged in a reform agenda that includes doing major randomized control trial studies of widely used mathematics curricula. This is a very significant step forward for the field because more typically these curricula are developed and marketed with very little formal evaluation. I think we can be very proud of our involvement in this effort.

You may be aware of some debate currently going on within the State College Area School district about the mathematics curricula that are in place. The kind of research being done by our Lab will inform these very real and lively debates and will be very useful to policy makers throughout the nation.

Working Collaboratively on Research

- Center for Study of Higher Education
 - NSF funded Evaluation of ABET Accreditation in the Field of Engineering
 - Prototyping the Engineer of 2020



Our Center for the Study of Higher Education has been deeply involved with the study of engineering education for the past several years. The Center has been the recipient of major funding from NSF and other sources to evaluate the accreditation standards being used by ABET, which is the specialized accrediting body for engineering as a field. ABET is moving toward a more outcome oriented set of standards and our Center was asked to assess their progress.

By the way, in the most recent *US News & World Report* rankings, our higher education program jumped ahead of Michigan and is currently ranked as the #1 program in the nation. As you might imagine, we were very pleased to see this ranking.

Working Collaboratively on Outreach

- Center for Science and the Schools (CSATS)
- NASA funded Aerospace Education Services Project (AESP) -- \$27.3 million over 5 years



The Center for Science and the Schools was created by Penn State about seven years ago and is based in the College of Education. It's a very innovative effort by the University to build bridges among STEM colleges, education, and the K–12 sector.

CSATS, as it's known, works with PI's on NSF proposals where they need to demonstrate the broad social impact of the work and this often involves links with the schools.

CSATS also works to provide in-service opportunities for teachers.

One of the most significant CSATS activities is the NASA project that I mentioned earlier. We proposed making a significant change in the interface between NASA and the K–12 schools throughout the nation, and I'm pleased to say that NASA recognized the merit of what we were proposing and awarded Penn State a \$27.3 million cooperative agreement that has created a Penn State presence in K–12 schools nationwide. The emphasis is on curriculum development and professional development for teachers. This is quite a coup for us, and we're about two years into this project. It's great to see the progress we have made in this very short time.

The Challenges and the Opportunities are Significant

- Thank you!

To sum up, the challenges in STEM education are daunting, but there are corresponding opportunities, and I think you can be very proud of what we are accomplishing at Penn State.

Thank you.