Tinker, Thinker, Maker, and CEO

Reimagining the physics student as Engineer, Inventor, and Entrepreneur

Physics Innovation and Entrepreneurship (PIE)

- Curriculum which includes not only physics content, but also experiences and coursework designed to prepare students for careers as entrepreneurs, inventors and product developers
- A handful of "official" physics innovation and entrepreneurship programs exist

What We Don't Know (Yet)

- Outcomes for graduates of existing PIE programs (beyond anecdotal)
  - student outcomes and departmental outcomes
- Detailed information about physics skillset performance in the workplace (i.e. an in-depth study)

What We *Do* Know

- Actual career trajectories of physics graduates (AIP SRC, NSF Surveys, etc.)
- Role of career preparation in increasing student retention in physics programs (SPIN-UP)
- Why employers seem to want to hire physics graduates (recruitments, feedback from industrial employers)—and what makes physicists "special."

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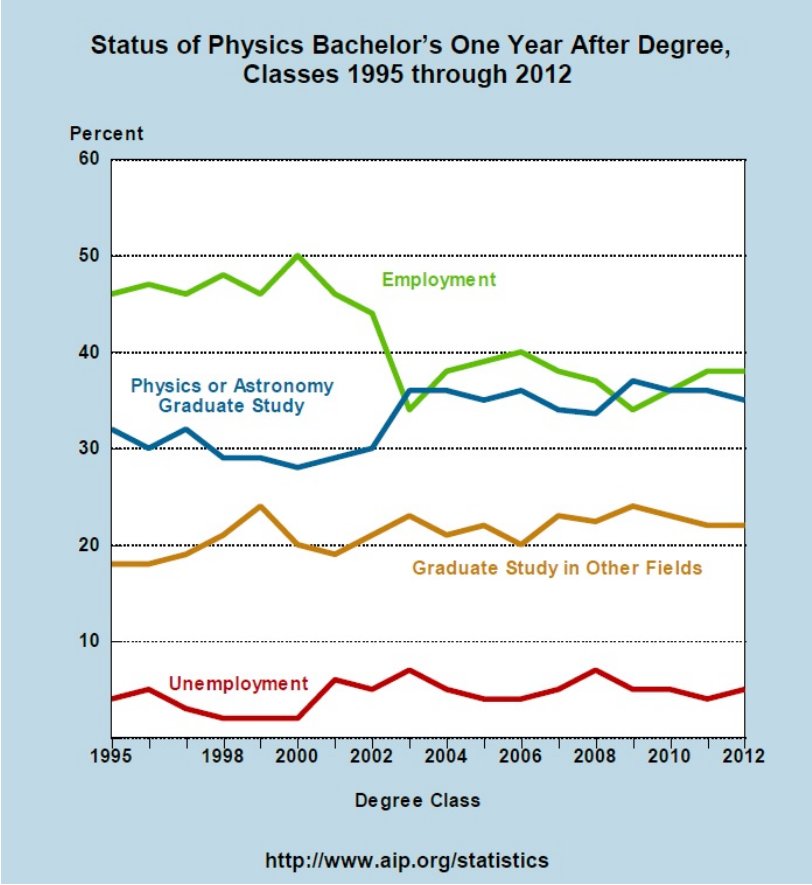
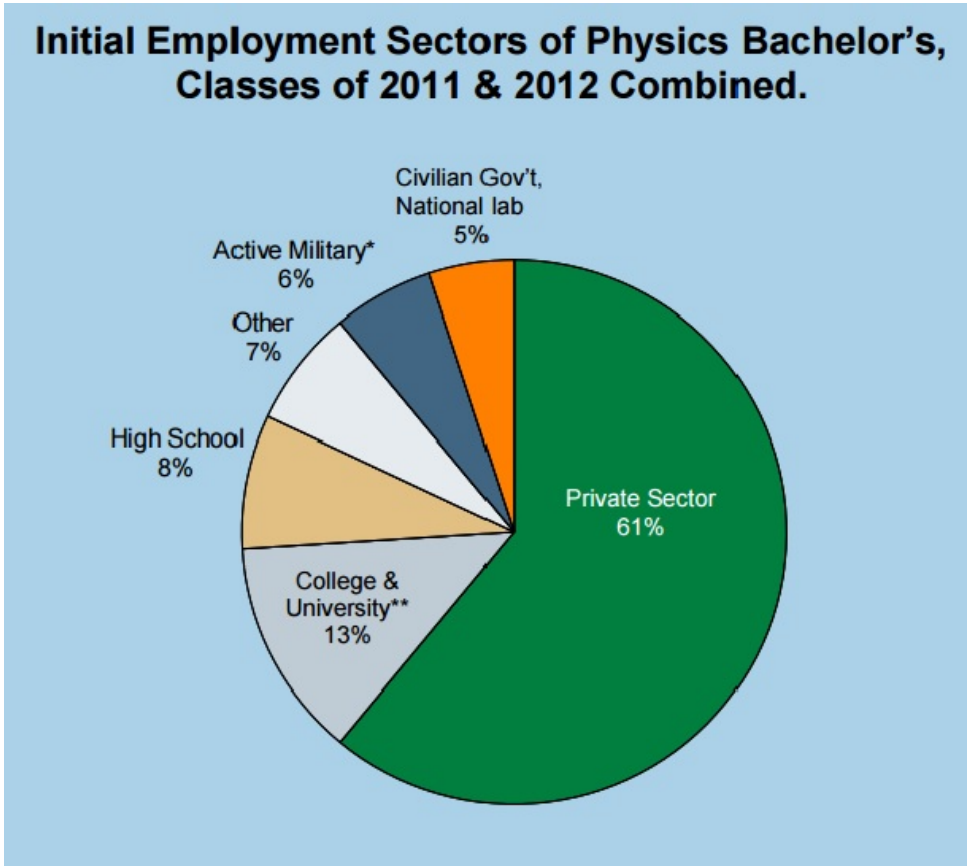
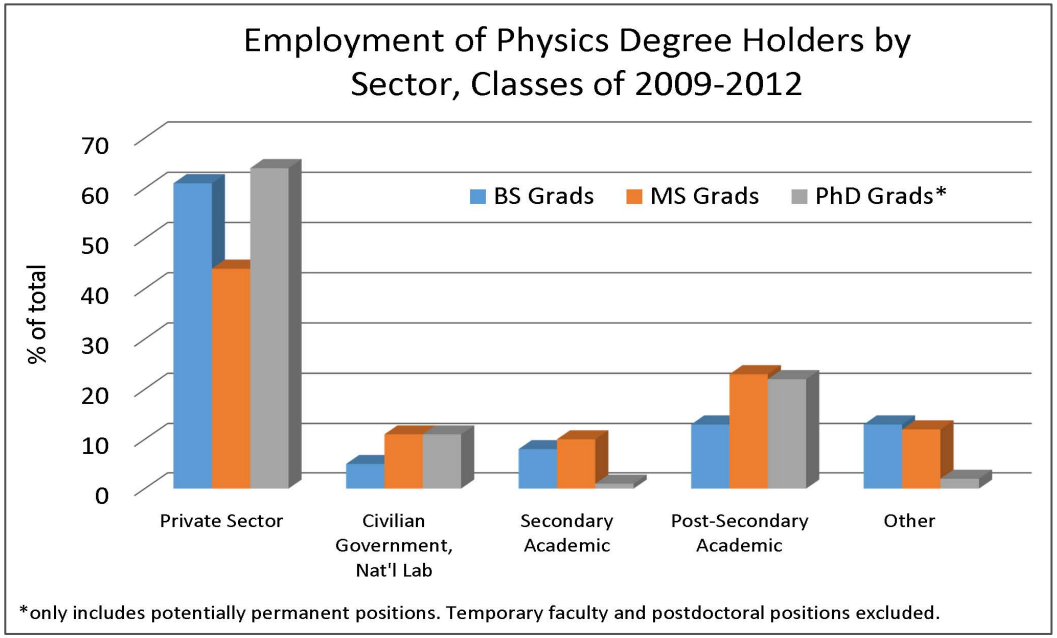
Where Physics Graduates Go



The majority of these jobs will be in the private sector, and 70% of those will be in STEM fields.



Around 40% of graduating physics bachelors will enter the workforce after graduation.



- A similar pattern holds for master's graduates, where about 40% of employed graduates work in the private sector.[1]
- And over 60% of PhDs permanently employed after graduation are also in the private sector, and also mostly in STEM fields.[1]

The AIP SRC estimates that about 30% of physics PhD graduates will become permanent academic faculty. And only about 18% of physics bachelors will complete a PhD in *physics*[2].

By these statistics and others, about 5 out of 100 physics bachelors will become permanent physics faculty…

…and 73 of them will end up working in a private sector job with a physics BS, MS or PhD[3].

[1]Combined data from AIP SRC *Focus On Physics Bachelor's Initial Employment* (2015), *Physics & Astronomy Master's One Year After Degree* (2014), *and Physics Doctorates Initial Employment* (2014) reports

[2]AIP Statistical Research Center, *Focus on Roster of Physics Departments with Enrollment and Degree Data, 2013*

[3]*NSF Survey of College Graduates*, *NSF Survey of Doctoral Recipients*, 2013 data

Physicists as "Scientists"

Employers in STEM fields value physics graduates in their companies as members of interdisciplinary teams.

- Standard physics curriculum creates familiarity with technologies commonly used in STEM workforce
  - Programming languages (e.g. C++, Fortran)
  - Circuit design and diagnostics (e.g. oscilloscopes, soldering)
  - Mathematical proficiency (e.g. differential equations, linear algebra)
  - Fabrication (e.g. lathes, bandsaws, screws)

- Language of Job Descriptions[1]
  - Common job titles across STEM recruitments (including physics), e.g. "analyst," "engineer," "developer," etc.
  - Common skills listed in recruitments for physics and engineering graduates:

    perform testing/analysis
    develop/design
    implement
    run queries and reports

[1]APS Job Board search, 4-year degree job postings

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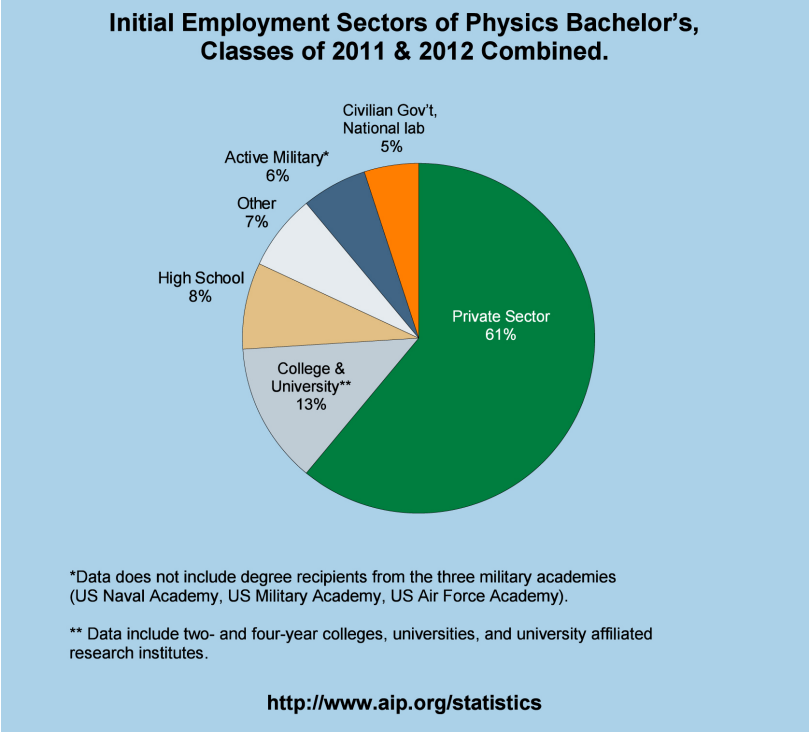
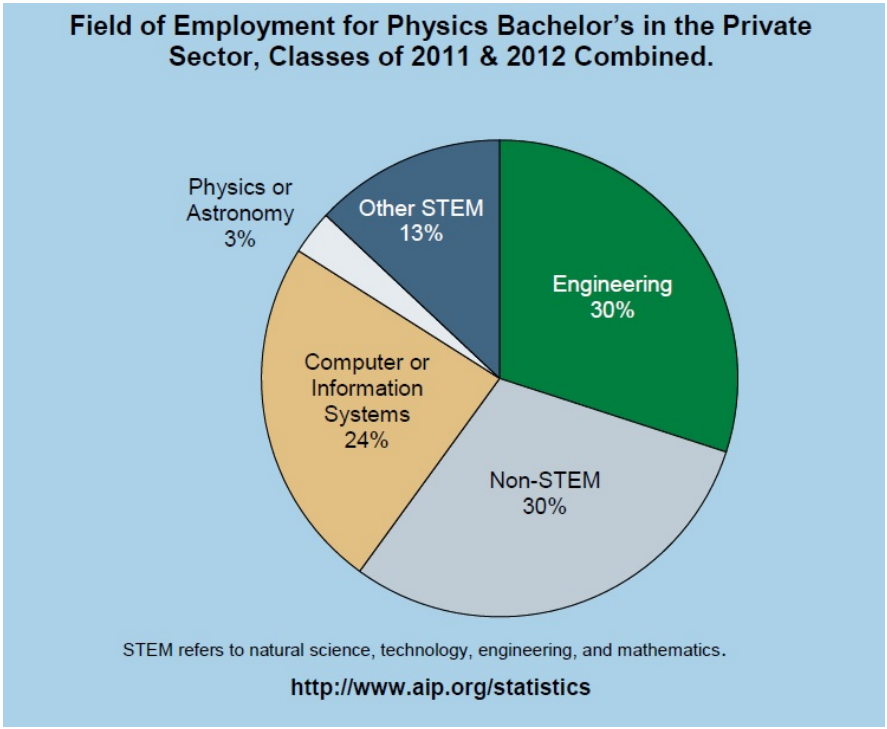
- They Hire Them:





- Similar figures hold for physics MS and PhD graduates between 2009 -2012:
  - 40% of MS graduates went into the workforce. Nearly half (44%) of these were in the private sector[2].
  - Of all PhDs entering permanent employment after graduation, over 70% of these positions were in the private sector[3].

[2]AIP Statistical Research Center, *Focus on Master's Initial Employment*, 2014
[3]AIP Statistical Research Center, *Focus on Physics PhDs Initial Employment*, 2014

- They Tell Us
  - "BYOCEO" meeting, April 2013. Nate Seidle, SparkFun:

    "Engineering is about putting the period on the sentence. The engineer may write the code, but the physics guy understands what it has to do with the larger context. Together they are very effective."
  - ABET Survey for Applied Physics and Engineering Physics Graduates, Kettering University.

Over 80% of surveyed employers[4] agreed that physics majors:

- Could easily grasp new knowledge and concepts
- Were able to identify, formulate, and solve problems
- Were able to successfully analyze and interpret data
- Could competently use computer applications and databases
- Were able to use current techniques/ tools for technical practices
- Could engage in *continued* learning and problem solving

[4]ABET Survey of applied and engineering physics graduates, Kettering University

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What else do STEM employers say?

That physics graduates are also missing important training and experience:

- Ability to design a system, component or process to meet a specific need[4]
- Ability to function on multi-disciplinary teams[4,5]
- Ability to recognize value of diverse relationships (customers, supervisors, etc.)[4]
- Leadership Skills[4]
- Familiarity with basic business concepts (i.e. cost-benefit analysis, funding sources, IP, project management)[4,5]
- Communication skills (oral and written) – esp. how to tailor message to audience[4]
- Real-world experience in companies before graduation[5]
- Awareness of career paths outside of academia[5]

[5]APS Workshop on Nat'l. Issues in Industrial Physics

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To summarize:

Based on available information we can say the following about the physics discipline regarding student career preparedness:

- Some content/knowledge overlap with other STEM disciplines.
  - e.g. particularly technical skills, techniques, equipment
- Some characteristics which are distinct from other STEM disciplines.
  - ability to grasp wider scientific context of work
  - ability to formulate problem solutions from first principles (i.e. the people who start the process rather than “putting the period on the sentence”).

Some important content is missing from physics training, and has been present in other STEM disciplines (particularly engineering) for at least two decades.

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Introducing Physics Innovation and Entrepreneurship (PIE) Education

Experiences, courses, and research opportunities which:

- Explicitly connect physics concepts with their real world applications.
- Utilize physics principles to create innovative solutions to real world problems.
- Include content relevant for careers in the private sector, such as communicating to audience, intellectual property, private and public funding sources, business models, budgeting, etc.

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Why PIE?

Fact: Most physics graduates will be working on interdisciplinary teams with engineers and other STEM grads.

Q: Why shouldn't we provide them with the same preparation as those graduates?

A: Because the physics graduates will learn what they need to learn on the job.

- Maybe, but first they have to get the job!

  They have to compete with other STEM grads who have already received intentionally workforce-relevant training

A: But you just said that nearly half of physics bachelors find work in the private sector. What's the problem?

- Half of physics BS go into private sector…but a much larger % of engineering grads do – and there's a lot more of them!

  Fixed number of jobs → physics grads at disadvantage

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A: Because that's just not what we do (translation: "we just train academics").

- Around 18% of physics BS majors will finish physics PhD[6].
- Fewer than 30% of physics PhDs become tenured professors[7]:

We would be training fewer than 4% of our physics students.

Typical faculty activities:

- **Teaching physics**
- Managing teams of researchers *(managerial skills)*
- Managing resources *(project management)*
- Communicating with other scientists (and non-scientists)
- Writing grants/pursuing funding
- Processing patents *(IP)*

Innovation and entrepreneurship training (project management, leadership, IP, cost benefit analysis, etc.) would generate better academics too.

[6]AIP Statistical Research Center, *Focus on Roster of Physics Departments with Enrollment and Degree Data, 2013*
[7]*NSF Survey of College Graduates*, *NSF Survey of Doctoral Recipients*, 2013 data

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Physicists as Innovators

During the past century, some of the world's most game-changing technologies were invented by physicists.

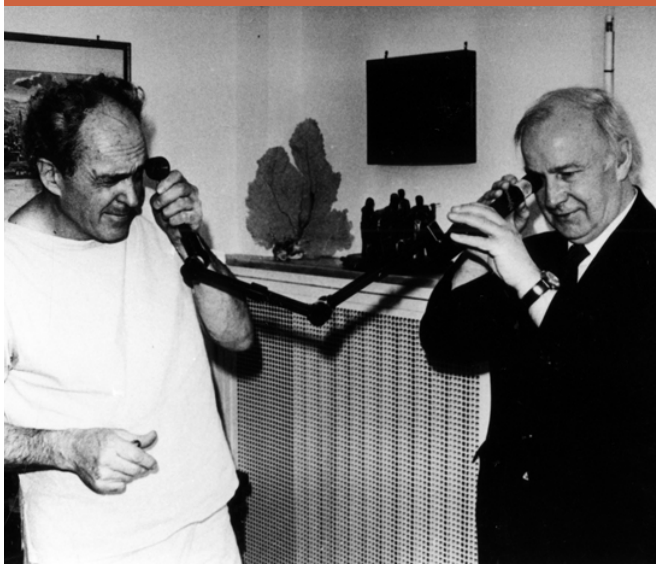
Laser

Arthur Leonard Schawlow, at Bell Labs circa 1960

Transistor

Bardeen, Shockley, and Brattain, at Bell Labs in 1948

Fiber Optics



Harold Hopkins and Avery Jones, in 1918

Image credits (L-R): Wikimedia Commons; Wikimedia Commons; Kelvin Hopkins, courtesy AIP Emilio Segre Visual Archives, Hecht Collection

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These inventions were a response to (existing or anticipated) necessity. But their development relied upon a deep, fundamental understanding of the laws of nature on the part of the inventors.

Fabry-Pérot Etalon: $T_e = 1/1 + F\sin^2(\delta/2)$ → Laser Cavity

Minority Carriers/Hole Current: $j_p = +\mu_p pE - D_p \partial p/\partial x$ → Junction Transistor

Total Internal Reflection: $\theta_c = \sin^{-1}(n_2/n_1)$ → Fiber Optic Cable

Such understanding, applied to real-world problems, leads to creative, out-of-the-box solutions and breakthroughs which lead to new technologies.

Physics as a discipline is *uniquely* positioned to provide this.

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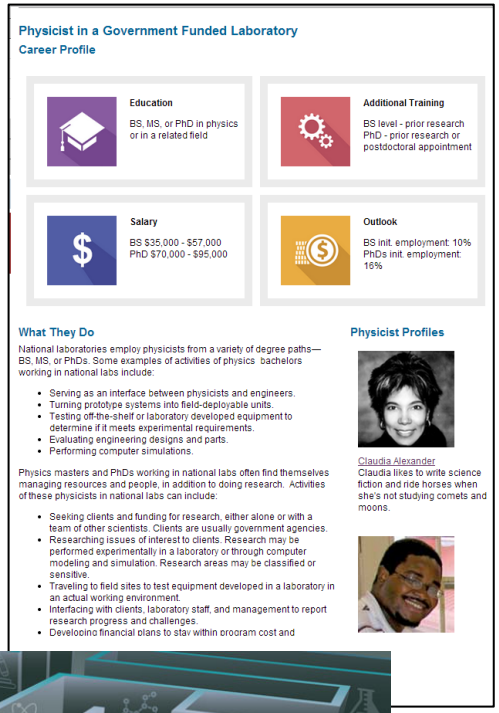
What Can You Do?

Broaden Your Students' Career Focus



Physicist in a Government Funded Laboratory
Career Profile

Education
BS, MS, or PhD in physics or in a related field

Additional Training
BS level - prior research
PhD - prior research or postdoctoral appointment

Salary
BS $35,000 - $57,000
PhD $70,000 - $95,000

Outlook
BS init. employment: 10%
PhDs init. employment: 16%

What They Do

National laboratories employ physicists from a variety of degree paths—BS, MS, or PhDs. Some examples of activities of physics bachelors working in national labs include:

- Serving as an interface between physicists and engineers.
- Turning prototype systems into field-deployable units.
- Testing off-the-shelf or laboratory developed equipment to determine if it meets experimental requirements.
- Evaluating engineering designs and parts.
- Performing computer simulations.

Physics masters and PhDs working in national labs often find themselves managing resources and people, in addition to doing research. Activities of these physicists in national labs can include:

- Seeking clients and funding for research, either alone or with a team of other scientists. Clients are usually government agencies.
- Researching issues of interest to clients. Research may be performed experimentally in a laboratory or through computer modeling and simulation. Research areas may be classified or sensitive.
- Traveling to field sites to test equipment developed in a laboratory in an actual working environment.
- Interfacing with clients, laboratory staff, and management to report research progress and challenges.
- Developing financial plans to stay within program cost and

Physicist Profiles

Claudia Alexander
Claudia likes to write science fiction and ride horses when she's not studying comets and moons.

APS Resources

- APS Online Professional Development Guidebook
  Key professional development topics such as skills self-assessment, networking, resume writing, and more.
- APS Careers Webinars
  Free, cover a wide variety of topics including careers in industry and entrepreneurship.
- APS Physicist and Job Prospects Profiles
  Information about salary, job outlook, and placement and advancement strategies for common physics career paths.
- Physics InSight Careers Slideshow
  Downloadable slideshow featuring physicists working in diverse fields, salary and employment info, and more.

Other Resources

- AIP Statistical Research Center
  Up to date statistics on physics employment, salaries, job outlook, job satisfaction, and more.
- YOUR Local Career Services Office
  Comprehensive self-assessment tools for students and expertise on non-academic fields.

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Encourage More Industrial Contact/Mentorship

- APS Distinguished Lectureship on the Application of Physics.
- APS Industrial Speakers List
- APS Local Links Program
- LinkedIn®
  Connect with your students now, and you'll be connected with industrial physicists in the future!

Include Physics Innovation and Entrepreneurship in Labs and Courses

- Experiential learning/"maker" spaces (e.g. the *Innovation Hyperlab, Garage Physics*)
- Enhanced co-op or internship programs
- Entrepreneurship tracks which incorporate physics and engineering or business courses
- Adapted "standard" courses which include relevance to applications and/or workforce
- New courses on communication, IP, business structures, etc.
- And others….

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Engage A Community of Practitioners

- VentureWell (formerly National Collegiate Innovators and Inventors Alliance, NCIIA)
- *Scienceworks* Physics Entrepreneurship Bachelor's Degree at Carthage College
- University of Colorado, Denver/*Innovation Hyperlab*
- Case Western University Physics Entrepreneurship Master's
- Loyola University, Kettering University, and many others.

"Reinventing the Physicist" Conference – June 2014

- Representatives from 50 institutions in attendance
- Dedicated sessions for physics innovation and entrepreneurship at APS annual meetings
- Online resources to foster development of community of practitioners
  - Creation of PIE Google Group/listserve
  - Regular APS communication on PIE activities to membership, other societies

PIPELINE program

- ***"P**romoting **I**nnovation and **P**hysics **E**ntrepreneurship through **IN**stitutional **E**ngagement"*** submitted to NSF.
- Unifies efforts of six institutions to build and implement new physics innovation and entrepreneurship curricular elements, to be evaluated and disseminated
  - Activities varied in scope and resources
  - Institutions varied in culture and resources
  - Assessment of effects of PIE implementation on student and faculty attitudes towards innovation and entrepreneurship.
  - Will seed a coherent community of expert practitioners who can mentor other institutions.

Conclusion

- Employers in STEM fields value physics graduates in their companies as members of interdisciplinary teams.
  - employers routinely recruit and hire physics graduates into STEM industries.
- Yet, we also know that physics graduates are also missing important training and experience from the perspective of employers
  - leadership, working well on interdisciplinary teams, communicating according to audience, understanding of basic business principles, etc.
- As a discipline that generates natural innovators, physics should be building an educational infrastructure to support a pipeline of workforce-ready graduates.
  - yet it remains reluctant to do so, despite many potential gains for students and departments alike.
- Efforts are underway to:
  - better understand workforce preparedness of physics graduates, as well as outcomes of existing PIE programs.
  - support and foster communication within a growing community of practitioners.
  - develop (hopefully) a robust nationwide program which would make innovation and entrepreneurship content a natural part of physics education.

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Get Involved!
Contact:

Crystal Bailey

bailey@aps.org