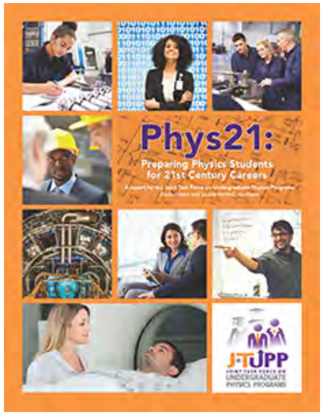

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PHYS21

PHYS21: Preparing Physics Students for 21st Century Careers

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University of Washington

AAPT PHYSICS EDUCATION

NSF

APS physics

Supported by NSF through DUE 1540570

Outline

- Summary of main points of PHYS21 report **30 mins**
  - The current landscape
  - Learning goals
  - Strategies for achieving learning goals
  - Programmatic change
- Discussions at tables **45 mins**
  - What next step could your department take?
- Reports from tables **15 mins**

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Each year:

7,500 bachelor's degrees in physics awarded

350 physics faculty members hired

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What do physics graduates do?

- **40% of bachelor's graduates enter the workforce immediately***
  - **61% work in the private sector**
  - 13% work in colleges and universities
  - 8% work in high schools
  - 6% work in the military
  - 5% work in civilian government or national laboratories

- 65% of physics PhD holders work outside academia

*Data from the published Phys21 report; these numbers were recently updated by the AIP

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Is there a problem?

- Most departments prepare students primarily for academic careers and do nothing special to prepare them for other paths.
  (Tacit assumption that the skills and knowledge needed for those careers develop "automatically.")
- Despite the lack of attention, physics graduates *are* successful in a wide variety of careers.

However,

- Many graduates report that they were unprepared in several key areas (job search, interviewing, adapting to a non-academic environment, etc.)
- Many talented students may be avoiding physics because of a perception that jobs are difficult to find with only a B.S. degree.

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APS and AAPT formed a joint task force

- The committee is charged with preparing a report that will engage and inform physicists in answering the question:

What skills and knowledge should the next generation of undergraduate physics degree holders possess to be well prepared for a diverse set of careers?

The report will:

- provide guidance to physicists on revising the undergraduate curriculum to improve the education of a diverse student population
- include recommendations on improving content, pedagogy, professional skills, and student engagement

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Task Force membership

Paula Heron, co-chair
University of Washington

Laurie McNeil, co-chair
University of North Carolina, Chapel Hill

Douglas Arion
Carthage College

Walter Buell
The Aerospace Corporation

S. James Gates
University of Maryland

Sandeep Giri
Google Inc.

Elizabeth McCormack
Bryn Mawr College

Helen Quinn
Stanford Linear Accelerator Center

Quinton Williams
Howard University

Lawrence Woolf
General Atomics Aeronautical Systems

Beth Cunningham
American Association of Physics Teachers

Bob Hilborn
American Association of Physics Teachers

Ted Hodapp
American Physical Society

Renee Michelle Goertzen
American Physical Society

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Task force process

- Examined reports and synthesized results
  - e.g., *Vision and Change in Undergraduate Biology Education*
- Commissioned two original studies
  - *Physics Majors in the Workforce (*R.E. Scherr, Seattle Pacific University)
  - *Departmental Case Studies (*S. Chasteen, Chasteen Educational Consulting LLC)
- Sought other perspectives
  - physicists in different employment sectors, representatives from APS careers office, AIP statistics office …

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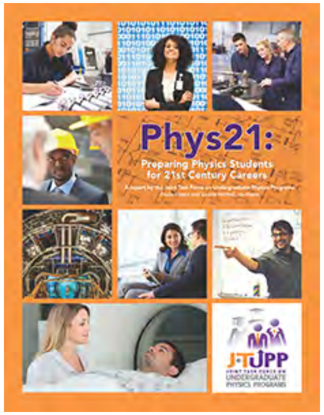

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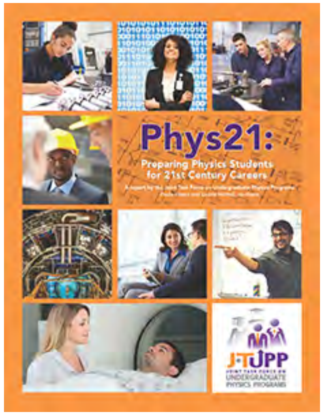
Key Parts of the Report

The Current Landscape

Learning Goals

Achieving Learning Goals

Programmatic Change



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What do employers want?

- The ability to **work well in teams**—especially with people different from oneself
- An understanding of how science & technology are used in the **real-world**
- The ability to **write and speak well**
- The ability to think clearly about complex problems
- The ability to analyze a problem to develop workable solutions
- An understanding of **the global context** in which work is now done
- The ability to be creative and **innovative** in solving problems
- The ability to apply knowledge and skills in new settings
- The ability to understand numbers and **statistics**
- A strong sense of ethics and integrity
- Ability to make decisions and solve problems
- Ability to **sell** to or influence others
- Ability to **plan, organize and prioritize work**

Synthesized from many reports and surveys

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What do recent graduates say?

Interviews with 14 recent graduates employed in various sectors

What did you learn in your physics program that prepared you for this job?

Physics

- Electricity and magnetism, circuits, electronics, electromagnetic effects on equipment, and the operation of resistors and diodes

Problem solving

- Breaking down a complex problem into its component parts and solving one part at a time
- Troubleshooting – tracing the possible origins of errors or undesirable outcomes in a complex integrated system of software and hardware

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What else helped?

Internships

Teaching experience

> *"I have a lot of children in my company and I need to teach them things."*

Teamwork

> *"To have a professor put me in a group with someone I hated, that was very useful…That's how it is in the real world."*

What do you wish you had learned?

Programming

“Programming is everything.”

- Numerical analysis, computational physics, or computer science
- MatLab, Python, Java, C#, C++, Visual Basic, and CAD
- General exposure to programming is helpful for learning any programming language later
- Analysis packages used in academic labs are not common in industry

What do you wish you had learned?

Experience in applied or industrial settings

> *"Companies want you to solve the problem that they have, not analyze something in the abstract."*

- Hands-on experience with designing, building, or troubleshooting real equipment themselves.

The marketability of their skills

- The wide variety of opportunities open to them.
- How to sell themselves to hiring managers.

What do managers say?

Interviews with managers who had hired recent graduates

What qualities or skills do physics majors have that makes you want to hire them?

- *"**I get really excited when I see a physics major**… Very technical, experienced with coding, strong problem solvers, comfortable with computer modeling and simulation, and fluent with math."*
- *"The instinct that a physics major has is 'yes I'm going to use this equipment but **I need to know what it does** so that I can modify it or use it off label'."*
- *"Physics majors have **broad training** (EEs are overspecialized). They interface well with scientists and can solve problems independently."*

What qualities or skills would make such individuals more valuable or easier to hire?

- More research experience
- More preparation in scientific communication, especially writing, to communicate with non-scientist stakeholders
- Less perfectionist
- Better "people skills," especially teamwork
- Better oral and written communication with team partners
- More collaboration and consensus; less defensive argumentation

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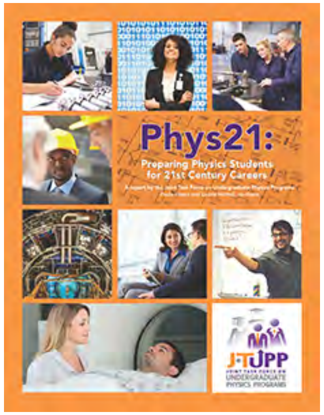
What advice would you give physics departments?

- Help physics majors understand their valuable skills
- Get undergraduates involved in research early
- Encourage students to think beyond academia
- Promote teaching opportunities
- Get undergraduates involved in internships
- Cultivate partnerships with local industry



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Learning goals

- Physics-specific knowledge and skills
- Scientific and technical skills
- Communication skills
- Professional/workplace skills

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Physics-specific knowledge

- Basic laws of physics
- Mathematical representations
- Problem-solving, including in applied areas
- …

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Scientific and technical skills

- Problem-solving competency
- Experimental competency
- Coding competency: write and execute a software to explore, simulate or model physical phenomena
- Software competency: learn and use industry-standard computational, design, analysis and simulation software
- Data analytics competency: analyze data (incl. statistical and uncertainty analysis), distinguish between models, present results appropriately

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Communication skills

- Communicate physics and technology concepts to scientists and non-scientists
- Organize and communicate ideas using words, mathematical equations, tables, graphs, pictures, diagrams and other visualization tools.

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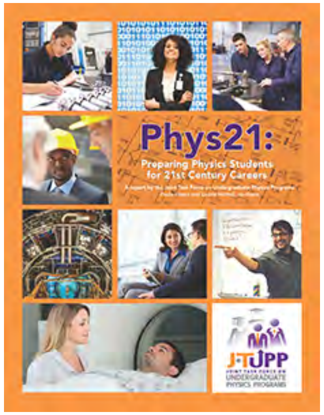
Professional/workplace skills

- Collegiality and cooperation in diverse teams
- Awareness of standard practices for effective resumes and job interviews
- Critical life skills: completing work on time, listening, time management, responsibility, cultural and social competence
- Awareness of career opportunities and pathways for physics graduates



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What are physics departments doing?

Case studies of a mix of large and small, public and private colleges and universities:

- Carthage College
- Florida State University
- St. Mary’s College of Maryland
- University of California – Davis
- University of Wisconsin – LaCrosse

What are physics departments doing?

- Turning institutional obligations (e.g., strategic planning) into opportunities
- Developing learning goals and letting them drive the curriculum
- Using varied assessment strategies
- Embracing experimentation but allowing time for results to appear
- Making sure they know their students and their alumni
- Making career preparation a departmental responsibility
- Ensuring that the administration is aware of how the department is supporting institutional goals

Strategies for achieving learning goals

- Utilize co-curricular activities
- Modify courses
- Infuse skills into “capstone” experiences
- Modify the curriculum
- Develop new tracks or programs

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Utilize co-curricular activities

- Invite speakers (including alumni/ae) on industrial/applied physics topics; have them meet w/students
- Encourage participation in extra-departmental events: trade shows, local professional society meetings (IEEE, OSA, …)
- Offer internships/co-ops
- Collaborate with the Career Services office for resume-writing, interviewing, job search techniques, etc.

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Modify courses

- Incorporate industrial and commercial application into labs
- Incorporate industry-standard software (CAD, LabView, OSLO, …)
- Assign homework problems involving real-world and cross-disciplinary applications
- Organize courses around a specific technology

  e.g., Use solar cells to teach quantum mechanics, thermal physics, optics, E&M, condensed matter physics, etc.
- Design open-ended lab projects to build teamwork and project management skills

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Infuse new skills into the “capstone”

- Encourage commercial/applied research projects
- Provide training on commercial software packages
- Establish “Maker spaces” for designing, developing and testing products or solutions
- Require presentations of findings to varied audiences (including non-scientists)
- Incorporate resume-writing and interviewing

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Modify the curriculum

- Make the major more flexible to meet different career goals (grad school, engineering job, entrepreneurial efforts, high school teaching)
- Substitute courses from speech, business, technical and creative writing, engineering, computer science, philosophy (ethics/reasoning skills) for some standard or elective courses
- Encourage students to take industry-related courses as electives: condensed matter, optics, electronics
- Adopt a “communicating in the discipline” requirement: lab courses, capstone courses, student research presentation
- Guide students to satisfy general education requirements with courses that offer professional development

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Create new tracks or programs

- Applied physics
- Entrepreneurship
- Joint programs with engineering, CS, medicine, graphic arts, …

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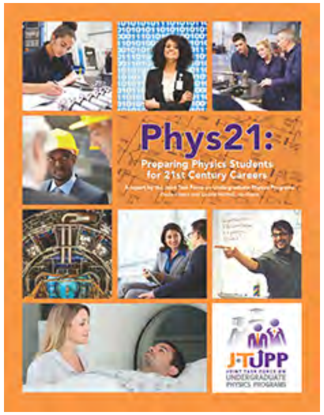

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Key Parts of the Report

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Programmatic Change

- Get to know your students and the jobs available to them
- Adopt learning goals
- Map learning goals to the existing program, identify gaps
- Develop a plan and implement it
- Assess the results and **use them to inform further modifications**

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Get to know your students

- Ask students about their career interests early (first year).
- Track how interests change as they move through the curriculum.
- Use exit interviews: how did program help career awareness and interest?
- Monitor where students go
- Survey alumni/ae: what parts of the program have high value, which parts have little value?

Adopt learning goals

- Use PHYS21 goals as a *starting point*
- Goals can be addressed at multiple points in a program.
- Be aware of careers your graduates *could* have, as well as those they do.
- Not all skills must be mastered; for some, exposure is enough.

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Map learning goals to your program

- How can students work toward the goals?
- How can they demonstrate their achievement?
- Are there important learning goals not supported by the program?
- Are there program components that don't support important learning goals?
- Which goals can be addressed by small changes (course tweaks, alumni/ae speakers)?
- Which goals need structural change (flexible major, internships)?

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Develop a plan and implement it

- Go after the low-hanging fruit first.
- Identify a team and a timeline.
- Identify and cultivate partnerships (other units, employers, career center,…)
- Define resource needs (including faculty development).
- Relate initiatives to larger institutional context.

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Assess the outcomes

- Direct evidence: performance of current students
- Indirect evidence: from alumni/ae and employers
- Fine-grained outcomes: e.g. specific physics knowledge
- Program-level outcomes: e.g. professional/workplace skills

Case study departments: Common themes

- Culture of continuous improvement
- Knowledge of their students and their alumni
- Awareness of national trends in physics education
- **Explicit respect for non-academic careers and students who pursue them**

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What are some challenges? strategies?

Physics faculty often lack familiarity with:

- non-academic careers
- private-sector practices
- industry-standard software packages, instruments, etc.

Strategies

- Collaboration with other units on campus, local industry
- Reaching out to alumni
- Networking with other physics departments

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What are the potential benefits?

- Happier students
- Enhanced recruiting
- Stronger alumni connections
- New funding opportunities
- A more satisfied administration
- Better prepared graduate students and postdocs

Conclusion

- Better preparing students for diverse careers does **not** imply abandoning the rigorous technical education that makes a physicist a physicist, **nor** does it mean regarding your program as providing only vocational training.

- It **does** mean evaluating whether your department is doing its best to prepare students to compete with graduates in other fields (such as engineering) for desirable employment and career options.

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Physics Innovation and Entrepreneurship (PIE) Education – Phys21 in practice

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, commercialization, etc.

APS PIPELINE Project

- Collaborative project, six member institutions: Loyola University Maryland, Rochester Institute of Technology, Wright State, UC Denver, George Washington University, and William & Mary.
- Advised by experts from established physics entrepreneurship programs (e.g. Carthage College, Case Western, Kettering University)
- Goals are:
  - to **deliver tested PIE curriculum** to a wider cohort of practitioners.
  - to **assess of effects of PIE implementation** on student and faculty attitudes towards innovation and entrepreneurship, and **discover barriers** to PIE implementation
  - to **build a community** of expert practitioners who can mentor other institutions.

www.aps.org/programs/education/innovation/index.cfm

Support for this work was provided by the National Science Foundation's Improving Undergraduate STEM Education (IUSE) program under Award No. 1624882

PIPELINE Projects Include:

New Curricular Development

- Technical Entrepreneurship Course (Loyola)
- Pop-Up Classes (RIT, Loyola)
- Prototyping and design thinking course w/experiential learning (W&M, UC Denver)
- Intermediate lab course w/communication skills emphasis (GW)

Curricular Modification

- Incorporate Technical Entrepreneurship Cases into existing Physics Courses (Loyola)
- Modify 1st Yr. Seminar Course to include PIE elements (Wright State)

Certifications and Focused Curricular Tracks

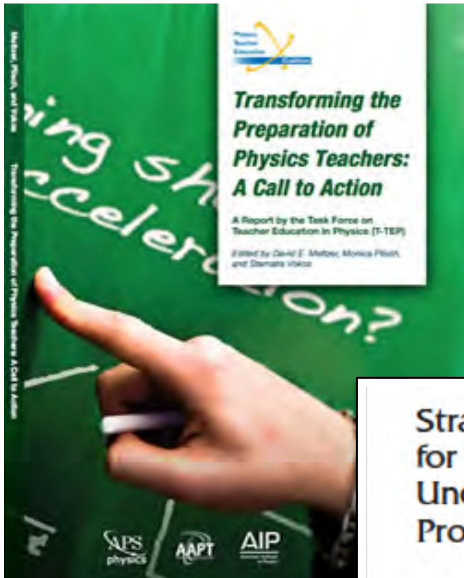
- Joint Entrepreneurship/Physics Track (W&M)
- Industry/innovation Track or Minor (RIT)

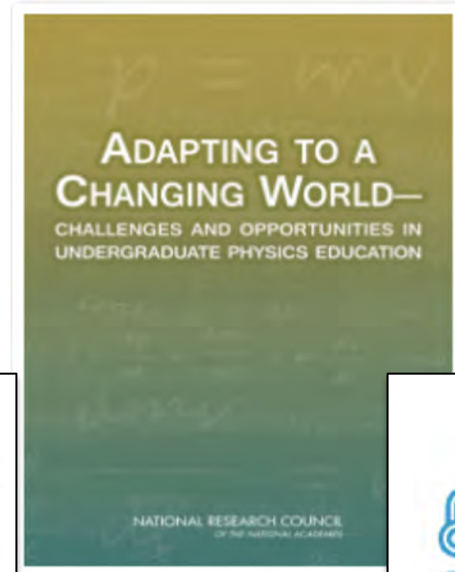
Co- or Extra-Curricular Activities

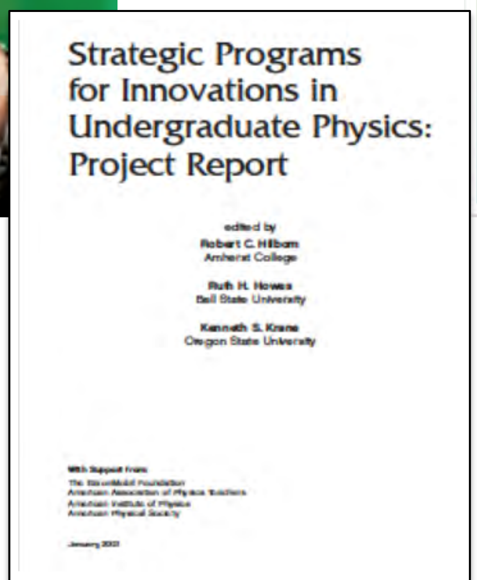
- Technical Speaking Events (Loyola)
- Reinvigorate Industry Co-Op Program (RIT)
- Expansion and Development of Innovation Hyperlab (UC Denver)
- Launch Physics Student Innovators, Psi* (UC Denver)

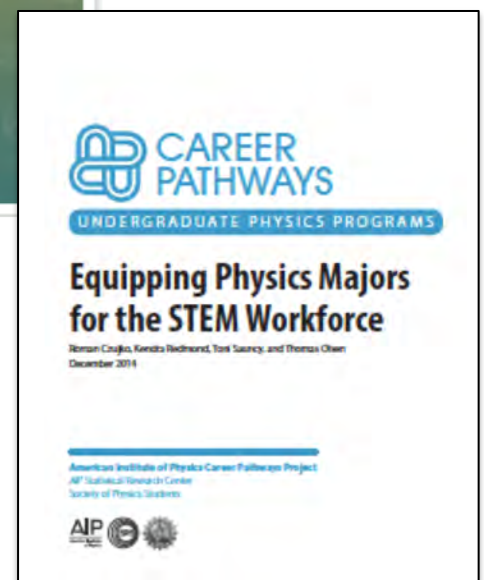
Activities promote key learning areas identified in the Phys21 report: physics specific knowledge, scientific and technical skills, communication skills, professional and workplace skills.

Other resources









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Small-group discussions 45 mins

- Tables are labeled according to institution type + one table for "PIE/Pipeline" entrepreneurship ◆◆
- Questions for each table
  - What next step(s) could my department take?
    - ● *Utilize co-curricular activities*
    - ■ *Change the courses*
    - ■ *Infuse skills into capstone experiences*
    - ◆ *Change the curriculum*
    - ◆ *Create new tracks or programs*
  - What resources and/or collaborations will we need?
  - What are the biggest barriers or challenges?

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Conclusion

- **Physics graduates can choose many careers:** bring flexibility, problem-solving skills, breadth of knowledge
- We need to **better communicate the capabilities** of physics graduates
- Physics graduates would benefit from
  - stronger technical skill base: **more computational analysis**
  - **more engagement with industry-type work**: internships and applied research projects
  - **better preparation in workplace skills:** teamwork, communication, basic business concepts
  - **more connection** between **physics content, innovation and entrepreneurship**

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