They Won’t All Grow Up to Be You: Preparing Students for Diverse Careers

APS and AAPT Joint Task Force on Undergraduate Physics Programs
Laurie McNeil and Paula Heron, co-chairs
Joint Task Force on Undergraduate Physics Programs

Commissioned by the American Physical Society and the American Association of Physics Teachers to provide a report 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?

Providing guidance to physicists on:

• Revising undergraduate curriculum
• Educating a diverse student population
• Improving content, pedagogy, professional skills, and student engagement

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TIME LINE

• Task Force formed: Summer 2014
• Initial meeting: November 2014
• Data-gathering, (initial) report drafting: 2015
• Second and third meetings: April, December 2015
• Completed report: Spring 2016
• Review and revision: Summer 2016
• Final report: October 2016
• Physics Today article: November 2017
A FEW FACTS

• 7500 people graduate with bachelor’s degrees in physics each year
• 350 people are hired as physics faculty members each year
• 5% of all physics bachelor’s eventually end up as physics professors
• 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
• 35% of physics PhD holders work in 4-year academic institutions

Various reports, AIP Statistical Research Center
IS THERE A PROBLEM?

Most departments prepare students primarily for academic careers and do not do anything special to prepare students for other paths.

Tacit assumption: the skills and knowledge needed for those careers develop “automatically.”

In spite of this lack of attention, physics graduates are successful in a wide variety of careers (including academia).

However,

Many graduates and their employers report that they were unprepared in several key areas.

Graduates in related disciplines are better prepared to compete for jobs.
THE CHALLENGE FOR PHYSICS DEPARTMENTS

To better prepare students for diverse careers does not mean 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.

It does mean that we should consider reframing education in the context of how it is used by our students.
DATA SOURCES FOR J-TUPP REPORT

Reports from:

• other disciplines, e.g., *Vision and Change in Undergraduate Biology Education*
• professional associations, e.g., the AAC&U
• industry, e.g., the Daniel Group’s survey of employers
• the AIP Career Pathways Project
• AIP Statistical Research Center

Two original studies commissioned by J-TUPP

*Physics Majors in the Workforce* (R.E. Scherr, Seattle Pacific University)

*Departmental Case Studies* (S. Chasteen, Chasteen Educational Consulting)
Consultants with knowledge of different employment sectors

- Crystal Bailey (APS Career Programs Manager)
- Cynthia Bauerle (worked on “Vision & Change”)
- Roman Czujko (American Institute of Physics)
- Bob Doering (Texas Instruments)
- Miles Finn (Start-ups and IP law)
- Barbara Jones (IBM)
- Duncan Moore (University of Rochester)
- Monica Plisch (APS & PhysTEC)
- Kendra Redmond (SPS)
- John Rumble (APS FIAP Chair)
- Kathryn Svinarich (Kettering University)
WHAT DO EMPLOYERS WANT?

1. The ability to work well in teams—especially with people different from oneself
2. An understanding of science and technology and how they are used in real-world settings
3. The ability to write and speak well
4. The ability to think clearly about complex problems
5. The ability to analyze a problem to develop workable solutions
6. An understanding of global context in which work is now done
7. The ability to be creative and innovative in solving problems
8. The ability to apply knowledge and skills in new settings
9. The ability to understand numbers and statistics
10. A strong sense of ethics and integrity
11. Ability to make decisions and solve problems
12. Ability to sell or influence others
13. Ability to plan, organize and prioritize work
CONCLUSIONS FROM MANY STUDIES

• *Physics graduates can choose many careers*: bring flexibility, problem-solving skills, technology exposure
• Technical skill base should be expanded: *more computational analysis tools*, esp. industry-standard packages
• We need to *better communicate the capabilities of physics graduates*: private sector, government, industrial positions
• Physics graduates would benefit from broader engagement with industry-type work: *internships* and *applied research projects*
• Physics graduates would benefit from more connection in their education between *physics content* and *innovation*
• Need better preparation in *workplace skills*: teamwork, communication, basic business understanding
INCENTIVES FOR CHANGE

Attract, retain, and better prepare students

• Students expect relevance, authenticity, application
• Clear connection between majoring in physics and rewarding careers will attract more diverse students (incl. 1st-generation college-goers and URM s)
• Clear connection between majoring in physics and solving societal problems will attract more diverse students (esp. women)
• NGSS provides learning experiences defining problems, investigating, analyzing and interpreting data, developing and using models, applying scientific knowledge, communicating information: students will expect this
• Enhancing career skills also enhances preparation for graduate school
INCENTIVES FOR CHANGE cont.

Attract new resources
• Connecting research with topics of interest to private sector can help establish new collaborations and new sources of research funding. *Even esoteric topics (see Google X, Microsoft Station Q)*
• Preparing graduates for success in high-paying jobs can lead to generous alumni and corporate support for programs

Improve program impact
• Enhance connections with other disciplines, joint research projects and double majors
• Enhance reputation, recruit excellent faculty with wide range of research interests.
  o Increased enrollment allows growth in faculty numbers
  o Broad research portfolio makes department attractive
WHAT THE REPORT CONTAINS

• **View of the landscape**: statistics, other disciplines, pressures faced by physics programs, findings from studies of employment and workplace skills
• **The case for change**
• **Knowledge, skills and attitudes** needed for success in the workplace
• **Learning goals** for physics programs for career preparation
• Approaches to *achieve the learning goals*
  • Modifying *courses* within the existing curriculum
  • Modifying the *curriculum* (changing requirements of the major)
  • Infusing new skills into *thesis/research requirements*
  • Creating *new tracks* or programs
  • Utilizing *co-curricular activities*
• How to accomplish *programmatic change*
• Role of *professional societies* and funding agencies
• **Case studies** of successful departments
LEARNING GOALS FOR PHYSICS PROGRAMS

Physics-specific knowledge, *e.g.*
- Basic laws of physics
- Mathematical representation
- Problem-solving, including in applied areas

Scientific and technical skills, *e.g.*
- Solve both well-posed and ill-posed questions and problems.
- Competency in basic experimental technologies
- Coding competency: write and execute 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
LEARNING GOALS FOR PHYSICS PROGRAMS cont.

Communication skills, *e.g.*
• Communicate with audiences from different cultures with maximum impact
• Orally 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.

Professional/workplace skills, *e.g.*
• Collegiality and collaboration in diverse teams
• Awareness of standard practices for effective resumes and job interviews
• Critical life skills: completing work on time, listening, optimism, time management, responsibility, cultural and social competence, ... 
• Awareness of career opportunities and pathways for physics graduates
APPROACHES TO ACHIEVE THE LEARNING GOALS

Modify courses

• Incorporate application of physics principles to industrial processes and commercial devices into lab exercises
• Incorporate industry-standard software (CAD, LabView, OSLO, ...)
• Homework problems involving real-world and cross-disciplinary applications
• Organize course around a specific technology

*Use solar cells to teach quantum mechanics, thermal physics, optics, E&M, solid state physics, etc.*

• Open-ended lab projects to build teamwork and project definition and management skills
APPROACHES TO ACHIEVE THE LEARNING GOALS cont.

Modify curriculum

- Make 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 more students to take industry-related courses as electives: solid state, optics, electronics
- Adopt “communicating in the discipline” requirement within the major: lab courses, capstone courses, student research presentation
- Guide students to satisfy general education requirements with courses that offer professional development
APPROACHES TO ACHIEVE THE LEARNING GOALS cont.

Infuse new skills into thesis/research/capstone requirement

- Commercial/applied research projects
- Commercial software packages
- Maker spaces to design, develop and test products or solutions
- Presentations of research findings to varied audiences (including non-scientists)
- Senior seminar including resume-writing and interviewing, presentations by physicists in varied careers

Create new tracks or programs

- Applied physics
- Entrepreneurship
- Teacher education
- Joint programs with engineering, CS, medicine, graphic arts, ...
APPROACHES TO ACHIEVE THE LEARNING GOALS cont.

Utilize co-curricular activities

- Speakers (incl. alumni/ae) on industrial/applied physics topics, meet w/ students
- SPS activities for professional development, incl. field trips
- Extra-departmental events: speakers, trade shows, local prof. society chapter meetings (IEEE, OSA, AAPT, ...)
- Internships/co-ops
- Career Services office for resume-writing, interviewing, job search techniques, etc.
Get to know your students and the jobs available to them

- 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 immediately and several years later.
- Survey alumni/ae: what parts of the program have high value, which parts have little value?

Adopt learning goals

- Be bold! You can do more than you think. Consider reverse course design.
- Goals can be addressed at multiple points in a program.
- Be aware of careers your graduates could have, as well as those they do.
- Begin departmental conversations on these topics
- Not all skills must be mastered, for some exposure is enough.
ACCOMPLISHING PROGRAMMATIC CHANGE cont.

Map learning goals to the existing program

- How can students work toward the goals?
- How can they demonstrate their achievement of those goals?
- Are there important learning goals not supported by the program?
- Are there program components that don’t support important learning goals?
- What goals can be addressed by small changes (course tweaks, alumni/a speakers)?
- What goals need structural change (flexible major, internships)?
ACCOMPLISHING PROGRAMMATIC CHANGE cont.

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.

Assess the results and use them to inform further modifications
• 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
• Continue departmental discussions
• Document changes
THE J-TUPP MESSAGE

• Be self-aware! Very few departments already meet all these goals, so we are not serving our students as well as we could.
• Be bold! Consider new design as well as incremental change—push the envelope.
• Be a leader! Promote a culture where innovation is encouraged, sustained when it succeeds, tolerated when it fails.
• Work together! The department is the unit of change
• Iterate continuously! One-time change will not result in sustained improvement.
• Steal from the best! Adopt successful models from other institutions.
To download the report:
compadre.org/phys21
BPUPP: Best Practices for Undergraduate Physics Programs

CHARGE

1. Develop a guide for self-assessment of undergraduate physics programs founded on documented best practices linked to measurable outcomes.

   The guide should provide a physics-community-based resource to assist programs in developing a culture of continuous self-improvement, in keeping with their individual mission, context, and institutional type. The guide should include considerations of curricula, pedagogy, advising, mentoring, recruitment and retention, research and internship opportunities, diversity, scientific skill development, career/workforce preparation, staffing, resources, and faculty professional development.

2. Recommend a plan for ongoing review and improvement of this guide under the oversight of the APS Committee on Education (COE).

www.aps.org/bpupp
BPUPP: Best Practices for Undergraduate Physics Programs

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