Trends in Undergraduate Physics Education in the United States

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Undergraduate Physics Circa 2000 in the US

- In the 1990s, the American Physical Society (APS) and the American Institute of Physics (AIP), note the deteriorating state of the production of Physics B.S. degrees in the USA. They start a campaign to reverse this alarming trend.
- In 1998, things hit bottom: About 760 Colleges and Universities with Physics programs graduated only 3,650 Physics majors, about 5 per institution!
- In 2000, APS, AIP, and AAPT (American Association of Physics Teachers) form a *Task Force on Undergraduate Physics* (with support from the ExxonMobile Foundation) to "*provide an overview of undergraduate physics revitalization efforts and to coordinate the efforts of physics professional organizations, individual physicists and physics departments, and funding agencies.*"

APS/AIP/AAPT Task Force – SPIN-UP Report

- The APS/AIP/AAPT Task Force visited in 2001-2003 a large number of Physics Departments around the US. In 2003, the Task Force published the **SPIN-UP** (*Strategic Programs for Innovations in Undergraduate Physics*) **Report**. The report identified the most important elements/factors of a successful Physics undergraduate program as:

1. A widespread attitude among the Faculty that the Physics Department has the primary responsibility for maintaining or improving the undergraduate program.
2. A well-developed curriculum, sound advising and mentoring schemes, and an undergraduate research program.
3. A strong and sustained leadership within the department, with a clear sense of the mission of its undergraduate program, and with the support of the upper administration.
4. A sense of constant experimentation with and evaluation of the program to improve physics teaching.

Strategic Programs for Innovations in Undergraduate Physics: Project Report

edited by
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American Association of Physics Teachers
American Institute of Physics
American Physical Society

January 2003

SPIN-UP Report Findings – What Matters (I)

- A Departmental Leadership and faculty members placing a high value in the undergraduate program.
- A clearly articulated undergraduate mission and vision shared among faculty and communicated to the students.
- A large fraction of the departmental faculty actively engaged in the undergraduate program.
- A strong administrative support from the Dean/Provost offices.
- A strong recruitment program focusing on high school students and first-year university students.
- A sound advising program for physics majors.
- Career mentoring efforts that make students aware of the wide range of careers possible with a physics degree.
- Introduction of flexible physics programs with different options or tracks leading to the B.S. degree.

SPIN-UP Report Findings – What Matters (II)

- Introduction of joint physics/engineering programs (3 years of physics followed by 2 years of an engineering field).
- Establishment of mentoring for new faculty, particularly for teaching.
- Creation of an undergraduate physics club or activation of the local chapters of the Society of Physics Students (SPS) of AIP.
- Creation of undergraduate student study, commons rooms or lounges.
- Creation of opportunities for informal student/faculty interactions.
- Special attention to the introductory physics courses. Assignment of the best teachers to these courses.
- Introduction of undergraduate research in the physics curriculum, either during the summer or during the academic year (AY).
- Making sure that Physics faculty keep abreast in developments and findings of Physics Education Research (PER), and apply them.

Undergraduate Physics Circa 2000 in the US

- Physics Nobel Laureate Carl Wieman writes in the early 2000s in the *Physics Today* that to fix the undergraduate physics problems in the US, among other things, College faculty should devote 10% more of their time on under-graduate affairs. (WISE and easy to say, but hard to apply!)
- University Presidents start raising questions on the number of B.S. degrees awarded by their Physics Departments.
- Many governmental, business/industrial/high technology, and national defense panels/committees/organizations raise flags and urge the revitalization of physics undergraduate education in the US.
- APS and AIP recommend that the Physics Departments in the US double their graduating physics majors within a decade.
- Physics Departments start (voluntarily or not!) to take some or even more action! Kent State University starts acting...

Kent State Undergraduate Program Overhaul

- Acknowledged the presence of the undergraduate students and importance of the physics major program.
- Created a professional environment and a sense of community and belonging for the undergraduate students.
  - Revived and strongly supported the SPS and its activities.
  - Made available to students a working space/lounge.
- Created a dedicated team of Faculty Advisors – Made student advising/mentoring a top programmatic priority.
- Hired a Tenure-Track Faculty with concentration on undergraduate physics education.
- Overhauled both Algebra- and Calculus-based Laboratories.
- Started efforts to introduce Active Learning methods in the Calculus-based introductory physics course sequence.
- Overhauled the undergraduate program and curriculum.
- Invited a SPIN-UP panel for a Departmental Evaluation.

Kent State New Physics Curriculum (I)

- **Introduced** a mandatory two-semester (full year) Modern Physics sequence covering the essentials of Relativity, Quantum Mechanics, Atomic, Molecular, Solid State, Nuclear-Particle Physics, Astrophysics and Cosmology.
- **Consolidated** five 1-semester Math courses (Calculus III, Linear Algebra, Ordinary Differential Equations, Partial Differential Equations, and Advanced Calculus) into an intense 2-semester sequence on Math for Physical Science.
- **Introduced** C^{++} Computer Programming and Data Analysis and Computational Physics Techniques as mandatory courses.

Kent State New Physics Curriculum (II)

- **Introduced** mandatory research through internal or external internship into the curriculum.
- Condensed Mechanics and Electromagnetism yearly sequences to intense 1-semester courses.
- All students are **required** to take Modern Physics I and II, Mechanics, Electromagnetism and Thermal/Statistical Physics.
- Students on research track are **mandated** to take Quantum Mechanics.
- All students are **offered** many Physics **elective courses**: Solid State, Nuclear-Particle, Biophysics, Materials Physics, Modern Optics, Astrophysics, Cosmology, Mathematical Methods, Electronics, and the freedom to take other courses in Mathematics, Computer Science, Chemistry, Biology, and Education.

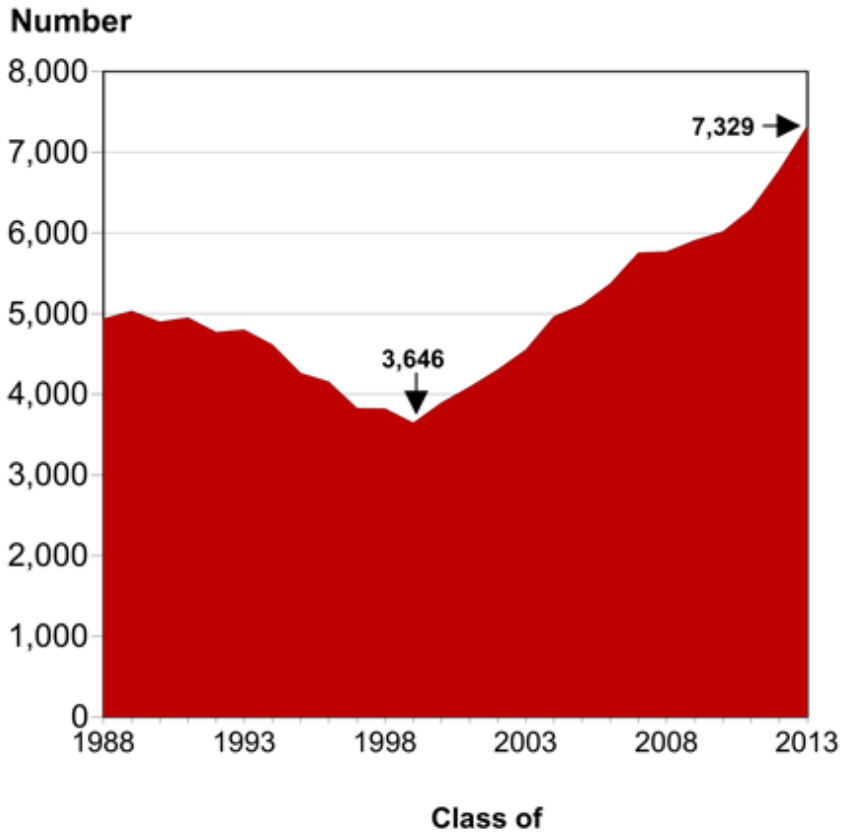
AIP American Institute of Physics

PHYSICS TRENDS

STATISTICAL RESEARCH CENTER www.aip.org/statistics

Physics Bachelor's Doubled!

Bachelor's Degrees Earned in the US



Fall 2014

Undergraduate Physics Circa 2010 in the US

- In 2013 the US Physics Departments meet the APS/AIP goal to double the number of physics B.S. degrees. At Kent State we tripled the number of Physics bachelors!
- By this time the AIP has amassed a large body of data (selected slides below) on the employment opportunities and careers of physics bachelors (and many other topics).
- It is now clearly realized that the 50% of physics bachelors who **do not** enter graduate programs but seek immediate employment **do not have** the necessary skills to succeed in the technical workforce!
- So, the APS and AAPT form in 2014 a *Joint Task Force on Undergraduate Preparation in Physics (J-TUPP)* (with support from the US National Science Foundation) to find out *"What skills and knowledge should the next generation of undergraduate degree holders possess to be well prepared for a diverse set of careers?"*

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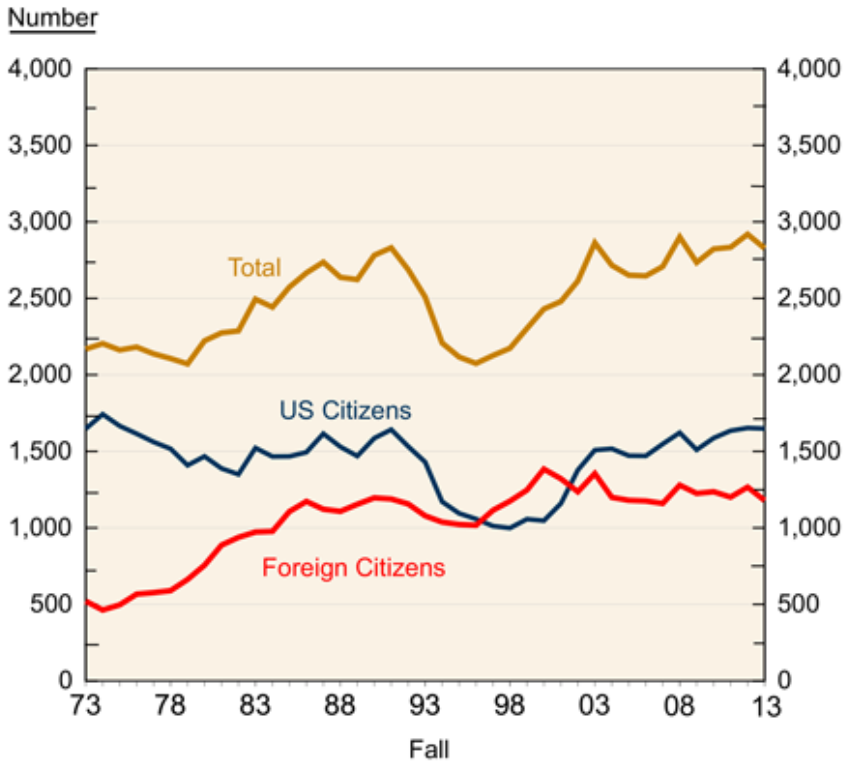
First-Year Graduate Physics Students

Enrollments in PhD-granting Physics Departments



Spring 2015

PHYSICS TRENDS

Contact: Patrick J. Mulvey
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Winter 2004

Physics Bachelors 1 Year Later

4000 Bachelors Degrees

50% | **50%**

Employment

1100	Private Sector
250	High School
190	Government
150	Active Military
230	Other

Graduate School

1160	Physics and Astronomy
320	Engineering
200	Other Science and Math
120	Medicine and Law
130	Education and Other

Four percent of the respondents indicated they were unemployed at the time of the survey, which represents about 160 individuals.

Source: Initial Employment Survey - Classes of 2000 and 2001.

AMERICAN INSTITUTE OF PHYSICS

Statistical Research Center

www.aip.org/statistics

PHYSICS TRENDS

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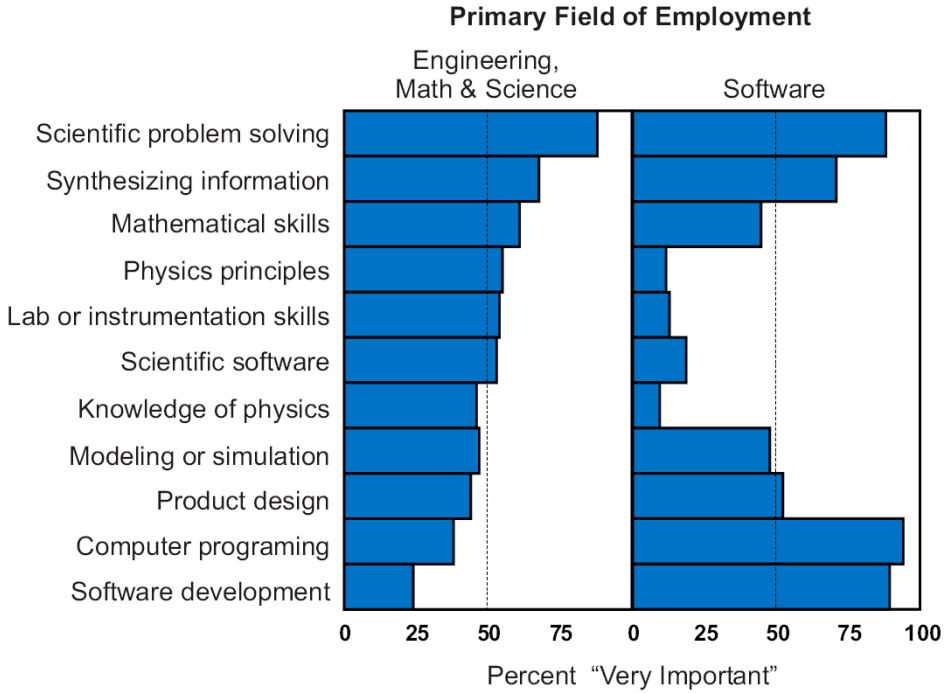
Fall 2001

What's Important?

Importance of knowledge and skills for physics bachelors, 5 - 7 years after degree



Percentage of physics bachelors who chose 4 or 5 on a 5-point scale where 5 = essential.

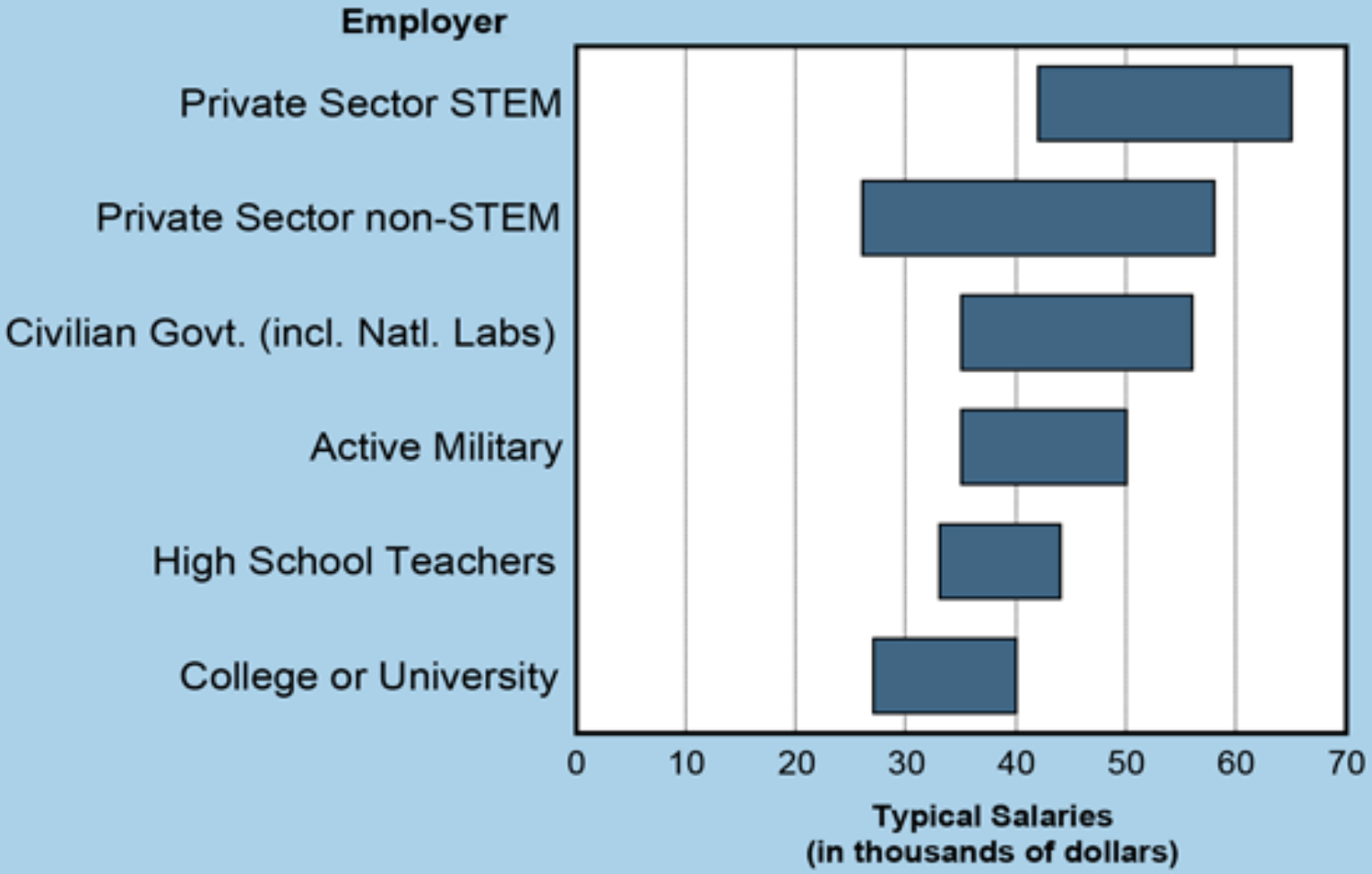
Source: 1998-99 Bachelors Plus Five Study, preliminary results

Question of APS, AIP and AAPT Leaders to 20 CEO's of industrial and high technology companies: **What is the most valuable skill for Physics B.S. graduates?** (Spring 2006, APS Center Meeting, Maryland).

Unanimous **Answer** of CEOs:

DATA MINING ABILITY

Typical Starting Salaries for Physics Bachelors, Classes of 2013 & 2014 Combined



This figure includes only bachelors in full-time, newly accepted positions. Typical salaries are the middle 50% i.e. between the 25th and 75th percentiles. STEM refers to positions in natural science, technology, engineering, and math. Data are based on respondents holding potentially permanent jobs in private sector STEM positions (498), private sector non-STEM positions (114), civilian government positions (52), the active military (44), high school teaching positions (82), and universities or colleges (84).

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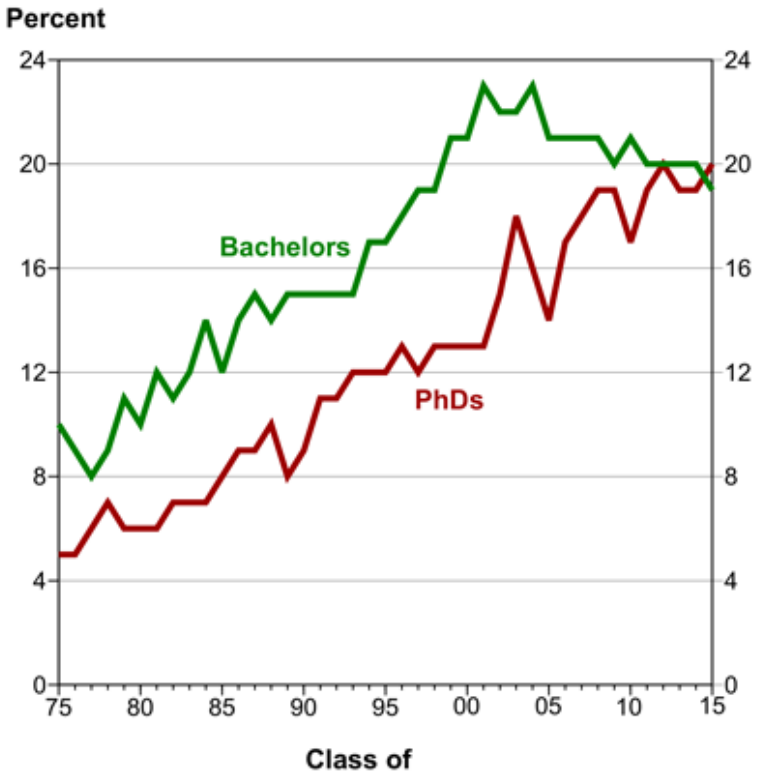
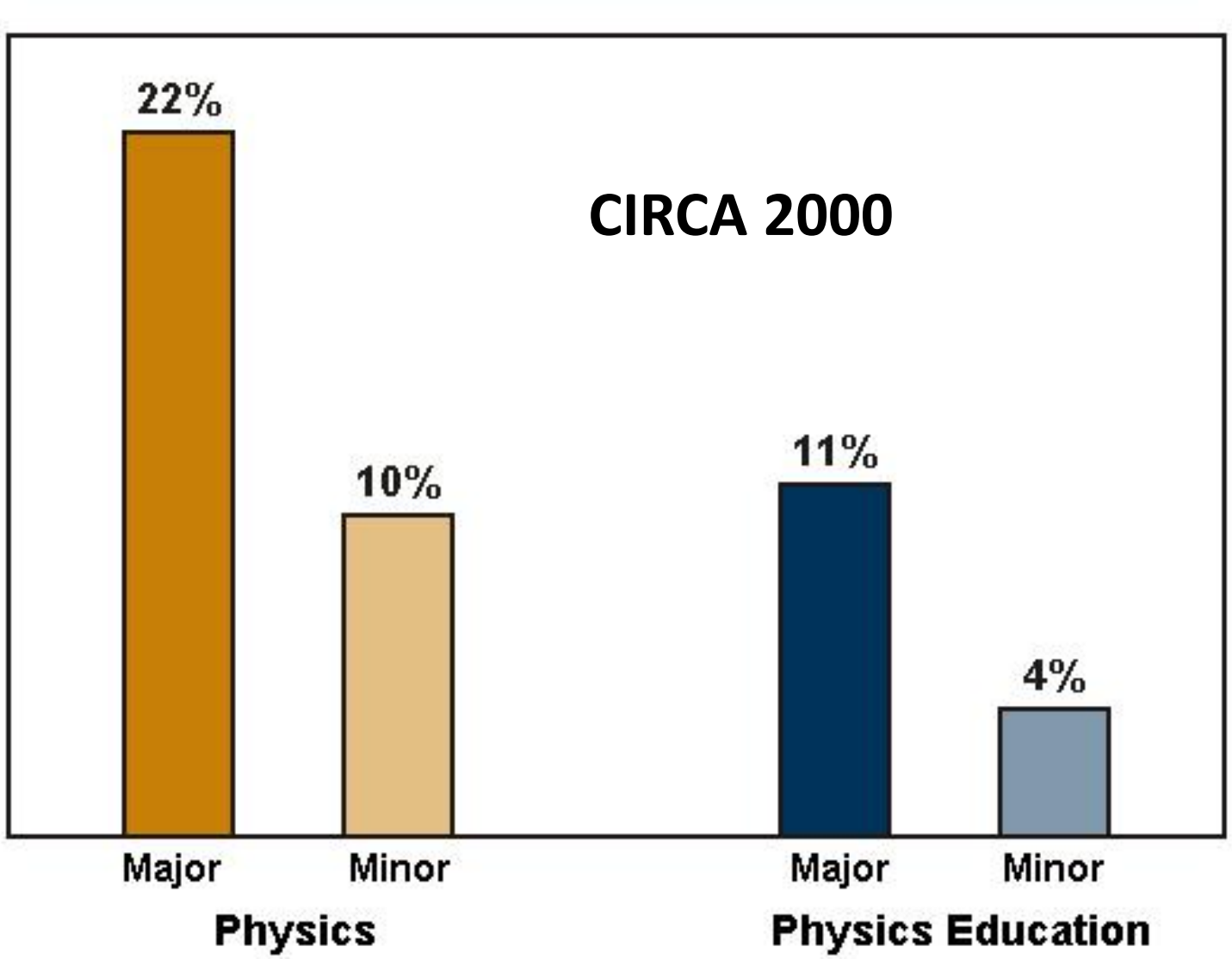
Representation of Women Among Physics Bachelors and PhDs



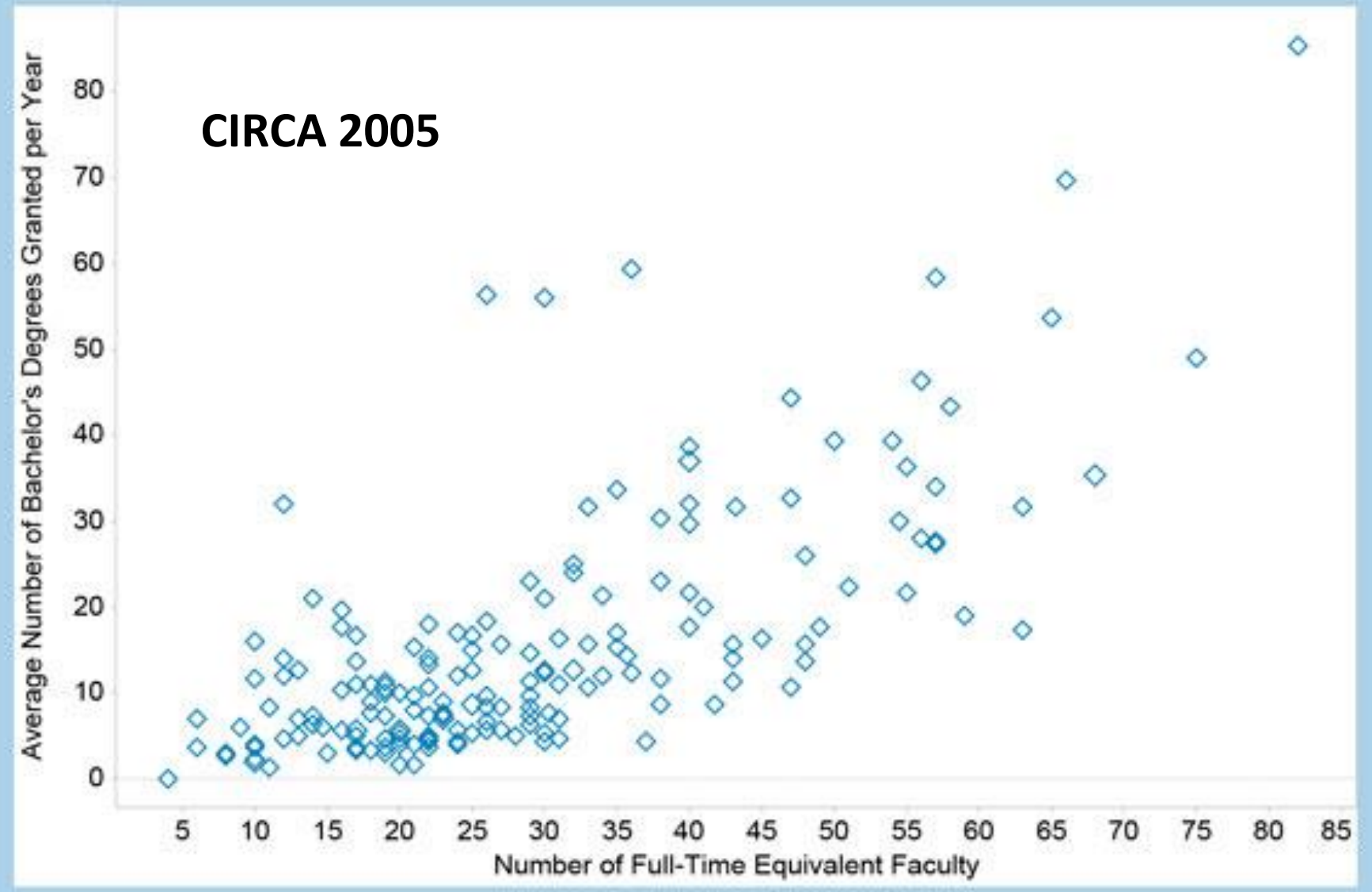
The number of women receiving physics PhDs and bachelor's degrees are both at all-time highs, 365 and 1,550 respectively. The percentage of physics PhDs awarded to women has been increasing, whereas the percentage of physics bachelors awarded to women has been declining in recent years.

Figure 7. Percent of Physics Teachers with a Physics Degree



Size of Physics Bachelor's Class by Number of Faculty

Doctorate is the highest degree offered by the department.



J-TUPP Report Findings and Recommendations (I)

- After two years of research and review, J-TUPP released in the fall of 2016 the report ***Phys21: Preparing Physics Students for 21st Century Careers***. *Phys21* offers new information for Physics Departments to better prepare their students for diverse employment paths beyond academics.
- While many faculty members consider a successful physics career to consist largely of academic research and teaching positions, the Task Force recognized that the *overwhelming* majority of students who receive a physics bachelor's degree end up employed outside academia for all or part of their careers (only about 5% pursue careers as physics professors!).
- The Task Force recommends that physics programs nationwide should be restructured to achieve the array of learning goals that other disciplines and employers desire.

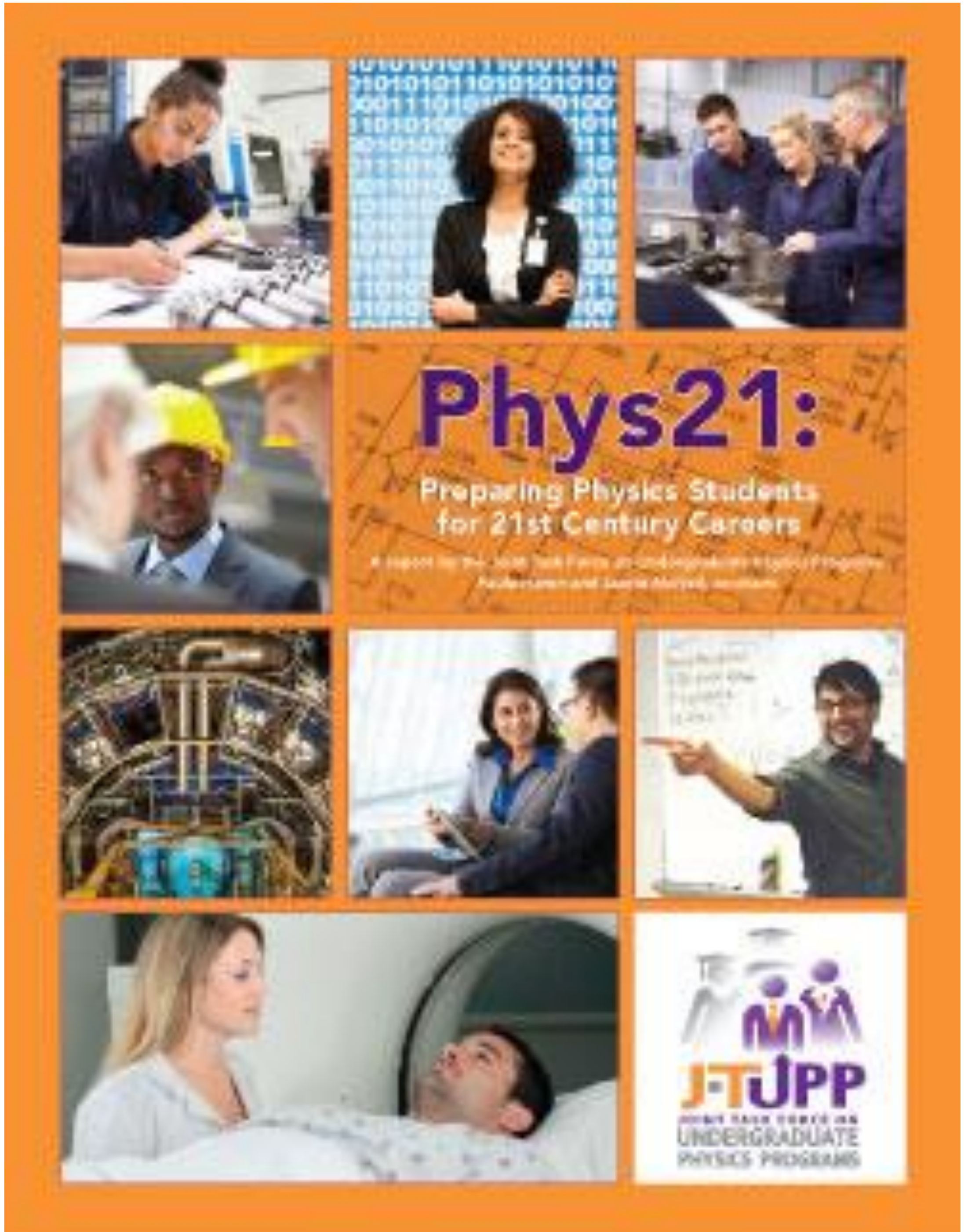
Skills Used Regularly

New Physics Bachelors Employed in STEM Fields

Note: Percentages represent the physics bachelors from the classes of 2013 & 2014 combined who chose "daily," "weekly," or "monthly" on a four point scale that also included "never or rarely." STEM refers to positions in natural science, technology, engineering, and math.

J-TUPP Report Findings and Recommendations (II)

- The J-TUPP group members identified that, along with the knowledge of the basic physics curriculum, **employers look for the student's ability** to i) work well in teams, ii) understand applications of physics in real-world, interdisciplinary settings, iii) use computer programming to solve problems, iv) manage complex projects, and v) master communication skills, both written and verbal.
- To acquire these skills, J-TUPP recommends that physics curricula should be modified to achieve an array of learning goals that other disciplines and employers desire.
- Besides the changes to curriculum content, pedagogy, and degree requirements, J-TUPP suggests increased collaborative efforts with other disciplines, and incorporation of co-curricular activities.



Phys21:
Preparing Physics Students for 21st Century Careers
J-TUPP
UNDERGRADUATE
PHYSICS PROGRAMS

J-TUPP Report Learning Goals-Skills

- **PHYSICS-SPECIFIC KNOWLEDGE:** Ability to use fundamental concepts to solve problems to diverse topic areas and applied contexts.
- **SCIENTIFIC AND TECHNICAL SKILLS:** Ability to solve ill-posed problems through experiments, simulations, and analytic models. Competency in instrumentation, software coding and data analysis.
- **COMMUNICATION SKILLS:** Ability to communicate orally and in writing with audiences that have a wide range of backgrounds and needs.
- **PROFESSIONAL AND WORKPLACE SKILLS:** Ability to work in diverse teams, obtain knowledge of technology resources, demonstrate management of difficult situations, including handling of budgets, overseeing quality assessments, etc.

Summary – Outlook

- The American Physics professional organizations (APS, AIP and AAPT) have been trying, for more than 20 years, to reshape the Undergraduate Physics Education in the United States.
- After a 15-year effort, the Physics Departments met, in 2013, the goal of APS/AIP/AAPT to double the number of the B.S degrees in Physics awarded in the US.
- The realization that many Physics bachelors enter directly the workforce and do not pursue graduate studies forced the professional organizations to form a investigative committee to make recommendations on the skills they must possess after their graduation.
- It is expected that the Physics departments in the US will respond positively and in a timely manner on the ways necessary to prepare majors for diverse careers by making proper adjustments to their programs.