Physics Bachelor Degrees (Who and Where)

Physics Majors: How many?
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Physics Majors: How many?

Where do they go to school?

<table>
<thead>
<tr>
<th>Number of Departments by Highest Degree Offered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bachelor's</td>
</tr>
<tr>
<td>Master's</td>
</tr>
<tr>
<td>PhD</td>
</tr>
<tr>
<td>Total Departments</td>
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</tbody>
</table>
Physics Bachelor Degrees (Who and Where)

Physics Majors: How many?

Where do they go to school?

Data from the AIP Statistical Research Center and the NSF S&E Indicators 2008.
Undergraduate Physics Programs in the US

How precarious are Primarily Undergraduate Institutions (PUIs)?

Number of bachelor’s-only departments* by the average number of bachelor’s conferred, classes of 2004 through 2007.

*This figure includes 505 departments where the bachelor’s is the highest physics degree offered.

AIP Statistical Research Center, Enrollments and Degrees Report.
Undergraduate Physics Programs in the US

Do we (at the PUIs) despair?


<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
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<td>21</td>
<td>Kalamazoo College</td>
<td>Private</td>
<td>Baccalaureate</td>
<td>195</td>
<td>7.7</td>
</tr>
</tbody>
</table>
Physics Bachelors (Who and Where: The Women)

Physics Majors:
How many?

[Graph showing the number of physics and all bachelor degrees over the years (1960-2000).]

Red - Physics Bachelor Degrees
Black - All Bachelor Degrees

Women in Science and Engineering Workshop, JLab - November, 2009. – p. 4/1
Physics Bachelors (Who and Where: The Women)

Physics Majors:
How many?

Percentage of Women

Data from the AIP Statistical Research Center and the NSF S&E Indicators 2008.
1. The number of physics bachelors degrees is small.

2. Primarily undergraduate institutions (PUIs) produce over 40% of the bachelors degrees.

3. PhD-granting institutions produce about half. There are a lot more PUIs than PhD-granting institutions.

4. Physics programs at many PUIs are more ‘precarious’ than at PhD-granting institutions.

5. Among elite liberal arts institutions, the PhD rate is high.

6. About one-fifth of the bachelors degrees go to women. They are an under-utilized source of potential physics majors.

Building undergraduate physics in the US requires attention across a wide range of institutions.
1. The number of boys and girls in high school taking physics is large.

![Graph showing physics enrollment in U.S. High Schools, 1948-2005]

2. Many go on to take physics in college, but go no further.

![Bar chart showing the percentage of females as a percentage of total enrollment in high school physics]


28%
3. The fraction of students, women and men, who take physics beyond the introductory course is very small, about 6,000 out of 300,000.

AIP Statistical Research Center.

5. There is a gender gap in introductory physics (and a learning gap too). The table below shows post-test results at Harvard for introductory physics taught in the traditional format.

<table>
<thead>
<tr>
<th>Category</th>
<th>Women (%)</th>
<th>Men (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Scoring</td>
<td>43</td>
<td>20</td>
</tr>
<tr>
<td>High Scoring</td>
<td>10</td>
<td>27</td>
</tr>
</tbody>
</table>

Post-test scores on *Force Concepts Inventory* (assessment test) for introductory students at Harvard (M. Lorenzo *et al.*, Am. J. Phys. 74 2, February 2006.).

Closing the Gap (and Recruiting too)

1. Interactive engagement (IE) methods have improved learning (R.Hake, Am. J. Phys. 66 (1), January 1998) and reduced or eliminated the gender gap (M. Lorenzo et al., Am. J. Phys. 74 2, February 2006).


3. Experience at the University of Richmond was very positive (Gilfoyle, Rubin, and Vineyard).

   - Notable increase in the number of women going on in physics.
   - Assessment tools showed clear and large gains.
   - We did NOT make a well-controlled study of the impact (limited time and resources).
1. Classes meet three times a week for two hours (or twice a week for three hours) in small (maximum of 24) sections. Each class is staffed by a single professor and 0-2 undergraduate assistants.

2. The laboratory is everything! Well, it’s a lot depending on the instructor.

3. Many students already know lots of physics, but much of what they know is wrong! They come in loaded with preconceptions about motion and other topics.

4. The philosophical approach is based on cognitive research in physics. It requires identifying what they know that is wrong (the unlearning) and using observation to replace the preconception.
Interactive Engagement Methods at Richmond

1. A topic is introduced by the instructor in a limited way (e.g. some of the kinematic features of circular motion are presented).

2. Students make predictions and record qualitative observations (e.g., toy airplanes on a string). Sometimes steps 1 and 2 are reversed.

3. Students develop the necessary mathematical ‘hardware’ to study the problem (e.g., derive the relationship between the acceleration and the velocity and radius of circular motion). Done as part of the lab.

4. They go and test their equation experimentally with limited guidance (e.g., film it with a digital camera and measure the kinematic quantities).

5. Last, they return to the original questions in step 2 and correct their preconceptions.

6. Strongly encourage discussion within and among groups (collaborative learning).
1. Results from some of my introductory physics classes using the *Motion and Force Concept Inventory* (MFCE). Typical pre-test averages are in the low 30s while post-test results are around 70.

2. Student responses to this format are varied. They have to ‘sold’ on the method and I routinely discuss why this class is so different from their other laboratory courses.

3. Tests should clearly connect to the labs otherwise they lose sight of their relevance.
IE Methods: Pros and Cons

1. Pros:
   (a) The MFCE assessment results point to the success of this approach.
   (b) We saw a noticeable increase in the number of women (and men) taking physics beyond the introductory course. The same effect was seen at Harvard (M. Lorenzo et al., Am. J. Phys. 74 2, February 2006).

2. Cons:
   (a) Significant start-up costs for equipment, faculty training, etc.
   (b) Labor-intensive: Workshop Physics requires small (24) sections. Methods are available to use IE in larger sections (Mazur’s Peer Instruction, NC State’s Scale-Up program, MIT’s TEAL).
   (c) Cover fewer topics than in traditional courses.
IE Methods: Why did the curve turn up?

Red - Physics Bachelor Degrees
Black - All Bachelor Degrees
Conclusions

1. The undergraduate physics enterprise in the US is small numerically and distributed roughly evenly between research institutions and liberal arts colleges.

2. Women make up a still small (about 20%), but growing fraction of those bachelors degrees. They represent an untapped talent pool.

3. The elite liberal arts institutions have a high rate of physics students going on to doctorates.

4. The pipeline does leak, but the introductory course loses the vast majority of possible physics students. There is also a gender gap in introductory physics.

5. Interactive Engagement methods have eliminated this gender gap though this result remains controversial.
Other Ways to Recruit Physicists

- No silver bullets.
- Sustained leadership and faculty buy-in.
- Do intro physics well!!!!!! → More modern physics.
- Clear undergraduate mission (the vision thing).
- Administrative support.
- Supportive environment: career mentoring, physics lounge, active Society of Physics Students, alumni relations, ....
- Undergraduate research!!
  - Conference Experience for Undergraduates at DNP.
  - Journal of Undergraduate Research at DOE.
Other Ways to Recruit Physicists

- Flexible programs: multiple tracks for majors, flexible scheduling, ....
- Recruit, recruit, recruit!
- Deconstruction night.
- LN$_2$ ice cream.
- Laser tag.
- Interdisciplinary physics with math, computer science, chemistry, biology, engineering.
- See, for example, Strategic Programs for Innovations in Undergraduate Physics, AAPT, 2003 for guidance on ‘best practices’. Richmond version at https://facultystaff.richmond.edu/~ggilfoyl/random/PhysicsBestPractices07.pdf.
Unanticipated Benefits/Costs

- Administration liked the IE approach. It provided a strong justification for renovating labs, obtaining new equipment, *etc.*.

- Faculty can buy into the approach in flexible amounts. Some lecture more and follow a more traditional pace.

- NSF funding is available for innovative, new ideas.

- New ideas/labs can be published in peer-reviewed journals (AJP, Physics Teacher, ...).

- Scheduling can be difficult because of the long lab sessions (and students give us negative feedback about the length).

- It’s essential to count instructor time properly (*i.e.*, contact hours versus credit hours versus units).