Integrating Research Experiences into the Undergraduate Education

Wolfgang Bauer
What I plan to cover ...

- Changes in curriculum
- Outreach efforts to increase recruiting base
- Building a community for our undergraduates
- Research integration into the introductory curriculum
- Research experiences
- ... a final thought on demographics
Curriculum Changes
Our Old Way of Offering Courses

- Take calculus first
- Take no physics class in 1st semester
- Start with calculus-based physics in 2nd semester (mechanics)
- Take E&M in 3rd semester, wait with modern physics until 4th semester
- Wait with exciting (advanced) physics labs until at least the junior year
- Pick up computer skills at your own peril
Our Old Result

- Physics majors did not take physics in the first semester
  - Top students moved to math in early semesters

- Physics majors saw very little of current interest until their junior year
  - Top students moved to engineering in sophomore and junior years

- Bottom line: Less than 80 physics majors in a university of ~40,000 students!
  - Compare: >150 grad students, ~60 faculty
Curriculum changes

> Get student to do some kind of meaningful experiments right away
  - Teach them the scientific method by inquiry

> Get them into small classes
  - Establish a community

> Enable students to use the computer right away
  - Allow them to tackle problems, for which they “do not have the math” yet
Physics 170 is a special course in EXPERIMENTAL PHYSICS for first year students. The main aim of the course is to have you learn something about REAL physics as done in a research laboratory. There will be no formal lectures (or exams) so that all of your learning will be done by: (1) reading, (2) having discussions with your lab partner and the instructors, and (3) performing "hands-on" experiments.

1. How to conceive, set up, and perform experiments in a few selected areas of physics.
2. How to use the computer to:
   a) Acquire, graph and analyze your data.
   b) Simulate your experiment.
3. How to keep a neat and meaningful laboratory notebook.
4. How to present your results in both written and oral format.
Computers in Physics Classes

> Only open to physics and astronomy majors
  - Optional, but may be made mandatory in the future
  - Hands-on, experiential, small-class

> PHY102: Mathematica
  - Non-linear pendulum, chaos, maps, motion in gravitational field, ...

> PHY201: Fortran 90

> PHY301: C/C++

> PHY480: Computational Physics
Outreach
Active physics outreach
Active Physics Outreach

- Science & Engineering Day
- Grandparents University
- Science Olympiad
- PAN (Physics of Atomic Nuclei)
- QuarkNet
- LON-CAPA
  - Many local high schools as partners
  - THE DUMP (Teachers Helping Everyone Develop User Materials and Problems)
  - See http://www.lon-capa.org/
lon-cap: the dump
Newsletter

- Once per year
- ~2,500 copies
- As PDF on the web
Website

> It’s where prospective students look

> Free opportunity for self-promotion
Feature Undergrads & Recent Alumni

- Newsletter, website features
  - Scholarships (Goldwater, Gates, Rhodes)
  - Departmental scholarships (a lot of “advancement” work)
  - Other awards
Community
A new building REALLY helps!
BPS Building

- Completed 04/2002
- 362,700 sqft
- $93 million
- Microbiology
- Physiology
- Physics/Astronomy
Atrium with coffee shop
> WiFi, plenty of plugs
> Attractive space to hang out, do homework, discuss, meet friends
> Open even on the weekend
Department BBQ

Building community with undergraduates
Student Organizations

› SPS
  - Receives annual funding from department
  - Has own lounge
  - Holds weakly seminars, but also movie nights

› Science Theatre
  - Initially founded by PHY grad students (Leslie-Pelicky, Mader, Kortemeyer)
  - Hands-off faculty advisor
  - Now more undergraduate students

› WAMPS
  - Women and Minorities in the Physical Sciences
Modern Research Results in the Introductory Curriculum
Recent Research Results

> Conventional lecture sequence emphasizes results that are older than 100 years
  - Biology: last 2 decades

> Can include recent results from particle physics, non-linear dynamics, astrophysics, nuclear physics, atomic physics into first year physics curriculum
  - Speaks to the relevance of the field
  - Lets students envision that they can contribute
  - Lets students see that physics is alive
Recent Research Results

Example: Momentum conservation and top-quark discovery
Research Experiences
Professorial Assistants

▷ Year-long one-on-one research experience for top incoming MSU freshmen in “lab” of a professor
▷ $3,000 stipend
▷ Renewable for subsequent years
▷ 100 students each year across MSU
▷ ~6–8/year in PHY
  ◦ (0.5% of MSU students major in PHY)
  ◦ More than 10 times more PAs than our “fair share”
▷ Excellent recruiting tool for PHY majors!
Weather Research

Brad Keusch
- MSU Freshman
- Professorial Assistant

Research project
- Examine how chaotic the weather is in different parts of the country
- Extract Liapunov exponents from comparing 10-day forecasts to the actual daily highs and lows
REU (since 1988)

(annual visit from Notre Dame REU)
Real Involvement in Real Research

W. Bauer, MSU
Real Involvement in Real Research

> ATLAS Calorimeter
Real Involvement in Real Research

> SOAR Telescope (Andes, Chile)
The Modular Neutron Array at the NSCL

Michael Thoennessen

Issues and Events

Undergraduates Assemble Neutron Detector

The Modular Neutron Array at the NSCL, or MoNA, a detector built in large part by undergraduate physics majors, was installed last summer at the National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University. The facilities offering the biggest competition for MoNA, he adds, are GSI in Darmstadt, Germany, RIKEN in Tokyo, and GANIL in France.

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The Modular Neutron Array (left) was assembled by undergraduates (above) at Concordia College and nine other institutions.

That’s what NSF is about” (Bob Eisenstein, NSF Assistant Director in 2001)
The Modular Neutron Array (MoNA)

- ToF Neutron Detector
- 10 X 10 X 200 cm Bar of Plastic Scintillator
- 9 Layers of 16 Stacked Bars
- Time Resolution < 1 ns
- Position Resolution ~ 10 cm
- Detection Efficiency ~ 70 % for 85 MeV/A Neutrons
... a final thought, perhaps