Responding to the challenge of raising enrollment – an Arkansas success story!

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Gay and John Stewart

A more scientifically literate society benefits physics as a profession. It is best realized by better serving all undergraduate physics students. Arguably, the most important are future K-12 teachers. In better serving all students, the department also benefits. University of Arkansas, Fayetteville has seen a drastic change in number of majors, the number of students active in research and the number of graduates pursuing graduate work while also increasing the number of majors who decide to teach. What worked to build these numbers and strengthen these resources at Arkansas will be discussed. Prior to our involvement with the Physics Teacher Education Coalition, graduation rates had increased by more than a factor of 4 in 4 years. After the increased efforts when we became a part of PhysTEC (www.PTEC.org) our graduation numbers doubled again. PhysTEC is bringing together innovative ideas and practices throughout the country to help meet the critical shortage of well-prepared and actively- supported teachers.

PhysTEC is a program to improve the science preparation of future K-12 teachers. It aims to help physics and education faculty work together to provide an education for future teachers that emphasizes a student-centered, hands-on, inquiry-based approach to learning science. http://www.ptec.org/

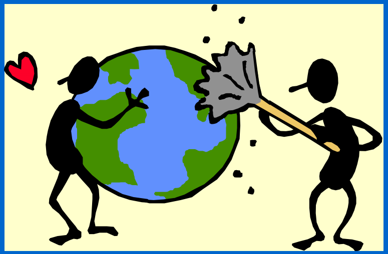
Works for majors too!

***Borrowed from a Carl Wieman colloquium*: Science education different, more important purpose than in the past.**

Not just for scientists

- Survival of world.

Wise decisions by citizenry on global (technical) issues.



- Workforce in High-Tech Economy.

Need to make science education effective and relevant for large fraction of population!

and diverse!

Where we began

University Physics II (UPII) is the calculus-based introductory electricity and magnetism course at the University of Arkansas. The class is taken mostly by science and engineering students. The final format of the class is that the lecture meets twice a week, on Mondays and Wednesdays. A homework assignment is due at the beginning of each class, and a lecture quiz is given at the beginning and end of each class. Labs are scheduled for two hours and meet twice a week. Lab activities are done in groups and scheduled so as to coincide with the lecture and homework topics, and students are required to have the lab instructor review their activity work before leaving for the day. Practice tests with solutions are published to aid in preparation for examinations. Use of these practice exams is encouraged, but not required. During examinations students are given as much time as needed to complete the exams. Exams include both multiple choice and free response questions, and partial credit is given for work shown on all non-multiple choice questions.

Experimental Class Format:

- Students required to read material and attempt homework before class
- Large number of experiments, activities and demonstrations
- Lecture kept to a minimum, met three times/wk in lab, 2-80min, 1-110 min
- One instructor, one TA in each class
- Interactive discussion strongly encouraged

The effect of missed assignments on performance

Missing	*Correlation with*	
	Test Average♦ (77%)	*Hake Gain‡ (51%)*
Homework	R^2=0.118	R^2=0.033□
Lab	R^2=0.115	R^2=0.038□
Lecture	R^2=0.104	R^2=0.068
Combined	R^2=0.151	R^2=0.076

♦N=364 students *‡N=313 students*

□Significant at the p = 0.05 level

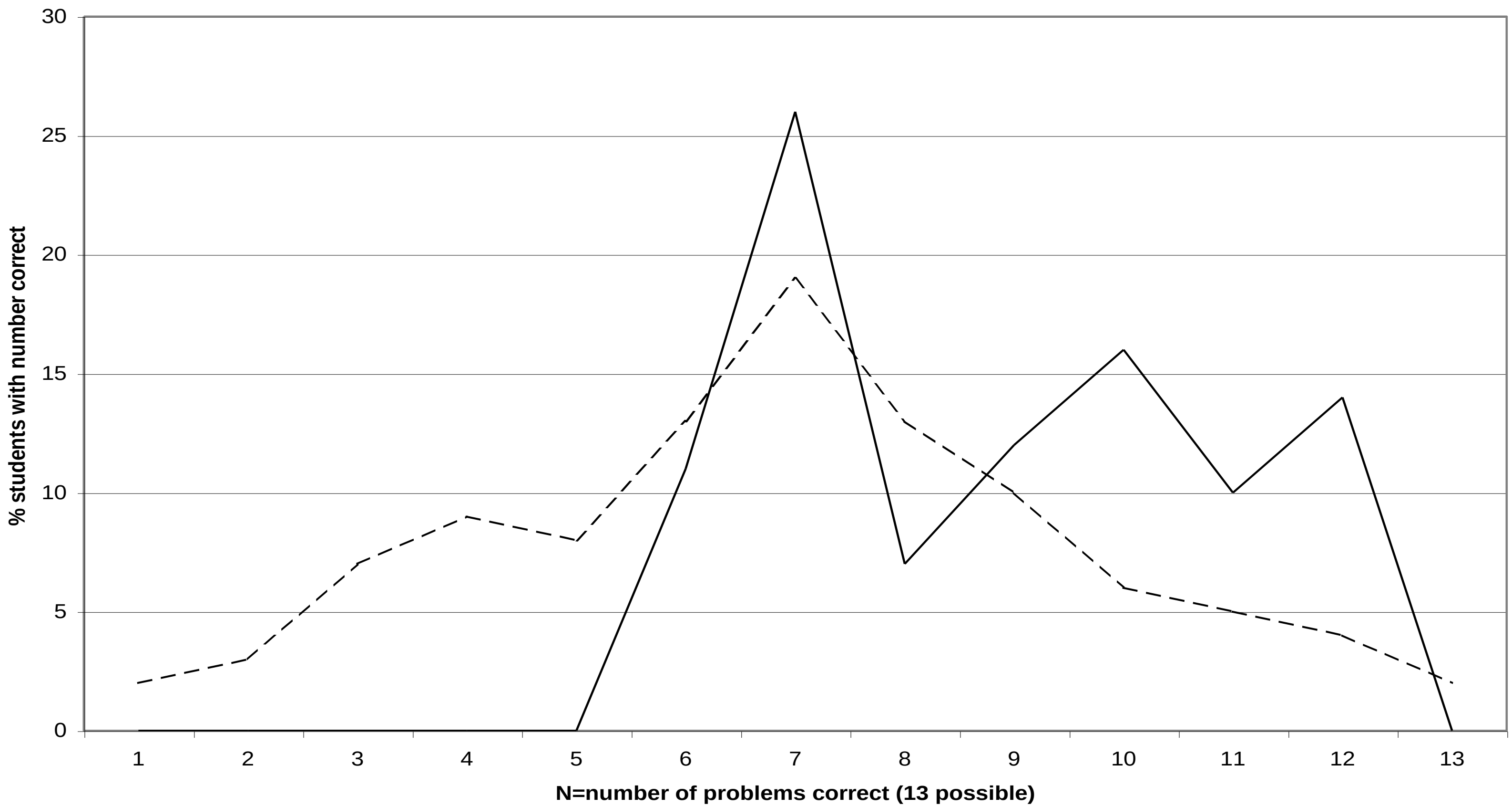
Remainder significant at the p = 0.0001 level

Phys. Rev. ST Physics Ed. Research 8, 010114 (2012) [14 pages] Using time-on-task measurements to understand student performance in a physics class: A four-year study

Student performance measures the faculty respect:

- Did better than previous UA classes on both problems and conceptual questions
  - Scored 10-18% higher on multiple choice conceptual questions given in previous version of course, even when not directly covered.
  - Compare results on a standard problem-solving test from a previous year

Results from a standard "problem-solving" exam



Popularity of Activities Using Everyday Materials –

- Of 17 in-class activities, 2 experiments and 14 demonstrations, when asked for their favorite, NO off-the-shelf E&M was chosen!
- Three top activities and experiments:
  - Motor/generator construction 40%
  - Speaker/microphone const. 23%
  - Earth's Magnetic Field 8%
- Favorite Demos: rail gun, Leyden jar
- Competitions: Motor, leaf electroscope

Student Perceptions

In response to the question "What would you do to make the class better?"

- 77% of students said they liked the new format and learned more from it,
- 18% liked the format but wanted more lecture,
- 5% of the students preferred the old format.
- Faculty received higher teacher ratings than in old format, even in less effective sections.

Design Criteria for Activities

- No Cookbook!

  The activities were rewritten so that the directions did not encourage students to follow them like a cookbook.

- Flash

  Memorable, makes a strong impression, tactile construction

- Long-term reproducibility

  Memorable enough, simple enough and inexpensive enough that they could be expected to repeat it 10 years from now, and because of the flash would want to! We recruit younger siblings.

- Dependability

Dependability is a problem!

"If it is green it is biology, if it stinks it is chemistry, if it doesn't work it is physics.

--middle school science teacher

Transportability

The three-instructor class format provided an excellent laboratory for how easily material constructed by one person can be transferred to another.

- Best of Circumstances:
  - Developer immediately available
  - All activities done in same setting after developer has taught the first section to catch any bugs
  - Supportive, involved faculty
- Results:
  - Massive differences in student perceptions and performance depending on primary instructor

Analysis of Differences:

- Problems:
  - Instructor attitude toward materials
  - Integration of in-class activities in with reading, homework and lecture depended on the instructor to guide the students to recognize
  - Instructor comfort with unstructured environment

Solutions:

- Build the questions you want the students to ask into the activities.
- Target the activities to specific goals.
- Tie activities to lecture: have students derive relationships in labs.
- Tie activities to homework: have students make measurements of quantities calculated in homework.

Notes page:

Fortunately the major problems arose in the first semester. For the second semester we revised the materials to strengthen integration:

- *have specific educational goals in mind as writing activities*
- *tie them into lecture by having them derive stuff in lab*
- *tie them into homework by having students make measurements in class*
- *write our own homework problems on trouble areas*
- *write our own homework problems for measurements*

In the second semester there was no significant difference in grades between instructors, although the teaching styles still varied. The one noted difference was that in the class were the instructor still lectured, the students left the class with a much less enthusiastic review, although that section had the highest test average, overall.

Once you get them

- Upper division courses get better…a lot of excited, well-prepared students
- They get involved in research…many of our undergrads are published
- The whole place just “feels” better
- Other faculty get involved

Of course, UPII wasn't the only change we made!

- The new class opened up a dialog with the engineering faculty.
- Our New BA Program
- Our New BS Program-Multiple Tracks for Multiple Career Paths
- Track Record of Graduates
- Exceptional mentoring and advising

Notes page

- Engineering was able to change some of their courses for which physics is a prerequisite, because the students were actually coming in knowing some of the material. They became very supportive of the physics dept and increased the number of technical electives ENGR students can take from physics toward their engineering degrees. This makes it easier to do both degrees.

Teaching Assistants

- TAs come in with strong attitudes on teaching:
  “Physics is supposed to be hard.”
- With adequate TA preparation, the setting becomes an opportunity for good student interaction:
  “I don’t know if I can still teach it that way!”
- Higher attendance at office hours and student approval ratings carried over to teaching a traditional lab.

To make reform work…

When we embarked upon the NSF project, it became clear that the first and greatest need for educational reform to be embraced and sustained was for our future faculty to be prepared to be as professional about their roles as educators as their roles as researchers. New college faculty members may find themselves preparing to teach a class for the first time, with little or no guidance. The biggest complaints employers have about those hired for research positions involve interpersonal skills. Also, more researchers are being called upon to do outreach. Teaching and participating in outreach activities develop these skills. Our focus at first was to add these kinds of activities to the graduate program, with the same sort of mentoring that accompanies the development of research skills, without extending the time to degree. Also, a new masters degree for those that find themselves insufficiently motivated to do research, but still loving physics, provides a route straight into teaching for these students at very low resource cost. These goals were enhanced by our participation in the Preparing Future Physics Faculty Program (AAPT).

Notes page

We expanded and combined our “apprenticeship class” PHYS 400V, (V for variable credit) and our TA training program. Previously, all incoming TAs were required to take the TA training course, but there was no grade associated with it, and it was hard to enforce attendance in the follow-up seminars. PHYS 400V was only taken by students who were quite serious about their teaching. Now, all incoming TAs signed up for at least one unit of PHYS 400V, which covers their performance in the TA training, their attendance and participation in follow-up seminars, and their response to mid-term student evaluations, done 6-7 weeks into the 14-week semester. These evaluations are reviewed with the TA and the grade received is strongly based on how well a TA works to overcome weaknesses identified in his or her teaching. We feel that this give students a more balanced view of their professional responsibilities. First-semester students take a research seminar course, and they have a similar experience for their teaching.

Teaching Apprenticeships

- Some undergraduates wanted good preparation before going off to graduate school
- Even engineering counts it as a technical elective- “you really know it, on a whole different level, when you can teach it”
- Great experience for future teachers, mentored in a reformed course. College of Education counts it as a student teaching experience.

Teaching Apprenticeships: some details

A Partial List of Topics

- Preparation for classroom presentations
- Testing and grading
- Addressing student alternative conceptions
- Effective use of classroom demonstrations
- Interactive classroom techniques

Course Structure and Grading Policy

- Four hours a week in an apprentice teacher role, 1 unplanned absence = 1/2 of a letter grade
- Week 1: 4 meetings on topics essential to classroom experience, 10-25 pages of reading per day.

Teaching Apprenticeships: some details

- Remainder of the semester, a 1-hour meeting each week to discuss the week's reading (20-25 pages).
- Performance in class is observed.
- First 4 weeks, observations provide feedback.
- Remainder of semester, results graded.
- New topics given 2-week period before evaluation. Progressively more responsibility given.
- The work in class is 1/2 of grade.
- Assignments accompanying weekly reading, 1/3.
- Final: develop a lesson or activity (1/6)

Teaching Apprenticeships: **Partial Bibliography:**

Section 1 – General (a few examples)

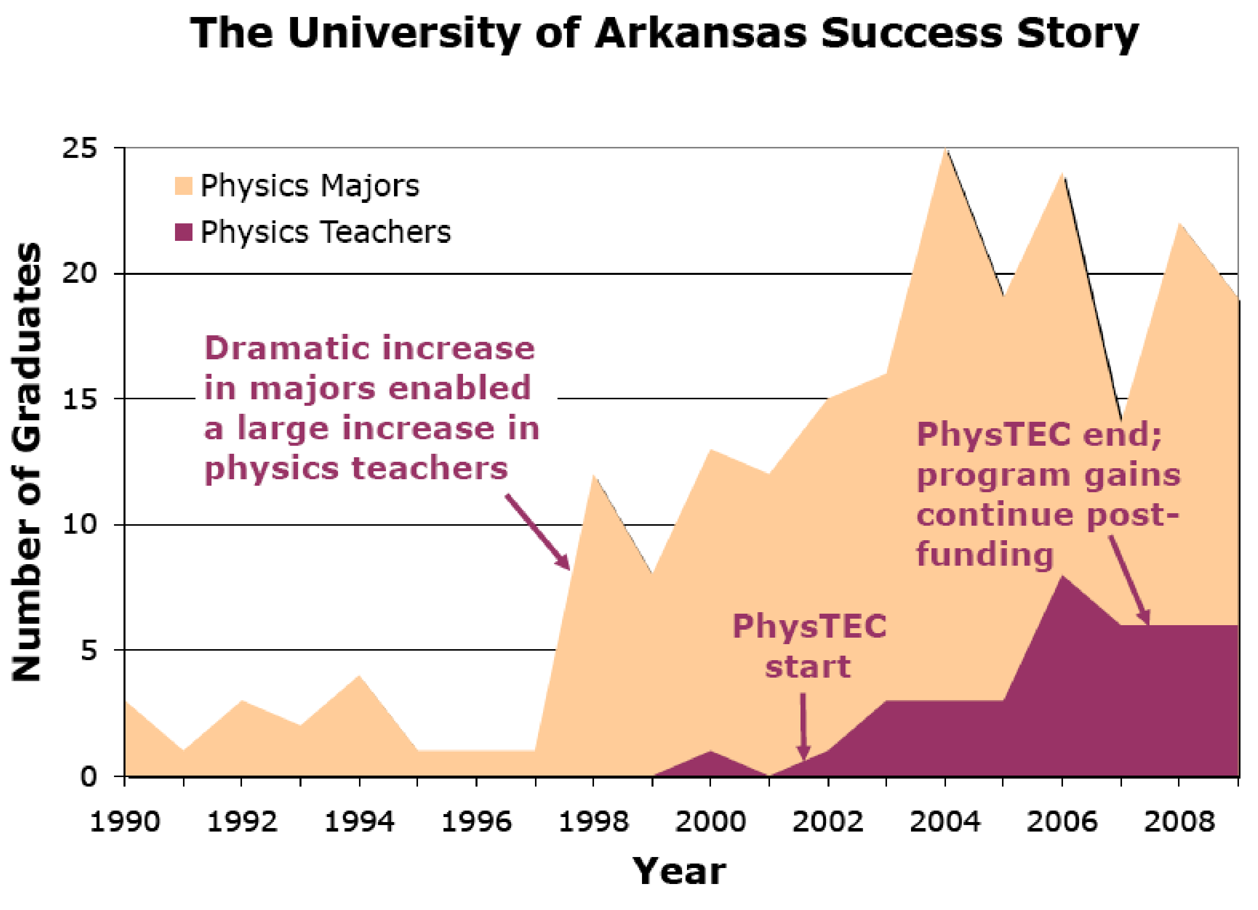
- Arnold Arons, *A Guide to Introductory Physics Teaching* (John Wiley, NY 1990)
- David Hammer, "Two approaches to learning physics," *The Physics Teacher,* December 1989, pp. 664-669.
- Robert Karplus, "Educational aspects of the structure of physics," *American Journal of Physics,* Volume 49 Number 3.

Section 2 -- Alternative Conceptions

Section 3 -- Labs and Cooperative Grouping

Section 4 -- Problem Solving and Grading

Results?


The University of Arkansas Success Story
Physics Majors
Physics Teachers
Number of Graduates
25
20
15
10
5
0
Dramatic increase in majors enabled a large increase in physics teachers
PhysTEC start
PhysTEC end; program gains continue post-funding
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
Year

Calculus-based class format:

- Students required to read material and do self-test homework before each class, daily quizzes make sure.
- Large number of experiments, activities and demonstrations
- Lecture kept to a minimum, closely tied to activities. Lecture/lab each twice a week
- Interactive discussion strongly encouraged

The big thing! Quality Advising. Once you have them, you can start doing some great stuff!

<u>10 things we came up with when we wanted to grow our undergraduate program</u>

1. When a student first comes in for advising, sit down with him or her and have a general conversation to get to know the student. For instance, you might ask students where they came from, what they liked in high school, what their interests are, whether they are working and if so how much, what they think they would eventually like to do for a career, etc. This gives you a general picture.
2. Make a real point of learning that student's name. Always try to greet your advisees, as well as other students, by name when you see them in the hall. It keeps the barriers down.
3. Create a file on that student in which you can jot down much of the above information, as well as information about what classes he or she is taking, etc. Make a point of getting the student's email address and home phone number.

4. At first we just used notebook paper, but then we made some nice forms on which one can keep notes. Use of some sort of a standardized form helps in case an adviser is on leave or just out when a student has a question. It makes it easier for someone else to quickly address simple questions, at least.

5. Most students will come by during the preregistration period, at least if you remind them. A sign up sheet with available times on your door can be an effective way to get everyone scheduled. For those students who don't, make a point of contacting them (usually using email is successful).

6. Try to look over their records after each semester to keep track of how they are doing academically. For those who seem at risk of drifting away for whatever reason, try to occasionally contact them (usually by email) just to check up on them. Emphasize that they should come by, call or email if there is anything you can do.

7. Keep a file of summer research opportunities that you hear about (and point the kids at the Nucleus). For the students that are in their sophomore or junior years and are doing well, motivate them to apply for summer research programs such as NSF-funded REU programs. Also encourage them to look around the department to find research projects that they can get involved in. Experience working in a laboratory can be key to getting a job or a high-end fellowship.

8. Often, students are interested in doing research but need a little kick from an advisor or professor to actually begin the process of looking. Students virtually always find the research experience rewarding.

9. Research experience will enhance students' future job or graduate admissions possibilities. Tell potential incoming freshmen that many of our physics majors participate in departmental or summer research programs, that we encourage it, and as their advisor you will be talking to them about it after a few semesters of course work.

10. For students that are doing well, it is essential that we keep on top of departmental scholarship deadlines and university and national awards and suggest to them that they apply.

Recruitment: Appears to depend on student perception of teacher attitude

In evaluating the reformed classes, there is a factor correlated with recruitment in our preliminary studies: student attitudes about the nature of science and science teaching.

Even when ***learning gains are similar***, the usual metric of how effective a reform is, there can be a difference in recruitment. When certain types of attitude questions dip, the number of majors recruited also dips.

Believe it or not, but the improvement in attitude that correlated most with MAJOR recruitment: ***I can teach science****.*

Summary: From course modification to recruitment

- Activities, homework and lecture or discussion must be integrated. You should have real learning goals in mind. Remember, we got factor of 4 with one class!
- The person “in front of the class” should be excited about physics and happy they chose it as a career.
- The person “in front of the class” needs to get to know the students. If they have potential, let them know that even if they aren’t majors, they are welcome to come talk to you.
- If the new major adviser is someone different, make the transition a personal introduction.

Little change in upper division courses

Once we had some students wanting to major in physics, and once we figured out how to advise them, it was time to think of some other things we needed to do to help them be successful:

1. Give them their own space, but visit.
2. Get them involved (outreach as well as research).
3. When an upper level class isn't going well, even with faculty mentoring, provide resources, encourage study groups.
4. Encourage them to apply for state and national awards, find out how to help them be successful in these applications, and celebrate their successes.

Further Information

- For additional information on what we have been doing at Arkansas, including detailed descriptions of the classes and research into quantitative education characterization and engineering:

  http://educationalengineering.uark.edu