If physics can do it, anyone can: Increasing student success

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A more scientifically literate society benefits all STEM disciplines, as well as society as a whole. It is best realized by better serving all undergraduate STEM students. In better-serving all students, a STEM department also benefits. The University of Arkansas, Fayetteville physics department 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. 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. Specific attention to class policy to impact student learning in our introductory courses and strong preparation of the graduate teaching assistants, and quality advising were our primary areas of emphasis. What worked to build these numbers and strengthen these resources at Arkansas will be discussed.

* **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)

What?
Who?

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/week in lab, 2-80min, 1-110 min
- One instructor, one TA in each class
- Interactive discussion strongly encouraged
- Now…

Calculus-based class format:

- Students required to read material and attempt homework before 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 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

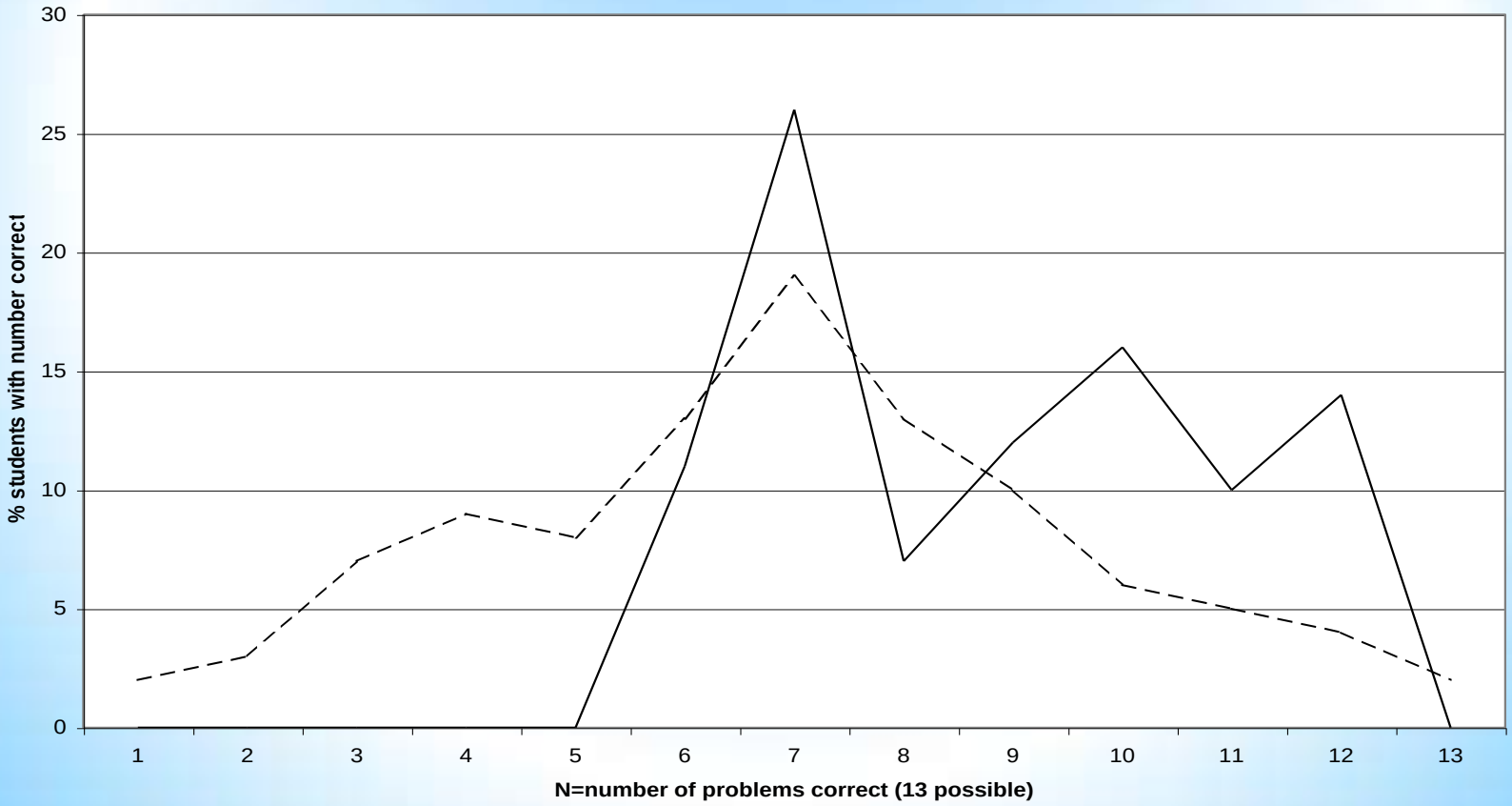
Remainder significant at the p = 0.0001 level

Phys. Rev. ST: PER 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 – special impact on teachers

- 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

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
  - 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.

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

Teaching Assistants

- TA's 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.

Not just 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.

Teaching

Outreach

Alternate path: new masters

(recruiting the next generation-long term solution)

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

Deep familiarity with content, then:

* 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.

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

10 things we came up with when we wanted to grow our undergraduate program

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. Summer research opportunities: 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. Encourage them to look around the department to find research projects. 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. We 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. 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.

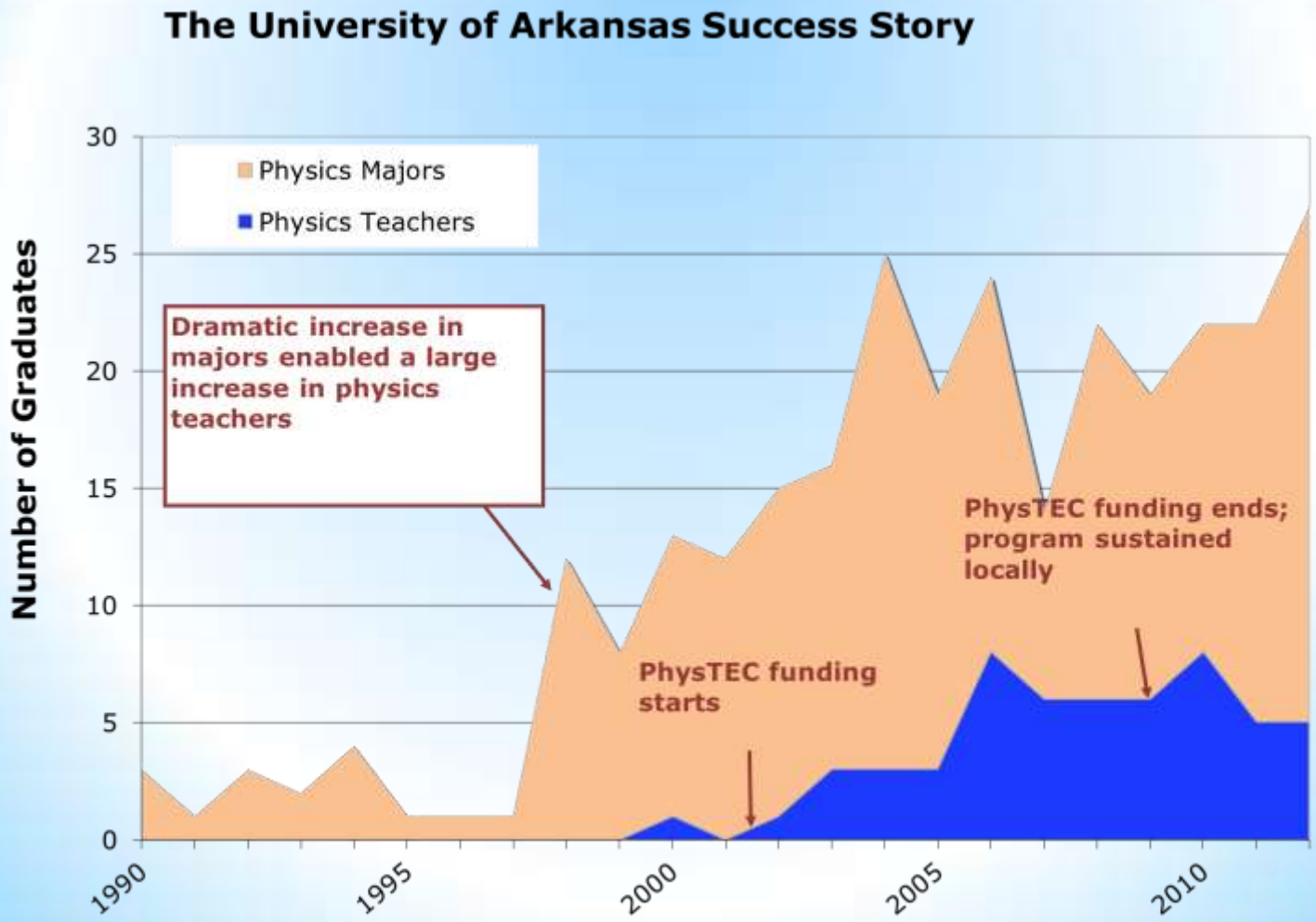
Believe it or not, but the improvement in attitude that correlated most with MAJOR recruitment: ***I can teach science****.*

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.

*Results?


The University of Arkansas Success Story
Number of Graduates
30
25
20
15
10
5
0
1990
1995
2000
2005
2010
Physics Majors
Physics Teachers
Dramatic increase in majors enabled a large increase in physics teachers
PhysTEC funding starts
PhysTEC funding ends; program sustained locally

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 their subject 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.

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