Forum on Education
American Physical Society

Fall 2008 Newsletter

Thomas D. Rossing, Editor

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The Forum on Education Newsletter is not a peer refereed publication. The articles and letters in this newsletter represent solely the views of the authors and not necessarily the views of APS.

A Message from the Chair

Ernest Malamud

The Forum on Education (FEd) continues to do well: informative newsletters, interesting presentations at both APS spring meetings, and a steady growth in membership.

Spring Meetings

The FEd has developed a strong presence at both APS spring meetings. In this issue Peter Collings previews the many interesting sessions the FEd program committee is putting together for the March 16-20 (2009) APS meeting in Pittsburgh and the "April" APS meeting in Denver, May 2-5, 2009. Many thanks to Peter and his committee.

FEd Executive Committee Elections

You will shortly receive your ballot for our annual FEd elections. The open positions are:

Open Positions

Vice-Chair (4 year term, April 2009–March 2013)
Member-at-Large of the Executive Committee (3 year term, April 2009-March 2012)
APS/AAPT Member-at-Large of the Executive Committee–Must be member of both FEd and AAPT (3 year term, April 2009–March 2012)

Please take a few minutes and vote! The nominating committee will then construct the ballot of candidates. Thanks to this year's nominating committee for an excellent slate of candidates.

FEd Nominating Committee

Larry Woolf (General Atomics), Chair
Mario Belloni (Davidson College)
Peggy McMahan (Lawrence Berkeley National Laboratory)
Rob Steiner (American Museum Natural History, New York)
Michael Thoennessen (Michigan State University)

This Newsletter

The Editor of this issue is Professor Thomas (Tom) Rossing, retired from Northern Illinois University, and currently a visiting professor of music at Stanford University. Tom has said this would be his last newsletter. Tom has been a FEd newsletter editor since the Forum was begun, nearly 15 years ago. Besides his major contribution to the Forum of putting together these timely and interesting newsletters (all archived and indexed on our FEd web page), Tom has regularly written the column "Browsing the Journals" which is widely read and appreciated. The newsletters are our most important function in terms of reaching our large and extended membership. We owe Tom a tremendous debt and many thanks for producing and contributing to these many newsletters.

Middle School Science

Why should the American Physical Society be concerned with middle school science? In order for there to be physicists in the future and a scientifically literate public, there must be young people informed about and motivated to learn physics. This process begins before high school. It is very easy for a high school student to graduate without being introduced to a high school physics course. Because middle school science is interdisciplinary, the APS should be concerned that the physical science topics (in the broadest sense) are taught well and integrated into a science program that increases student interest in science. Additionally the science program should be integrated with a mathematics program that prepares students for further study in science. Middle school age students learn about science and science careers not only in the classroom but also in science museums, in after-school activities, (science clubs, 4-H, Scouting, Boys and Girls Clubs, summer camps) numerous science outreach programs including APS outreach and in the media. Many of these programs target females and students from groups underrepresented in STEM disciplines.

An outstanding APS education outreach program aimed at middle schools is PhysicsQuest. I am exploring the implementation with APS staff of a suggestion made by Judy Franz at our FEd Executive Committee meeting at the St. Louis meeting that the 4,600 member Forum on Education could be a resource to help with PhysicsQuest. Can FEd and APS staff working together foster connections between the local middle school teachers who have APS PhysicsQuest kits and local APS-FEd members? We have begun by selecting a few of these "coincidences" (using zip codes for middle schools with kits and FEd members) as a "pilot" project.

The goal is to increase the number of APS members helping as volunteers to improve middle school science teaching. We realize that there are hurdles to surmount in fostering productive relationships. Using phone calls, emails and written guidelines we will try and work our way through these challenges.

Conclusion

In my last message I made a pitch to you to become involved in FEd activities. Newsletters would benefit from more discussion and controversy. There are divergent views on many topics. Write a Letter to the Editor!

Mini-grants of up to $500 are available and the turnaround is fast. Examples of past mini-grants are providing a prize for an essay competition among high school students at a Section meeting or partial support for a community physics day for high school students and teachers with a guest speaker.

As in any volunteer organization we welcome new blood to participate in FEd activities. Right now a particular need is for newsletter editors. If you think this is something you would enjoy doing, let me know.

Ernest Malamud, retired from Fermilab, is currently a member of the Adjunct Faculty at the University of Nevada in Reno. He can be reached at: malamud@foothill.net

From the Editor

By Thomas Rossing

The APS Forum on Education is now 15 years old. A number of changes have taken place in the Forum over the years, but the objective still remains the same: "The objective of the Forum shall be the advancement and diffusion of knowledge regarding the inter-relation of physics, physicists and education. The Forum shall provide for all members of the Society an opportunity for discussion of and involvement with matters of physics education."

The first chair of the FEd was Drasko Jovanovic at FermiLab. The first secretary-treasurer was Natalia Meshkov at Argonne National Laboratory. Oldtimers will remember the long line of distinguished officers, including the first five chairs: Drasko Jovanovic, Ken Lyons, Ruth Howes, Beverly Hartline, and Rush Holt. Others serving as secretary-treasurer have included Mort Kagan, Ernie Malamud, and Bruce Mason. Under their leadership the FEd has prospered.

From the beginning, the FEd has had a newsletter, generally published three times a year. The first newsletter editors were Stan Jones, Diandra Leslie-Pelecky, and Tom Rossing. Originally, the newsletters were mailed to all FEd members, but later it was decided to post them online only. The online archive includes all but the first year. This will be my last newsletter as editor, and I have enjoyed serving the FEd. Stan Jones also has an article in this issue.

FEd has a fine website with a lot of interesting and valuable information. However, no actual history of the Forum appears, and probably it is time to post one.

Thomas Rossing, Distinguished Professor Emeritus at Northern Illinois University, is currently a visiting professor at Stanford University.

Letter to the Editor:

College scientific literacy courses make a big difference

Physics teachers, especially physics education researchers, need to know about the science education research of Jon Miller, Professor of Interdisciplinary Studies and Director of the International Center for Scientific Literacy at Michigan State University. He is probably the world's leading expert on the measurement of scientific literacy. This is profoundly important work, because most national and global problems cannot be solved without a scientifically literate populace.

Miller and his colleagues have developed a set of basic science knowledge (concepts such as molecule, laser, DNA, biological evolution) and scientific process (an understanding that science is based on evidence and reason) questions used to study adults in many nations. He has used these questions, periodically updated to reflect new knowledge, in adult scientific literacy tests since 1988. A person scoring above 70 on these tests probably has sufficient knowledge to understand science-related stories in the daily newspapers, and is thus considered to be scientifically literate. By giving his test to a representative sample in each nation, Miller can determine the scientifically literate fraction of that nation's population, called the "scientific literacy rate" (SLR).

The bad news is that global scientific literacy is shockingly low. Among the 34 nations tested in 2005, the SLR rose above 30% in only one nation, Sweden, whose SLR was 35%.

For the United States, the good news is that in all of Miller's results since the beginning of testing in 1988, the U.S. scored above nearly all other nations. In the 2005 tests, for example, the U.S. ranked second with an SLR of 28%; next-ranked were Netherlands, Norway, Finland, and Denmark at 20 to 25%; then 15 European nations including Germany, France, and the United Kingdom scoring between 10 and 19%; and finally 13 other nations including Ireland and Japan at under 10%. In light of American students' mediocre showings in international science tests at the primary and secondary school levels, this is surprising. What happens to Americans after secondary school that accounts for this result?

To investigate this question, Miller asked each U.S. participant in the 2005 tests their age, gender, highest level of education, number of college science courses, number of children present in the household, their use of informal science learning resources (museums, magazines, etc.), and whether their adult occupation is science-related. He found that, over all these variables, the strongest predictor of adult scientific literacy was the number of college science courses taken; 75% of the variability in different people's scientific literacy scores could be predicted simply from this number. In assessing the effect of this variable, the number of college science courses was grouped into just three levels: (1) no courses, (2) one to three one-semester courses, and (3) four or more courses. People falling into the latter two groups were far more likely to be scientifically literate than those in the first group. Note that category (2) represents non-science students who are required to take a few science courses.

Thus the college experience is a strong determinant of scientific literacy in the U.S. The college experience is significantly different in nearly all other nations insofar as science education is concerned. Because other nations focus only on professional training at the college level, they don't require students outside of scientists and engineers to enroll in any science courses at all. Thus they have very few category (2) students. Miller concludes that "the college and university general education requirement to take at least a year of science courses makes a major contribution to the civic scientific literacy of [U.S.] citizens," and that the surprisingly high U.S. SLR is a result of the positive impact of these college-level science courses for non-science students.*

So it seems likely that all nations could increase their SLR by requiring science courses for non-science college students. Looking only at Europe, we might expect (in light of the superior performance of most European nations relative to the U.S. at the secondary level) such a requirement to raise the median European SLR to at least the 28% U.S. rate. In Miller's 2005 tests, the median European SLR was only 14%. Thus it's plausible that a science literacy course requirement for European non-science college students could double the median SLR in Europe!

But regardless of the precise effects on any nation's SLR, Miller's results certainly underline the importance of college scientific literacy courses. The U.S. should more strongly emphasize these courses, and all other nations should teach them.

I'd be delighted to discuss these ideas with anybody who is interested. Email ahobson@uark.edu.

Art Hobson

Art Hobson is Professor Emeritus of Physics at the University of Arkansas in Fayetteville, and author of a scientific literacy textbook Physics: Concepts & Connections*, now in its fourth edition. This letter is loosely based on the author's paper "The surprising effectiveness of college scientific literacy courses" appearing in* The Physics Teacher*, October, 2008.*

* Jon D. Miller, "The impact of college science courses for non-science majors on adult scientific literacy," paper presented to a symposium titled "The critical role of college science courses for non-majors" at the annual meeting of the AAAS, 18 Feb 2007, San Francisco.

Greetings to the APS Forum on Education Members from the AAPT Executive Officer

I am pleased the FEd Newsletter editors offered me an opportunity to communicate to you as the AAPT Executive Officer. As I write this I am completing my first month in this position, having taken office on September 2nd. As some of you may know, I was AAPT Associate Executive officer from February 1997 until September 2007 when I went to NSF as a rotator to serve as Division of Undergraduate Education program officer.

There are many challenges we share in common and have been addressing for years and finally physics education, and STEM education in general, are being recognized by leaders in industry, the military, and government. Among these recognized challenges is the need to increase the number of undergraduate STEM majors and also to increase the number of these majors choosing pre-college teaching as a profession. This is *especially* critical for physics. Although the number of students receiving a bachelor's degree in physics has been increasing recently, the percentage of all undergraduate students graduating with a physics major is actually decreasing. The number of physics or physics education majors entering pre-college teaching each year is about 300 (less than 0.4 physics teachers per bachelor's degree granting physics department) however, the documented need is about 1,000. In addition to pre-college teaching, those students graduating with a bachelor's degree in physics are well-qualified for many positions in industry as documented by the work of John Rigden and Bo Hammer.

AAPT works with APS to address many physics education issues. I serve as co-principal investigator with Jack Hehn from the American Institute of Physics on the Physics Teacher Education Coalition (PhysTEC) project for which Ted Hodapp, APS Director of Education and Diversity, is the principal investigator. Out of PhysTEC and the AAPT Committee on Teacher Preparation, a National Task Force on Physics Teacher Preparation will study why some institutions graduate significantly higher numbers of students prepared to teach pre-college physics. The study will document best practices used to prepare physics teachers. Much of the progress of the PhysTEC project and the Physics Teacher Education Coalition (PTEC) has been documented in previous issues of the Teacher Preparation Section of this newsletter.

The continuing series of NSF-funded New Physics and Astronomy Faculty Workshops are organized by AAPT in partnership with

APS and the American Astronomical Society (AAS). The workshops began in 1996 and were directed, for the first 10 years, by Ken Krane of Oregon State University. Bob Hilborn, University of Texas at Dallas, is now the principal investigator for the grant and Ted Hodapp, Kevin Marvel (AAS), and I are co-principal investigators. We recently received a third grant to fund workshops for five more years. Over 900 physics and astronomy faculty in the first three years of a tenure-track position have participated in the workshops. The workshops are now offered twice per year in alternating years to meet the growing demand. Approximately 180 new faculty members will attend two workshops held in June 2008 and November 2008. More information can be found at http://www.aapt.org/Events/newfaculty.cfm

A third collaborative project between AAPT and APS, which also includes AIP/SPS, is the NSF-funded National Science Digital Library project. The ComPADRE (Communities for Physics and Astronomy Digital Resources for Education) Pathway is developing collections of digital materials for a number of topical areas in physics and astronomy, as well as developing collections that target specific grade levels. For example, the *Physics Front* is directed at pre-college physics teachers with the materials arranged into teaching units. The *Physics Source* includes resources for an introductory university physics course. *The Nucleus* is a "gathering place" and collection of materials for undergraduate physics students. Other collections are being developed for an advanced laboratory course, quantum mechanics, and thermal physics, to name a few examples. Bruce Mason, Oklahoma University and FEd Secretary-Treasurer, is the principal investigator and Jack Hehn, Ted Hodapp and I are co-principal investigators.

In addition to these projects, AAPT is collaborating with APS on a Noyce Scholarship grant, a proposal for renewal of the PhysTEC project, PhysTEC II, the doubling initiative, and issues associated with underrepresented groups in physics. All these collaborative grants and projects involve FEd members as well as AAPT members and there is a clear synergy in our efforts.

I look forward to continuing these many collaborative efforts with APS and the Forum membership in my role as AAPT Executive Officer. I welcome any suggestions you might have on how AAPT and the Forum can cooperate on additional projects to improve physics education at all levels. If you are currently not a member of AAPT, I would invite you to join and help AAPT strengthen physics education and support physics educators.

Warren Hein
AAPT Executive Officer

Excellence in Physics Education Award Goes to the Two Year College Workshop Team and AAAS Leadership in Science Education Prize

The winner of the 2009 Excellence in Physics Education Award of the American Physical Society goes to the Two Year College Workshop Team. The award consists of an honorarium of $5,000 and support to attend the April APS meeting to give invited talks. The leaders of the Team are **Curtis Hieggelke** (Joliet Junior College), **Thomas O'Kuma** (Lee College), and **David Maloney** (Indiana University–Purdue University–Fort Wayne). The citation reads: "For leadership in introducing physicists in two-year colleges to new instructional methods, in developing new materials based on physics education research, and in fostering faculty networking, particularly in two-year colleges."

The Excellence in Physics Education Award is the only APS award specifically targeted at a group, although other prizes and awards often go to multiple recipients.The endowment, which funds this $5,000 award and travel for the recipients, must remain above $100,000 with a nominal 5% annual return. The endowment during these first three years has been adequate to fund the award and travel but the amount available has been tight. I'd like to see the total in the endowment grow somewhat so that there is never an issue of having enough to fund travel for the recipients. Can you help? You can make a tax deductible donation to build up this endowment by sending your gift to Darlene Logan, Director of Development, American Physical Society, One Physics Ellipse, College Park, MD 20740, or you can make an online gift by going to the APS homepage www.aps.org and clicking on the "Support APS" banner halfway down the page.

AAAS Leadership in Science Education Prize

Congratulations to Diane Riendeau, Deerfield High School, winner of the 2008 AAAS Leadership in Science Education Prize for High School Teachers. Riendeau's "Make It, Take It, Teach It" program gives students a chance to observe basic physics concepts as they build a simple object such as a kaleidoscope and use their creation to teach their parents about reflection, for example. The combination of hands-on learning and teaching by the students—along with positive feedback from their families—has raised physics comprehension and interest, according to data collected on the program.

The annual prize of $1000, supported by AAAS member Edith Neimark, recognizes a high school teacher who has contributed significantly to the AAAS goal of advancing science education by developing an innovative and demonstratably effective classroom strategy, activing, or program. The prize also includes a visit to the Shanghai International Forum on Science Literacy of Precollege Students.

FEd Sessions at the 2009 March and April APS Meetings

Peter Collings

March Meeting – March 16-20, 2009–Pittsburgh, PA

Invited Sessions

1. Gordon Research Conference on Computational Physics - joint with DCOMP
2. Informal Science Education
3. Teaching Biological Physics–joint with DBP
4. Student Preparation, What Physicists Do in Industry–joint w/ FIAP
5. University–Science Center Collaborations–joint with FPS
6. Results After One Year of the Doubling Initiative

Focus Sessions

1. The Physics and Astronomy New Faculty Workshops
2. Incorporating Computational Physics into Teaching–joint with DCOMP
3. NSF's Research Experiences for Undergraduates (REU)

Program: Overview and Perspectives

Sunday Workshop

1. Integrating Computation into Upper Level Physics Courses

April Meeting–May 2-5, 2009–Denver, CO

Invited Sessions

1. Physics on the Road Conference
2. Teaching About Energy I–joint with DNP
3. Teaching About Energy II–joint with DPB
4. Teaching Physics and the Arts
5. Excellence in Physics Education Award Session
6. Introductory Physics for Pre-Health and Biological Science Students

Focus Sessions

1. Professional Preparation of Teachers of Physics
2. Adopting PER-Based Teaching Methods and Materials

FEd Program Committee
David Bennum (University of Nevada, Reno), Olivia Castellini (Museum of Science and Industry, Chicago), Wolfgang Christian (Davidson College), Peter Collings, Chair (Swarthmore), David G. Haase (North Carolina State University), Theodore W. Hodapp (APS), Ernie Malamud (University of Nevada, Reno), John Radzilowicz (Carnegie Science Center), Thomas Rossing (Stanford University), Peter Shaffer (University of Washington), John Thompson (Univesity of Maine), Larry Woolf (General Atomics)

Engaging Faculty in the Teaching/Learning Process

Stan Jones

Much has been written about the importance of engaging students in their own learning process. Active and collaborative learning techniques that engage students have been shown to significantly improve student learning. But what about the faculty: are they fully engaged with the students' learning process? In particular, how committed are the faculty to the health and vitality of the introductory courses offered by their department? In the process of helping my department to implement active learning strategies in introductory physics, I have found an unexpected side-effect: the faculty themselves become engaged. The result is substantially more faculty involvement in curriculum development, laboratory improvement, and general concern for the introductory courses.

Prior to our implementation of course reform, it was generally the case that faculty had little awareness of the lab content, and made little effort to incorporate the labs in their teaching. I suspect this is still the case at many research universities where the lab sections are taught by graduate students. I argue that this is a dereliction of duty on the part of faculty, and that even in the largest classes it is feasible and desirable to integrate the laboratory material with the lectures.

Introductory physics at the University of Alabama is now taught primarily in an integrated lecture/lab format (sometimes referred to as studio physics). In contrast to the traditional format of three lectures and a separate laboratory each week, we have two two-hour lecture/labs per week, plus a recitation session. Interestingly, this model makes the course quite similar to a high school course, especially one on a block schedule. With our studio format, the professor is directly involved in the lab, and the teaching assistants are present for both the lecture and labs (as well as other in-class exercises). There is considerable use of active learning techniques, including peer-instruction, collaborative work, computer simulations, interactive labs, and use of student response systems (clickers).

Among the advantages of lecture/lab integration is the timeliness of lab experiments. The experiments are intimately coordinated with the lectures, and both labs and lectures can be cross-referenced by the instructor to reinforce the concepts. Moreover, because the course is essentially taught in the lab setting, there are frequent opportunities to go right to the equipment to illustrate a point or answer a student's question that might arise during a lecture.

While integrating lectures and labs makes labs more meaningful, there is another benefit: the faculty members are also more engaged with the process. Although there is a certain learning curve for the faculty to climb the first time they teach labs, it has frequently been the case that faculty go on to make improvements to lab experiments and to develop new experiments themselves. In the past, only one faculty member supervised the labs, and only that person (with input from the graduate teaching assistants, of course) participated in updating experiments and introducing innovations in the lab. Now at Alabama we have most of the faculty involved in studio physics instruction, and many improvements have been introduced by both theorists and experimentalists alike.

To start with, many professors have been making improvements in existing labs. This is going on continuously, and almost every week there is an email discussion among faculty members about possible improvements or extensions of that week's experiments. And we do not confine experiments to just one day a week when the equipment can be used to advantage more than once. On another level, there have been several entirely new experiments developed by professors who ordinarily would not even be involved with the laboratories. As an example, one of our new assistant professors got an internal grant to develop interfaces that allow students to use the computer as an oscilloscope for I-V curves and for time constants for RC and LC circuits. Another colleague introduced an experiment using GMR probes to measure magnetic field strength and directly verify Ampere's Law. Both of these were quite ingenious, and drew upon the specific research strengths of these faculty members. An experiment on coefficient of restitution, one on error analysis, one measuring the tension in an Atwood's Machine, and a simulation of motion of a charged particle in an E-field (using Interactive Physics) were all developed by faculty who ordinarily would have little to do with labs. In short, the faculty members are now engaged in the laboratory course just as much as the students are.

Our experiences have shown that the studio format is an excellent one for engaging both students and faculty in the teaching/learning process. Studies show that a result of this engagement is that both conceptual learning and problem-solving skills are improved. The studio format stimulates much more student-teacher interaction than is possible in a lecture setting. Faculty involvement leads to continuous improvement of the lab and other activities in the course. While there are limitations to the size of a studio class, when it is a viable option the evidence does seem to show that integrated lectures and labs are a superior learning environment.

What if your class size is too large to accommodate a studio approach? This has started to be a problem at Alabama, where enrollments are rising rapidly. We now teach in both the large lecture and studio formats. I have found that since I am now familiar with the lab experiments, I can still incorporate lab experiences in my lectures when teaching in a traditional lecture setting. I can still have a voice on which experiments are done, and ask the teaching assistants to look at specific details if that will coordinate better with lectures. I think the students really appreciate my referring to the experiments when discussing theory and problem-solving in the lectures. The fact that I am not in the lab with them is unfortunate, but the fact that I am familiar with the labs allows me to make reference to them as evidence for the concepts I am teaching in lecture. So if you cannot implement a studio format, you can still familiarize yourself with the lab experiments in order to make the connection between them and material you introduce in lecture. I would argue that it is a professor's responsibility to do so. I know that in many universities this is in fact happening. But if it is not happening in yours, well… it should be.

Our development of studio physics courses at Alabama has benefited immensely from interactions with Bob Beichner and project SCALE-UP, and funding from the University of Alabama and the U.S. Department of Education.

Stan Jones is Professor of Physics Emeritus at the University of Alabama and a former editor of the FEd newsletter.

Teaching Modern Physics using Selected Nobel Lectures

A. Stinner

Introduction

Some years ago I realized that what I can do as a University educator preparing students who are planning to become physics teachers is to build on their undergraduate knowledge of modern physics using an unconventional approach. I decided to give them some enthusiasm and self confidence for the teaching of the ideas and the concepts of modern physics, using a selected number of appropriate Nobel lectures. Based on my prior experience, I was convinced that the conventional approach revisiting the main ideas of modern physics using a textbook would only lead to boredom.

Using seminal papers of the great physicists of the past to teach physics is notoriously difficult. Papers by the Nobel laureates chosen that contributed to the work on which the Nobel Prize was awarded are generally inaccessible to students. However, there are many Nobel lectures that are accessible and can be fruitfully studied by students.

What follows is a brief description and a rationale of the course I present to physics teacher candidates at the University of Manitoba. The paper also containes a shortened version of a handout produced by one of my students (in consultation with the instructor) based on the work of J.J. Thomson, as reported in his Nobel lecture.

Description of the presentation

I always begin my classes with a quotation by G.P. Thomson, the son of J.J. Thomson, taken from his Nobel lecture:

The goddess of learning is fabled to have sprung full-grown from the brain of Zeus, but it is seldom that a scientific conception is born in its final form, or owns a single parent. More often it is a product of a series of minds, each in turn modifying the ideas of those that came before, and providing material for those that came after. The electron is no exception.

I then emphasize that the Nobel lectures chosen must illustrate the interconnectedness of ideas and the dependence of new work on earlier achievements, as described in the statement. (Nobel lectures chosen, with a shortened version of the citation, are listed below.)

A note of explanation must be added here. Roentgen did not give an acceptance speech and Einstein's Nobel lecture (given a year later) was not based on the work for which he was awarded the prize (photoelectric effect). For Roentgen, my students read relevant articles taken from the special edition of "History of Physics", an AAPT publication. The Einstein acceptance speech is based on his two theories of relativity, and is generally inaccessible to students. Here I made an exception, and I ask my students to read the first part of his ultimately revolutionary 1905 paper on relativity. Finally, Rutherford received his Nobel Prize in chemistry, much to his annoyance, and the second Nobel Prize of Madame Curie was also in chemistry.

The following is a *shortened* version of a student's summary of the work of J.J. Thomson. This report is handed out after the PPT (PowerPoint) presentation by the student-presenter, to be discussed in detail in the following session. Of course, appropriate diagrams and pictures are contained in the PPT presentation, which are also handed out to the students.

Carriers of negative electricity

Thomson begins his lecture by reviewing the experiments by Crookes to show that cathode rays travel in straight lines. These "rays" were found to be absorbed by a thin plate of mica. Two views were prevalent in 1897: one, held by English physicists, that the rays are negatively electrified bodies, shot off the cathode with great velocity, and the other, supported by German physicists, that these rays are vibrations in the ether.

The arguments in favor of the rays being negatively charged particles were: they are deflected by electric and magnetic fields, as we expect moving charges to behave, and they can be confined in a vessel to give up their negative charges.

If the electric field E and the magnetic field B are so arranged that the forces cancel we have:

$$\mathbf{Bev = Ee}$$

$$\text{Therefore: } \mathbf{v = E / B}$$

where **B** is the magnetic field, **e** the charge on the negative particle, **v** is the velocity of the particle (in the horizontal direction) and **e** the electric charge of the particle.

We can now determine the velocity of the particles. It turns out that the velocity can be as high as 1/3 the velocity of light, or about 60,000 miles per second.

Having found the velocity of the rays, we can determine the **e/m** ratio of the particle. When the particles find themselves in a constant electric field they experience a constant force. The physics here is like that of a bullet projected horizontally with a velocity **v** and being acted upon by a gravitational force. It is easy to show that the displacement of the particle will be given by

$$\mathbf{d = \tfrac{1}{2}\, Ee\, l^2 / mv^2}$$

where **l** is the horizontal length, m the mass of the particle.

We can now find the displacement **d** and then calculate the e/m ratio of the particle:

$$\mathbf{e/m = V / B^2 l^2}$$
(Thomson expressed this as) $\mathbf{e/m = V\,\theta / B^2\, l\, d}$
where $\boldsymbol{\theta = d/l}$

This ratio seems to be independent of the velocity as well as the kind of electrodes we use!

The value for **e/m** found was about **$1.7\text{x}10^7$** as measured in the **cgs** system of units. The value of this ratio found for atoms of hydrogen was only about **10^4**. Therefore, this ratio for the corpuscle associated with cathode rays is about 1700 times larger. The conclusion Thomson reached was that the mass of the corpuscle was about **1/1700** that of the hydrogen atom.

There are many sources of cathode rays: metals heated to a high temperature and any substance when heated gives out corpuscles to some degree; sodium and potassium give off negative corpuscles even when cold and exposed to light. Radioactive materials (uranium and radium) emit them continuously and at very high velocities

Thomson goes on to describe how the newly discovered *Wilson cloud chamber* has assisted physicists to show those properties described above. He also discusses a first attempt to find the charge on these particles using Stokes' law. He then estimates the charge on a particle to be about **$3.0\text{ x}10^{-10}$** electrostatic units, or about **10^{-20}** electromagnetic units.

Since we know the charge to mass ratio, we can now estimate the mass of the negatively charged particle. This mass turns out to be about **$6\text{x}10^{-28}$ g**.

The conclusion then is that "in all known cases in which negative electricity occurs in gases at very low pressures, it occurs in the form of corpuscles, small bodies with an invariable charge and mass.

Questions based on the Nobel lecture by J.J. Thomson:

1. In what year did J.J. Thomson discover his "negatively charged corpuscle" that we now call the electron?
2. What were the two hypotheses about what cathode rays are initially?
3. What were the main arguments in favor of the particle theory of cathode rays?
4. What were the two main conclusions about the "particle" that was discovered?
5. What physical arrangement allowed the calculation of the velocity of the particle?
6. About how fast did these particles move?
7. What are some of the sources of these particles?
8. How was the Wilson cloud chamber used to find the charge of the particles?
10. How did Thomson estimate the mass of the particle?

Thomson concludes his lecture by stating that: "In all known cases in which electricity occurs in gases at very low pressures, it occurs in the form of corpuscles, small bodies with an invariable charge and mass. The case is entirely different with positive electricity." What did he mean?

Main concepts: Electric field, magnetic field, electric charge, force, potential difference, kinetic energy.

Questions and Problems:

1. How do physicists produce a constant electric field? A constant magnetic field? Explain.
2. Who first suggested the name of electron for Thomson's electric corpuscle? When was this suggested?
3. What were the arguments and evidence for believing that cathode rays are negatively charged particles?
4. Describe how Thomson set up his apparatus and explain how he found the e/m ratio of the electron.
5. How did Thomson estimate the charge on the electron?
6. In our experiment, we used a 2000 V potential difference for both the plate voltage and the anode voltage. The coil had 320 turns, and its diameter was 15 cm. The plate separation was 5.0 cm, and the length of the plate 7.0 cm. The ammeter reading of the current was 1.0 Amps. Using the method of Thomson, calculate the e/m ratio, based on these figures.

Comparison with a "typical" contemporary textbook presentation:

1. Read the textbook presentation of J.J. Thomson's experiment and compare the content with the historical description, taken directly from the Nobel lecture. Comment.
2. Here is one of the questions in the text: "Electrons move through a $6.0\text{x}10^{-2}$ T magnetic field balanced by a $3.0\text{x}10^3$ N/C electric field. What is the speed of the electrons?" What assumptions does the author make about students conceptual understanding? How would you change, or extend the problem in order to go beyond just testing the students' ability to "plug in values" and find an answer?

Relevant Articles:

"The discovery of the electron: a centenary", by Leif Gerward, *Physics Education*,

"J.J. Thomson, The Electron, and Atomic Structure", by Helge Kragh, *The Physics Teacher*, Sept. 1997.

Conclusions:

My students have generally found the reading, the studying, and the discussions of the selected Nobel lectures refreshingly different from the lecture-based and textbook-centered presentations in their undergraduate years. Revisiting the basic ideas, concepts and empirical evidence presented in textbooks using this historical approach allows students to read the summary of the work of a Nobel laureate from an accessible primary source. It is hoped that having had this background study they not only understand the basic ideas of modern physics better but also have developed confidence and enthusiasm to present them on a level accessible to their physics students in high school.

Wilhelm Roentgen, The discovery of the remarkable rays named after him. (1901)
J.J. Thomson, The experimental investigations on the conduction of electricity by gases. (1906) (Our emphasis is the discovery of the electron.)
Ernest Rutherford, The chemistry of radioactive substances. (1908)
William Henry Bragg, and William Lawrence Bragg, The analysis of crystal structure by means of x-rays. (1915)
Madame Curie, The discovery of the elements radium and polonium. (1911)
Niels Bohr, The structure of atoms and of the radiation emanating from them. (1922)
Albert Einstein, The discovery of the law of the photoelectric effect. (1921)
Robert Millikan, The elementary charge of electricity and the photoelectric effect. (1923)
Arthur Compton, For his discovery of the effect named after him. (1927)
Lois de Broglie, For his discovery of the wave nature of electrons. (1929)
James Chadwick, The discovery of the neutron. (1935)
G.P. Thomson, The experimental discovery of the diffraction of electrons. (1937)

Arthur Stinner is a professor of science education at the University of Manitoba. He specializes in physics education and history of science, and his interests are in contextual science teaching and the writing of science plays. This article is based on a paper presented at the 2008 summer AAPT meeting in Edmonton.

Physics Teaching as a Performing Art

Brian Jones

You Are a Performer

> *We are what we pretend to be, so we must be very careful what we pretend to be.*
>
> Kurt Vonnegut, *Mother Night*

Some years ago I took part in a workshop on "Teaching as Performing" led by Morris Burns of Colorado State's Department of Music, Theater and Dance. Morris started with a simple premise: When you teach, you are performing. You make choices about your costuming, your set, your gestures, your language, the stories you tell. He advised us to think about our goals as teachers, and then to make conscious, deliberate choices about all of these elements and more.

I was skeptical. But he ended the workshop with a very practical suggestion that showed me that he was, in fact, correct.

Arrange for a Critique

Morris suggested that we arrange for a critique, that we have someone who knows a bit about performing come to a class to observe and critique—not our pedagogy, but our performance.

I took his advice, and had a performer friend watch me teach. He made a very unusual suggestion: He told me to stop writing on the blackboard. "When you are solving problems," he said, "That's when your students feel the most uncertain. That's when they need you the most. And you turn your back on them." He suggested that I use an overhead projector and write on transparencies, so that I always face the class. And so I did.

That single change made more of a difference in my lecture teaching than anything else I have ever done. When I used the overhead instead of the blackboard, not only was I facing the students—which they noticed and appreciated—I could watch them, to see their reactions, and tailor my teaching to suit.

Ask someone who knows a bit about performing to watch you and observe all of the cues that you give—to critique your performance. You might be surprised at what they suggest!

We all know that lecture isn't the best way to teach students. But if you have a large class, you will probably spend much of the time lecturing. You will be performing. As long as you are on stage, you might as well put on a good show.

Setting the Stage

> *The only thing that doesn't change, makes everything else rearrange*
> *Is the speed of light, the speed of light*
> *My love for you must be the speed of light*
>
> \- Julie Miller, *The Speed of Light*

I teach in a large lecture hall. Some years ago, one of my students noted that the lecture hall had a great sound system. Could I, he asked, play music before class?

I could, and I did. This popular change had two very practical benefits. First, I could play music that related to the day's topic. Students would listen for this, and appreciate it. But—perhaps more importantly—I can time the music so that it fades out precisely when class is to start. Students know that when the music stops, class begins. That's a great way to lead off.

Once you—and your students—start looking for good songs, you'll find that there are some really great ones out there.

> *This wounded world keeps spinning*
> *Turns me over, upside down*
> *I should be thrown into oblivion*
> *But gravity's got me down, down, down.*
>
> - Friction Farm, *Gravity*

I teach in front of a large screen on which I project a series of slides. A few years back, I realized that most of the time my slides consisted of bullet points and equations. That's fine, of course, but it's really underutilizing the medium.

My projector can display a full-color image four meters high. It can show movies. It's got a great sound system attached. I realized that I should use the power of the projector to show things I couldn't have shown on an overhead projector.

These days, I show video clips regularly. I use simulations. I use animations. And when I introduce a topic, I always do so with a compelling image that sets up the topic I am about to begin. With cheap digital cameras, downloadable video clips, online image sources and full-featured presentation software at my disposal, I've realized that it was time for me to move beyond using the projector as a glorified overhead projector.

Sharing the Stage

As often as possible, I like to share the stage with students. My favorite way to do this is via something I call "Physics Theater." I ask students to come in front of the class and, truly, perform.

On the day when we talk about angular momentum, I invite three students to stand in a line in front of the class. "Imagine," I say, "you are standing on the edge of a tall building. I give you a push, and you try—hard—not to fall off. Make us believe that you are in danger of falling, that you are trying hard not to." And then I give them each a shove, and we watch what they do. 95% of the time they windmill their arms—spinning them forward, thus rotating their body backward.

I then follow up with a great video clip of someone doing just this on Skylab. Arms rotate forward, body rotates backward.

This is a great way to introduce the concept of angular momentum, but, more than that, it's a great way to get students involved. My willingness to let students be the stars once in a while really breaks down barriers.

Pretending to walk on a tightrope high above a city street. Why does everyone extend their arms?

A slide from my second lecture on optics. Humans have red eye; dogs have eyeshine—a great way to introduce reflection from thin films.

Telling a Story

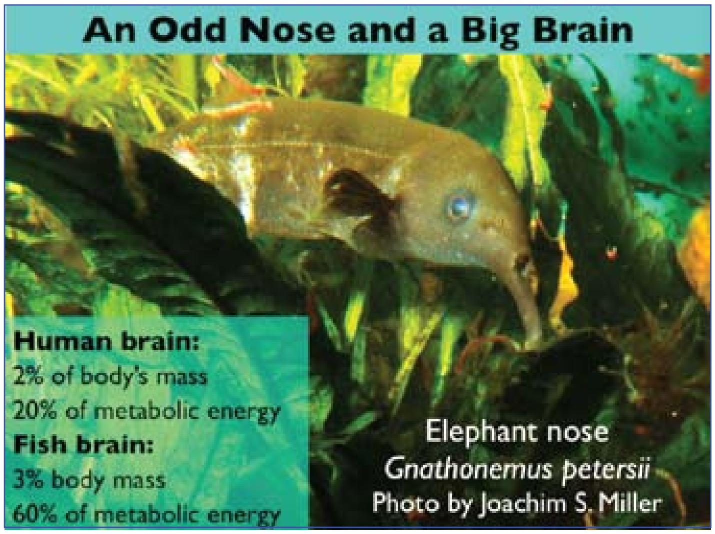
We physics educators have a strong tendency to "bury our lead." We write equations, we do derivations... and, at some point, we get to the stuff our students really care about, a connection to the way the world works.

When I teach my students (who mostly major in the bio sciences) about electric fields, I start with an interesting fact: The animal with the biggest brain in the world isn't us. As far as I can determine, it's a weakly electric fish from turbid rivers in Africa.[1] This raises some interesting questions—How does a fish make an electric field? How does this allow it to find prey? And why does this require such a big brain?—that we can return to as the topic unfolds.

If you are using pictures to help tell your story, you need good pictures. The photo in this slide came from www.flickr.com. This and other photo sites have a remarkable range of photos, many available under a Creative Commons license. Such photos can be reproduced and distributed as long as you don't earn any money (as educators, this is a danger we easily avoid) and as long as you credit the photographer.

Using Props

We all use lecture demonstrations—these are our props. But I've always felt that I should be doing a better job with them. When I watch someone who's really good at presenting a demonstration, like Stan Micklavzina of the University of Oregon, I can tell he's put a lot of thought not just into what he's doing, but how he does it.



A slide from the first class on electric fields and forces.

I've learned a lot from watching other physics folks, but I've learned just as much from watching magicians. When you watch a really skilled magician, he makes you look just where he wants. When something happens, you notice. You are waiting for it. And you're surprised.

Why should we do any less when we present a lecture demonstration? Think about your staging, your presentation, your timing. And practice. You are, after all, a performer. You might as well be a good one!

The Upside

After a few years of putting real effort into classroom presentations, I see changes in class attendance, interest level, engagement level—and in the level of understanding.

When I first started making changes in my class, I was skeptical that these changes would make a difference. But they do, and not just because my students are more likely to be in class and be awake.

As one of my students noted, classes made her "want to care." If I play the role of an active, interested, engaged instructor, my students are more likely to play the role of active, interested engaged scholars. And that's got to be good.

[1.] Nilsson, G. Brain and Body Oxygen Requirements of Gnathonemus Petersii, a Fish with an Exceptionally Large Brain. *The Journal of Experimental Biology* **199**, 603–607 (1996)

Brian Jones is best known as the Director of the Little Shop of Physics, an outreach program of the Physics Department at Colorado State University,

High School Physics and the Challenge Index

Susan White

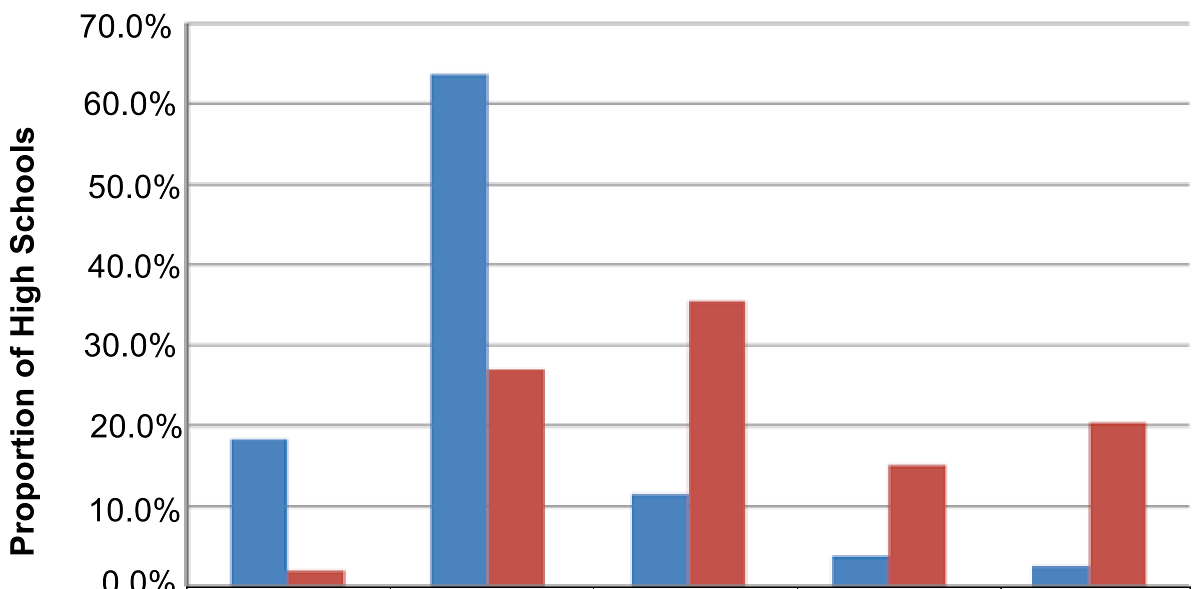
Since 1998, *Newsweek* and *The Washington Post* have calculated Challenge Index (CI) ratings for US high schools. The Challenge Index is calculated by taking the total number of Advanced Placement, International Baccalaureate or Cambridge tests given at a school in May and dividing by the number of seniors graduating in May or June. Schools with a CI of at least 1 are included in the Challenge Index list. A CI of at least 1 means that a school gave as many advanced tests as it had graduates; this list, then, represents schools that challenge their students across the curriculum to prepare for college. About 5% of US high schools have a CI of 1 or higher.

Is there any evidence of a relationship between physics in the high school and broader academic challenge, as reflected by advanced test taking in all subjects? We examine physics at high schools that were included on both the 2007 and 2008 lists in order to answer that question.

We identified 1,137 schools that appeared on *both* the 2007 and 2008 Challenge Index lists. We then compared those schools with the 3,447 schools in our representative national sample of US high schools for which we have data about the number of teachers teaching physics in 2005. There are 152 schools that appear on both lists.

The difference between the distribution of teachers teaching physics at the schools with a CI of 1 or higher and the distribution at all US high schools is striking and is shown in the figure above.

Number of Teachers Teaching Physics: 2005[1]



	0	1	2	3	4 or more
US Sample	18.3%	63.8%	11.5%	3.8%	2.6%
CI Sample	2.3%	27.0%	35.5%	15.1%	20.4%

[1]While these data seem to indicate that about 18% of US high schools do not offer physics at all, it should be noted that some schools offer it only in alternating years and are represented by a 0 here because 2005 was a "no physics" year.
Source: AIP Statistical Research Center: 2004-05 High School Physics Survey & *Newsweek/Washington Post* Challenge Index

While less than 3% of all US high schools have 4 or more teachers teaching physics in a typical year, over 20% of the high CI schools fall into this category. In fact, the proportion of high CI schools with 4 or more teachers teaching physics is *almost 8 times higher* than that of all US high schools. Multiple teachers teaching physics indicates larger enrollments in physics at these schools. Even though 89% of US high schools, serving 97% of the students, offer physics regularly, more than 80% of these schools have only one teacher teaching it; the opposite is true for high CI schools with *over 70%* of the high CI schools having more than one physics teacher.

Certainly the CI is an imperfect measure in trying to determine the "best" or "top" high schools. It does not include pass rates on the exams, and it does not account for differences in the underlying student populations which affect the number of students taking exams. The list is incomplete since there is no national database that includes the required data; schools that believe they qualify with an index of 1 or higher are invited to submit data after publication. Furthermore, a group of 38 school superintendents from five states requested that their schools not be included in the 2008 list.

At the same time, the CI does provide quantitative information about what is happening in US high schools. Jay Mathews, Education reporter at *The Washington Post* and creator of the Challenge Index, reports that schools on the list "turn out to have principals and teachers who are trying hardest to raise the achievement of each child, with college as a useful goal for all." As the US struggles to reinvigorate interest, enrollments, and diversity in science, technology, engineering, and mathematics (STEM) disciplines, it is important to note the high correlation between having two or more teachers teaching physics and achievement as measured by the Challenge Index. Furthermore, these data suggest that a vital high school physics program is a fundamental part of the recipe to challenge students in all fields.

Susan White is a member of the Statistical Research Center of the American Institute of Physics.

Browsing the Journals

Thomas D. Rossing

- "The Large Hadron Collider runs on woman power" is the title of an article in the May issue of *CERN Courier* which presents brief interviews with nine physicists and engineers working at the Large Hadron Collider (LHC). They gave varying answers to the question of whether they considered themselves to be at a disadvantage working in a field dominated by men, but most of them did not. Several of the women had children ranging in age from 2 to 18, which presented a challenge to balance their profession with their family.
- There's no real difference between the scores of US boys and girls on common math tests, according to a paper in the July 25 issue of Science. A study 20 years ago showed a "trivial" gap in math test scores between boys and girls in elementary and middle school, but it did suggest that boys were better at solving more complex problems by the time they got to high school. Now, even that small gap appears to have disappeared. Among the highest scorers, white boys outnumbered white girls about 2:1, but among Asians, however, that result was nearly reversed, which suggests that cultural and social factors, not gender alone, influence how well students perform on tests. Boys do outperform girls on the mathematics section of the SAT test, but that may be due to the fact that more girls than boys take the SAT.

  The most disturbing finding is that neither boys or girls get many tough math questions on state tests now required to measure a school district's progress under the No Child Left Behind law. The authors worry this means that teachers may start dropping harder math from their curricula because more teachers are gearing their instruction to the tests.
- "UK Education Reform: Too Much of a Good Thing?" is the title of a news item in the 12 September issue of Science. For more than a decade, the U.K. government has tweaked and revamped high school curricula and examination system to stop a worrying slide in the number of children who study science and mathematics in their last 4 years at school. Last week, the Royal Society issued a report that says the government implementation of science education reform is unscientific. The changes have come so fast, one after another, that it's impossible to know whether anything has worked or just added to the problem, the report says. The report concludes that the political pressure to deliver results before a government faces the next election is not compatible with methodical reform. Meanwhile the dwindling science pipeline feed U.K. universities has a noticeable impact: 22 physics departments have closed since 1997.
- Combining teaching with research is always tricky, particularly if one is aiming for tenure. An article in the 6 September issue of New Scientist includes some hints for how to get ahead. One way is to avoid growing your lab too large in the early years. "Graduate students are hard to train. For many years, the best hands you'll have to do the experiments are your own." Don't discount the need to write and present your work well. If you want to stay on the tenure track but want a more even distribution of research and teaching, consider a position at a small college where teaching is considered more heavily in tenure decisions. Once tenured, avoid shifting too much of your workload into administrative or service roles.
- Physics is generally perceived to be a difficult subject, so the use of demonstrations to promote understanding as well as generate student interest among students is valuable. Three practical demonstration experiments from the New Zealand Institute of Physics conference are described in the July issue of *Physics Education*. One has to do with diffraction at parallel grooves left on a sheet of plastic by a coarse sheet of sandpaper. The second illustrates how internal resistance generates heat in a

battery. The third is a demonstration of the Leidenfrost effect by water droplets on a hot metal plate.

- Despite ever-rising college costs a $4.5 billion federal aid program to lure students into science is vastly undersubscribed, according to a note in the 15 August issue of Science.

  The Department of Education is spending money at only half the rate Congress envisioned in 2006 when it created the 5-year National Science and Mathematics Access to Retain Talent (SMART) and the Academic Competitiveness (AC) grant programs. Secretary of Education Margaret Spellings says the reason so few college students are eligible for the largest federal aid program of its kind is that they haven't taken the necessary courses in high school. To be eligible for the AC grant, students must have graduated from "a rigorous secondary school program," which means 3 years of higher level math and science and at least 1 year of a foreign language. The shortfall caused Congress to cut the 2007-08 allocation to $397 million.

- Contrary to several textbooks and websites, the daily tides on opposite sides of the Earth are due entirely to Newton's inverse square law, an article in the March issue of Physics Education reminds us. Newton's law predicts that the gravitational field of the Moon and Sun will be greater on side of the Earth than the field on the other. It has nothing to do with the rotation of the system or with centripetal or centrifugal forces.

- A new study has found that the most likely undergraduate alma mater for those who earned a PhD in 2006 from a U.S. university was Tsinghua University, while Peking University, its neighbor in Beijing, was second. Between 2004 and 2006 these two schools overtook the University of California, Berkeley as the most fertile training ground for U.S. PhDs, according to an article in the 11 July issue of Science. South Korea's Seoul National University occupies fourth place, followed by Cornell University. The rankings were compiled by the Commission on Professionals in Science and Technology from a survey conducted by the U. S. National Science Foundation.

- The American Association of Physicists in Medicine (AAPM) is celebrating its 50th anniversary, and an anniversary paper in the August issue of Medical Physics reviews the development of x-ray computed tomography and the role of AAPM and Medical Physics in its development. The introduction of the first commercial CT scanner in 1972 led to a flurry of publications by academics and industrial researchers. The original system was a dual-slice system that acquired one ray for each of two slices at a time. The source and detector needed to be translated along each section of the patient and then rotated, with the process repeated for 180 projection views. During the 1970s, a more time-efficient fan-beam imaging system developed. The article includes a "look to the future" and 218 references, which may be the most useful feature for medical physics teachers.

- "Paperless Approach Catching On" is the title of a story in *Digital* Directions published online August 28 by Education Week. Across the country, more high schools are moving toward paperless classrooms, equipping them with laptop computers, foregoing paper textbooks for online versions. Popular platforms, such as Blackboard, provide "lockdown" modes so that students can take exams on their laptops without browsing the Internet or opening a document. If the test is multiple-choice, students get their scores immediately after taking it. An earlier story in Digital Directions (June 9) compared commercial software, such as Blackboard, with open-source software, such as Moodle.

- Historically black colleges and universities (HBCUs) play a key role in producing future scientists and engineers, according to a recent National Science Foundation report on "Baccalaureate Origins of African-American S&E Doctorates." In 2006, 33 percent of the African-American students who earned science or engineering doctorates came from HBCUs, as compared with 25 percent in the early 1990s, according to the report. The top five U.S.-wide baccalaureate-origin institutions for African-American S&E doctorates during the period 1997-2006 were: Howard University, 224; Spelman College, 150; Hampton University, 135; Florida A&M, 100; and Morehouse College, 99.

- Students learn better when they construct their own understanding of scientific ideas within the framework of their existing knowledge. An article in the 31 October issue of Science summarizes some of the research of the Physics Education Technology (PhET) project, particularly that related to simulations and student motivation. An important element of educationally effective simulations is that students view these much as scientists view their research experiments. A number of characteristics that make a simulation engaging include some of those which make video games engaging including: 1) dynamic visual environments that are directly controlled by the user; 2) challenges that are neither too hard nor too easy; 3) enough visual complexity to create curiosity with being overwhelming. Students are not able to make sense of the science in the simulation just from watching; they must interact actively with the simulation. "Most of the learning occurs when the student is asking herself questions that guide her exploration of the simulation and her discover of the answers." This sort of self-driven exploration is very similar to what a scientist does with an experiment.

Thomas Rossing, Distinguished Professor Emeritus at Northern Illinois University, is currently a visiting professor at Stanford University.

Section on Teacher Preparation

From the Editor of the Teacher Preparation Section: John Stewart (johns@uark.edu) *University of Arkansas*

The American Association of Physics Teachers meeting in Edmonton this summer featured a wealth of excellent talks on teacher preparation. The three articles that follow were solicited from talks at this meeting. Two of the articles are by Teachers in Residence (TIR) at two of the four new PhysTEC primary institutions: Cornell and the University of Minnesota–Twin Cities. Jon Anderson, who took over TIR duties from Nancy Bresnahan this year, discusses the Learning Assistant program at the University of Minnesota, Twin Cities. This program features a novel implementation of the LA program in a large lecture class and has generated excellent student evaluations. Marty Alderman, currently TIR for Cornell's PhysTEC site, discusses often ignored problems in providing high quality physics instruction to all students. These issues, including the allocation method used by high schools to assign physics classes to teachers, the Small School Initiative, and the role of private schools, may be unfamiliar to people who work in the university environment.

Finally, Richard Steinberg, a Professor in the School of Education and the Department of Physics and Program Head of Science Education at City College of New York, discusses his extraordinary experiences teaching high school in a poor area of Manhattan. During a sabbatical, Richard gained a teaching license through alternate licensure and spent a year as a high school teacher. The transition from the college classroom to an underprivileged high school classroom provides an eye opening picture of the challenges our future teachers face. Richard's talk at the AAPT meeting generated more post-talk discussion than any other I have ever attended.

The 2009 Physics Teacher Education Coalition (PTEC) Conference on the Preparation of Physics and Physical Science Teachers will be held in Pittsburg, Pennsylvania on March 13th and 14th immediately before the APS March Meeting. The theme of the meeting is "Institutional Transformation." Registration information will be provided at PTEC.org when it becomes available.

John Stewart is professor of physics at the University of Arkansas. Email: johns@uark.edu

The First Year of PhysTEC at the University of Minnesota

Jon Anderson

The University of Minnesota became one of four new PhysTEC primary institutions in 2007. PhysTEC is a national program of the American Physical Society (APS), the American Association of Physics Teachers (AAPT) and the American Institute of Physics (AIP). It receives funding from NSF and private donors and is designed to increase the number of highly qualified high school physics teachers. The University of Minnesota PhysTEC program involves faculty from the School of Physics and Astronomy (SPA), the Department of Curriculum and Instruction (C&I), and the Department of Postsecondary Teaching and Learning (PSTL). The project was initiated in 2007-08 with a focus on the primary goals that are shared with the national PhysTEC project. These goals are:

- increasing the number of highly-qualified high school physics teachers educated at the U of M.
- improving the quality of physics teacher training using the results of continuing Physics Education Research (PER) and incorporating the best practices developed at PhysTEC primary institutions and at the U of M.
- enhancing peer and U of M support for in-service physics teachers and for new teacher induction.

It should be noted that the SPA has a longstanding commitment to improving the training of physics teachers and to improving education in physics based upon the work of the PER group and proven best practices. Additional goals include:

- providing leadership for the transfer of similar practices and programs to other local and state-wide colleges and universities that have physics teacher training programs.
- increasing the coordination between the SPA and the departments in the College of Education and Human Development (CEHD)
- continuing to improve our existing physics instruction for pre-service elementary school teachers enrolled in our CEHD.
- providing support for current and future high school physics teachers in the Twin Cities metropolitan area and the state of Minnesota.

PhysTEC Program at the University of Minnesota

The PhysTEC program at the U of M is based on the experiences of other PhysTEC institutions and adapted to the needs and strengths at the U of M. Members of the PhysTEC team at the U of M have a long history of commitment to improving education. Leon Hsu of PSTL and Ken Heller of SPA have both been awarded the Morse Teaching award, a university-wide award for excellence in teaching. Ken Heller is past president of the AAPT. Cynthia Cattell of SPA, the PI, is the organizer of the outreach group known as "The Physics Force" and a Fellow of the American Geophysical Union. Charles Campbell of SPA is a recipient of the George W. Taylor Award for Distinguished Service. First year TIR Nancy Bresnahan is a member of the "Physics Force" and has received the Minnesota Academic Excellence-Teacher Achievement Award. Current TIR Jon Anderson is also a member of the "Physics Force" and has received the CBS Motivational Teacher Award.

At the heart of the U of M PhysTEC program is the use of Learning Assistants (LAs), a successful component of other PhysTEC sites. The LAs are recruited from the top 10% of the students in the introductory calculus-based physics classes. They are hired to work in *Physics 1101*, a large, lecture-format, algebra-based physics course. The goal of this placement was to put the LAs in the role of "in lecture peer experts" and to break the large lecture down into more of a studio-style learning environment. The LAs:

• attend every lecture of the course. They always sit and work with the same group of 16 -18 students. These groups are organized by lab/discussion sections. The professor for the course provides multiple opportunities in each lecture for the LAs to interact with their group of students. These opportunities take the form of in-class "clicker questions", short discussion questions, problem solving exercises, and end of the lecture check out questions. This structure allows for frequent and relevant interactions between the LAs and the students both during and before and after the lecture.

• maintain an office hour that is open only to students in P*hysics* 1101. This means that the students can seek assistance from a tutor who is knowledgeable in the subject matter and in the specifics of the course.

• attend either a weekly discussion session or a lab. At these sessions, they assist the TA and help the students in the session or lab.

• perform almost all of the lecture demonstrations for *Physics* 1101. This adds an amateur quality and a genuineness to the demonstrations that can't be achieved in other ways. It also more fully captures the attention of the students in the lecture.

• collect homework weekly and grade one problem based on a solution provided by the professor.

• facilitate and conduct review sessions before each of the four scheduled exams.

• perform scaled down "Physics Force" shows as *Physics Force–The Upcoming Generation* for school groups and others that are visiting the U of M. This show is approximately 20 minutes in length and is organized around a central theme.

This early experience as an educator has been shown to be a successful strategy for recruitment of undergraduates into the high school physics teaching profession. Therefore, one of the goals of the U of M PhysTEC program is to provide positive, early teaching experiences for our LAs and hope that this entices them to continue and perhaps pursue a career in teaching. To this end, the U of M PhysTEC program is now working with the DirecTrack to Teaching program, a new initiative of CEHD. DirecTrack, designed for exceptional undergraduate students interested in secondary school teaching, allows these students to begin course work towards a teaching license as an undergraduate and provides varied opportunities for early teaching experiences.

Another of the program elements borrowed from other PhysTEC institutions and a key component of the U of M program is a Teacher-in-Residence (TIR). The TIR is a master high school physics teacher who spends an academic year at the U of M and is responsible for overseeing many aspects of the PhysTEC program. The TIR has significant experience using best practice methodologies in a high school setting and, therefore, provides the experience needed to develop an effective program of coursework and early teaching experiences. It is the TIR's responsibility to:

• teach one section per semester of *Physics 3071: Lab based Physics for Elementary Teachers*. The other section of this course is taught each semester by a U of M tenured faculty member. This arrangement lends itself to significant cooperative planning and collaboration between the two instructors and is therefore a mutually beneficial professional development activity.

• actively recruit students to consider teaching high school physics as a possible career choice. This is accomplished by one-on-one conversations with potentially interested students, making announcements to lecture sections of physics courses, and sending emails inviting and encouraging students to attend information sessions about teaching high school physics.

• hire and supervise LAs for use as previously described.

• plan and prepare lecture demonstrations to be performed by LAs.

• plan and conduct a weekly seminar for LAs that is designed to both prepare them for the upcoming lectures and to introduce them to some pedagogical aspects of teaching physics.

• act as a mentor to interested students and help coordinate new teacher induction and in-service mentoring.

• plan and participate in bi-monthly PhysTEC team meetings.

• participate in information sessions for students that are considering transferring from two-year colleges to the U of M. This is an opportunity to make them aware of the PhysTEC program.

First Year PhysTEC Results

The first year of PhysTEC at the University of Minnesota was largely successful. In its second year, the program continues to evolve with a focus on continued improvement and on accessibility to as many students as possible.

The placement and use of LAs in the lecture proved to be a very successful aspect of the U of M PhysTEC program The ten LAs that worked in *Physics 1101* in the spring 2008 semester brought a pioneering, adventurous, "make it work" attitude to their job. This was demonstrated by the way that they interacted with the students, by the feedback that they gave at the weekly LA seminar, by the way that the LA program (and consequently PhysTEC) evolved in response to the feedback given by the LAs, and by the overwhelmingly positive formal assessments of their value in the lecture.

Perhaps the best measure of the success is that provided by the *Physics 1101* students themselves through the end-of-course survey. Two questions best illustrate the impact of LAs in the lecture. The score shown is an average of 116 responses.

1. "How valuable were the LAs in clarifying points of confusion during lecture?" 3.88/5

2. "If you were to take the sequel to this course, *Physics 1102*, would you like to have LAs in the lecture?" 4.32/5

These two questions and the responses to the other questions on the survey provided numerical support for the anecdotal evidence that the LAs had been providing all semester.

Most of the efforts of the U of M PhysTEC program in this first year were directed toward program implementation, hiring LAs, working with the LAs in their role in lecture, and organizing the seminar for the LAs. Additionally, because the program was in its infancy, there was no history of recruitment or related successes to draw upon. In spite of this, the U of M program did succeed in recruiting three future high school teachers. One of them came from the LA corps and is now in the DirecTrack to Teaching program, one of them was a physics major who attended the LA seminars and subsequently made the decision to pursue his post-baccalaureate degree in Physics Education in CEHD. The third individual is someone who worked closely with the PhysTEC program as a graduate student TA for *Physics 1101*, attended the LA seminars and applied for and received a fellowship that fast-tracked her into a physics teaching position in the St. Paul, MN schools. She will now be working on fulfilling her requirements for her teaching license.

Future

Now in the second year, the PhysTEC program includes 15 LAs working in the *Physics 1101* lecture and associated labs and discussions. In upcoming years, the LA program will expand to provide different teaching experiences to second and third year LAs who have decided to pursue a career in high school physics teaching. Additionally, the possibility of expanding the use of LAs into other physics courses is also being explored and discussed. Some of the ongoing goals for the U of M PhysTEC program include:

• searching for a TIR for the 2009 – 10 academic year
• working toward making the TIR a funded position
• continuing recruitment of future physics teachers
• tracking of PhysTEC teachers
• recruiting area high school teachers for a Teacher Advisory Group (TAG)

The TAG will be a group of experienced teachers that provide input on the direction of the PhysTEC program and will provide a classroom setting in which future physics teachers can observe and obtain some practical classroom experience.

The program at the U of M continues to be under development. The U of M is well-positioned to have a highly successful PhysTEC Program by virtue of:

• numerous existing programs that provide a high quality education to pre-service high school physics teachers and elementary science teachers.

• research in and commitment to the use of best practices in teaching and assessment.

• a strong base of public programming and outreach to build interest in physics teaching careers.

• experience with in-service teacher support.

• the effective and strong interactions between the SPA and C&I faculty and graduate students.

As the flagship public education and research institution in the state of Minnesota, and with its location in the major metropolitan center of the upper Midwest, the U of M is also well-positioned to provide leadership and support for physical science teacher training and in-service support for a large network of educational institutions.

Conclusion

The first year of the PhysTEC program at the University of Minnesota was successful, well received, and smoothly implemented. As the program moves further into this academic year and beyond, it will continue to play to its strengths, solicit and incorporate feedback from the LAs, the students, the TAG and the PhysTEC team. As this feedback is evaluated, the program will continue to evolve in an effort to meet the primary goals of the national PhysTEC program: more physics teachers, better prepared physics teachers, and increased retention of existing physics teachers.

Jon Anderson has been teaching physics since 1986 and is currently the Teacher in Residence for the University of Minnesota's PhysTEC program. His diverse experience includes university research experiences through both the REX (Research Explorations) and the RET (Research Experiences for Teachers) programs. Through a Fermilab Teacher Fellowship, he spent the 1999–2000 academic year on sabbatical leave while working as a researcher at the D0 detector at FNAL. He trained as a QuarkNet Lead Teacher in 2002 and has used that training to conduct annual multi-day workshops for science teachers at the U of M addressing the implementation of particle physics topics into high school science courses.

Non-Physics Teachers Are Teaching Physics–We Cannot Replace Them, But We Can Help Them!

Marty Alderman

Fact #1: Non-physics teachers are teaching physics.
Fact #2: Fact #1 is usually (not always) a bad thing.
Fact #3: Fact #1 is not likely to change … ever!

That is a rather depressing way to introduce this article, but it is true. I propose to explain why it is true, in spite of the best efforts of well thought out programs like those in PhysTEC and UTeach. I will suggest an additional program goal for PhysTEC and similar programs, and will also suggest goals relating to this topic for all working physics teachers.

While the development of a course master schedule and the associated staffing in public high schools, colleges, and universities undoubtedly share some characteristics, it is not something most faculty think about beyond noting, generally with dismay, the size of their classes and their number of preps.[1] The course staffing process is important to this discussion, and a sample public high school staffing process works as follows:

1. In the late winter, each science teacher presents course options (e.g. physics at various levels of difficulty, AP courses, or other electives) to her/his students. If possible, the physics teacher will visit other science teachers' classes and do a brief marketing pitch with an engaging demonstration.
2. Each student prepares a proposed course list for the following year, and the current science teacher signs off on the appropriateness of the request or recommends a more appropriate placement.
3. The counseling office tallies student course requests and forwards the results to the principal.
4. The district administration informs the principal of the total staffing he/she will have available in the coming year based on projected student population and without regard to specific subject area.
5. The principal prepares a sectioning list based primarily on student course requests, class size limitations, and whole-school staffing limitations. While a specific department staff size might be considered in this process, specific teachers and their certifications generally are not.
6. The principal will negotiate for additional staffing as needed, and district level administration will negotiate for cost constraint in the sectioning list, resulting in minor sectioning list adjustments.
7. The principal and department chairperson will 'fight' a bit over class sizes and final sectioning is determined.
8. Finally, the department chairperson works out teacher assignments within the now-fixed sectioning as well as possible in accordance with certifications.

In most states, teachers are allowed to teach a certain percentage of their day outside of their certification areas. This is where the non-physics teachers teaching physics generally occurs. The other common out-of-certification-area teaching occurs in unregulated private schools and will be discussed later.

The Large School Issue

The odds against the number of sections of particular course offerings exactly matching the teaching loads and certification areas of all the teachers in a school are substantial. Couple that with year-to-year fluctuations in demand, and it is easy to understand why there is generally one or two 'extra' sections of science courses that need to be staffed and lead to multiple preps for teachers. Such sections are ideally staffed by teachers with more than one certification area, but there are not enough multiply certified teachers of physics to meet the demand, and in the effort

1 A 'prep' is a class period requiring preparation which is distinct from other class periods. A teacher might have four class groups/day in only one level of physics class with a lab period every other day resulting in 1.5 preps/day filling the 6 teaching periods. A teacher with a mix of physics and chemistry, both with labs, <u>and</u> a mix of levels has 6 preps/day in the 6 teaching periods and has a much more difficult teaching assignment!

to raise standards, states are making multiple certification even more difficult.

One solution would be to hire part-time science teachers, but it is almost impossible. Retirees, while an obvious source, are often severely limited in the amount they can earn in an in-state public school system and continue to receive full pension. Even if this were not an issue (the law could be changed), schools are reticent to pay what veteran teachers cost in a time when they are offering attractive retirement incentives in the effort to cut budgets. Virtually all newly certified science teachers are seeking full time employment. If they do not find the public school position they want in the region they want, they can do better, financially, teaching full time in a private or parochial school than by teaching part time in a public school.

The unavoidable fact: Large schools will often have some physics classes taught by 'non-physics' science teachers. Teachers in public schools can and do legally teach a portion of their schedules outside their certification areas in most states.

The Small School Issue

I believe this is even more common than the large school situation. There is simply not sufficient demand in small, mostly rural schools to warrant multiple sections of physics. For a variety of (misguided) reasons, counselors often fail to encourage students to take all four core sciences at some level. It is common for science teachers to argue with parents, counselors and students' peers who tell students they don't **need** physics.

A new aspect of this is the Small Schools Movement, which argues that 'Small Is Better' and divides larger schools into smaller units. It is unclear how popular the Small Schools Movement is likely to become, but it seems to be quite popular in some areas. To site an interesting example, there are some schools in New York City where *each floor* of the formerly single large-building school is now a fully autonomous school unit with its own administration and staff. While there are certainly benefits to be had from such small schools, one byproduct is that more science teachers (and other teachers, as well) have multiple preps and more teachers are working outside of their certification areas during a portion of their day. If science teachers were shared among these single-floor schools, then the multiple prep and teaching out of certification area issues could at least partially be resolved in this example. If each floor-school has one section of physics, then one fully certified physics teacher shared among 4 single-floor schools sounds like a wonderful, if logistically non-ideal, option. Sharing of teachers is not the norm.

There is more to the small school story, but the unavoidable fact is that small schools have the same situation as large schools with some physics classes taught by 'non-physics' science teachers.

The Private or Parochial School Issue

Briefly, this is much like the small school issue with the added complication that private schools are not regulated the way public schools are. Since private and parochial schools do not have the same certification requirements public schools have, physics classes are commonly taught by 'non-physics' science teachers.

The Solutions

PhysTEC and Similar Programs

The Physics Teacher Education Coalition (PhysTEC), as it currently stands, has 5 principal goals:

1. Recruit people into physics teaching.
2. Prepare people to be effective and successful teachers.
3. Integrate people into a system that may or may not currently be prepared to support them.
4. Mentor & support new teachers so they will remain in this difficult career field, and hopefully flourish.
5. Reform physics instruction, consistent with physics education research (PER), in order to make it more effective.

While PhysTEC is supporting many wonderful, creative, and effective efforts to bring more people into physics teaching, they are not specifically designed or intended to address the situation described above. PhysTEC <u>could</u> add a program for this additional goal as part of its continuing effort to test and disseminate new approaches and best practices in physics teaching. Such an effort would encourage targeted content and pedagogical content knowledge (PCK) oriented summer courses for non-physics certified science teachers to help satisfy cognitive needs and encourage high-interest activities to help satisfy affective needs. If the teacher isn't excited about the subject, the students will surely be 'turned-off' to physics! This program would have to be very well promoted, since a teacher who has only one section of physics might be much more inclined to do professional development in her or his primary teaching assignment, which is likely to also be the teacher's primary area of interest.

Professional Development Workshops

Here we have some problems. Lacking hard evidence, it is hard to say, but it seems a person teaching one section of physics and three sections of another science would be more inclined to spend professional development funds on the three section science. That professional development would likely be seen as giving the teacher maximum return on investment *and* more likely be in the subject of his or her passion.

Looking at the professional development provider's side of the issue; the best fully funded professional development opportunities require application and will tend to accept people who teach mostly physics in order to get the most value out of <u>*their*</u>

investment. While this is an understandable position, it does not help resolve the issue of helping non-physics teachers who find themselves teaching a section or two of physics. Recognizing this suggests the need to seek funding, develop, and market programs specifically for these teachers. One hook might be professional development in biophysics, materials science, geophysics, and the like … all with an emphasis on the physics the teachers will need to teach and engaging the teachers where their passion lies. Key to obtaining funding would probably be a commitment from the school administration that the funded teacher would be teaching physics for several years. Such a commitment would make the anticipated return on the professional development investment much more secure and palatable to the funding organization.

The Certified Physics Teacher's Role–Be a Mentor!

Experienced physics-certified teachers are probably the best 'first line' in professional development for non-physics teachers who find themselves teaching physics. It is a shame that satisfaction is the only compensation they routinely get for mentoring people new to physics teaching, but satisfaction is often enough in this line of work. The critical elements here are reaching as many physics-certified teachers as possible, making them aware of the need for their assistance, suggesting ways for them to offer their assistance, and connecting them with the non-physics teachers who need their assistance.

This will not be easy. All teachers are time constrained by the demands of their own work teaching. Most teachers interact well, but not all are cut out to be mentors. First, mentor teachers will need to invite, then encourage, then push people to:

- Attend Physics Alliance[2] meetings
- Attend professional development courses and workshops
- Cornell Institute for Physics Teachers (2-week summer program, 1 day fall workshop, 1 day spring workshop, etc.)
- Arizona State University's Modeling Physics workshops
- Quarknet summer workshops, PTRA workshops, etc.
- Attend meetings of state and national professional organizations and attend sessions in physics … not just in their first certification area. (E.g. APS, AAPT, AIP, NSTA, STANYS, and PSTA)

Next, mentor teachers will need to GUIDE people through the location and use of resources. Awareness is NOT enough! [E.g. ComPADRE, ISLE (Interactive Science Learning Environment) activities, Workshop Physics materials, and Physics Instructional Resource Association (PIRA) materials]

Next, mentor teachers will need to be open to helping teachers in school districts beyond their own, and to take a leading role with little outside motivation. They will need to be open to sharing their materials without waiting to be asked. People will not generally ask for materials, so the mentor should be open to freely offering them.

And finally … the mentor teachers will need to Be Positive! Encourage! Keep the focus on the students, and help the (often reluctant) newbie project a positive vibe!

Non-physics teachers teaching physics can grow into excellent physics teachers if given the right support, or they can sour students to science forever if they are left to flounder. Since there does not appear to be a way to provide fully certified physics teachers to all physics classes, a well thought out program of support and development needs to be provided.

Martin Alderman retired from teaching physics in a Syracuse, NY area high school in 2007 after 30 wonderful years of working with students in class, Science Olympiad, underwater field studies, and more. He spent 11 of those years as Science Department Instructional Specialist (the 1/6 time department chairperson in the high school), served on the district curriculum council, is active in the CNY Physics Alliance, has spent 6 summers co-teaching the Cornell Institute for Physics Teachers, and is now in his second year as Cornell University PhysTEC TIR (Physics Teacher Education Coalition Teacher In Residence). He can be reached at 101 Clark Hall, Cornell University, Ithaca, N.Y. 14853, email: mda35@cornell.edu.

2 'Physics Alliance' is one common name for a regional physics teachers' collaborative group. Generally sponsored by a college or university, such groups meet roughly monthly with a variety of programs ranging from sharing sessions to lectures to discussions to make-and-take equipment building sessions. The Central New York Physics Alliance held at Syracuse University is an excellent example of such a group.

Away from the ivory tower: Real challenges teaching high school physics in an urban environment

Richard Steinberg

For the 2007-08 school year, I took a sabbatical and became a full time high school physics teacher in a public high school in New York City. In preparation, I spent the 2006-07 school year participating in an alternative teacher certification program. As a college professor teaching teacher education courses and standard introductory undergraduate physics courses, both populated by many New York City public school graduates, the experience was illuminating, and a little scary. The respect and admiration that I already had for many wonderful science teachers throughout the city grew even more.

Prior to my sabbatical, from my experiences learning physics I saw the beauty and elegance of the subject matter, often delivered to me by master physicists. From my experiences in education I saw the importance of setting up an environment, both affectively and cognitively, conducive to maximizing learning. From my experiences conducting physics education research I saw the need to understand and address specific difficulties students have learning the subject matter. After my first day teaching high school, I saw that all my experiences meant nothing compared to getting through the day unscathed (literally) and that all that mattered was my students' success on a standardized exam that I was confident correlated little with anything that was important about knowing physics. It is clear that physics teachers are taught physics one way, are taught to teach it another, are told something different still by the school system, and are then put in a room where none of it works. Classroom management, which I will not focus on in this article, is a big part of the challenge, but not all of it.

My experience was in a poor area of Manhattan. Almost all of the students were Black or Hispanic. There were good support services. There were fewer than 25 students in each class and a relatively large proportion of the students eventually end up going to college. However, those that know more about the school system than me tell me that student background, student discipline, and overall challenges were not very different than what is encountered at many New York City public schools. This particular school requires physics though, which allowed me to get to know a full cross section of students. It also presented the challenge that many of the students were not motivated or interested in taking the course.

Challenges with student attitudes, expectations

I came with enthusiasm about teaching, about being with kids, and about having real fun with physics. Nevertheless, I ran into numerous challenges with the way my students approached learning including what appeared to be apathy and laziness. There were obviously many reasons for this, but at least part of it was a learned approach to school where success is based on being told what you are supposed to know and repeating it back on a test. "Is that going to be on the Regents?" "This problem is way too long" (about 10 minutes). "What do I do next?"

Students wanted (more like demanded) to be told exactly how to do things. They were not shy about their expectation of what the teacher's job is. "How am I supposed to know what to do if you don't tell me? Hey (Phil), go build a rocket but I am not going to tell you how." This shout to a friend across the room was in response to me trying to get the student to figure out for himself how to convert 16g to kg after having already shown how to convert 7g.

Even my attempts to bring in fun, interactive learning activities met with mixed success. Much of this was tied to classroom management, such as disengagement during group work, disappearing equipment, and misuse of projectile launchers. However much of it was also the seeming disconnect of how these foreign experiences would help them with the test and an unfamiliarity of how to simply explore ideas and phenomena.

Challenges with student background knowledge, approaches

As I got to really know the kids, I was genuinely impressed that they were smart and capable of thinking at an appropriate level, at least when removed from the typical classroom expectations. When I talked to them about their hobbies, ambitions, or even why they approach my class the way they do, I truly believed that they had all the underlying intelligence needed to succeed.

Nevertheless, I would often see many students struggle with basic skills that I hoped they would have mastered by their junior year of high school. I was disappointed when I asked a class to solve $5x = 80$ and so many came up with $x = 75$. I was even more disappointed when during one lab a group of 4 students (they happened to be a bright and engaged group) measured a volume twice, first 36ml and then 38ml, and then averaged the numbers and came up with 57ml. Student aptitudes with proportional reasoning, interpreting a graph, and reading and understanding grade level text were all problematic.

However, I am confident that they were all smart enough to succeed in the course and that holes in their content and skills background were all addressable. What concerned me more was that they had approaches to thinking in general, and schoolwork in particular, which were flawed. They had an algorithmic approach, sometimes a skillful one and other times not, that seemed devoid of making sense of what they were doing. A careless mistake with a calculator could account for coming up with 57 as the average of 36 and 38, but if the students really understood what an average is and how it is calculated, then they would have realized how ridiculous 57 is. My experience with the students and teachers suggest that the algorithmic approach is institutionalized.

At one point still early in the year, partly out of frustration with the complaints that everything was too hard and partly to make a point, I put one homework assignment on the board that read (verbatim), “A car moves with a constant velocity of 9.5 m/s. What is the velocity of the car?” I was trying to convince them to step back and think as they go. Many students did not do the homework, but more surprising to me was that a few who were trying came and asked for help with this one. One bluntly stated, “I could not do this one because I did not know which formula to use.”

Consistently I tried to emphasize to the students the need to make sense of what is in front of them, but I feel I met with mixed success at best. For example, well into the school year, when I asked a question about the final temperature of a 10g piece of Zn at 71°C placed in 20g of water at 10°C, the few students who attempted to do the math and submit an answer came up with a temperature NOT between 10°C and 71°C. All signs suggest that rote algorithmic skills without an understanding of the underlying concepts and ideas is not only fleeting, but fosters an approach to schoolwork where students look to be told the algorithm and not make any meaningful sense of the material being studied.

Challenges with the emphasis on standardized, short answer exams

To the students and the principal alike, it is all about the Regents, an essentially short answer standardized exam given throughout New York at the end of the year in the different high school subjects. The physics Regents covers a breadth of material that is well beyond what is capable of being understood by my college engineering students in a year. My college students have the benefit of having been selected as the most able and motivated of the New York City high school students and also have considerably more science and math background. For the Regents, students are given the physics reference tables, which are tables of formulae and other information provided with the intent that students need not memorize to succeed. However, even the good students see the reference tables as a means of obtaining an answer to a question irrelevant to an understanding of the basic ideas.

Late in the year, I put on a quiz the following question, which is an actual Physics Regents question:

The tau neutrino, the muon neutrino, and the electron neutrino are all:

A. leptons B. hadrons C. baryons D. mesons

82% of the students answered this question correctly. I could not help but juxtapose this result with these same students struggling to average 2 numbers, read a graph, or know how fast a bus is going when they are told how fast the bus is going. As far as I am concerned, my students were not given the chance to learn the difference between a neutrino and Newfoundland and the 82% “success rate” is a grossly misrepresentative measure of my students understanding of anything.

In working towards giving my students the chance to see that physics is something that is understandable, something that can make sense, something they can do, I gave them an independent in-class worksheet with 10 questions in the domain of physics. All could be answered without relying on the formalism from class or the reference tables. (See Figure 1 for sample questions.) However, there were 2 versions. The questions were identical, but the instructions were different. One set of instructions read:

> *“Use your reference tables to answer the following questions. Show all work including the equation and substitution with units.”*

This is the language used on the Regents exam. The other set of instructions read:

> *“In answering the following questions, do NOT use your reference tables. Answer the questions how you would have answered them had you never taken a physics class. Explain how you determined your answers.”*

The results are hard to interpret because of the number of students who put their heads on their desks for the entire time and because of students such as the one with the second set of instructions who handed in a mostly blank worksheet and told me “I do not know how to do this without the reference tables.” Nevertheless, I did see some alarming trends. Figure 2 shows the overall correct response rate for the 2 sample questions in Figure 1. Not only was the success rate higher for the students who were asked to pretend they never had physics, they went about attempting the problem more sensibly than students who were asked to use their reference tables. (See Figure 3 for representative responses for the first question.)

•A truck starting from rest accelerates at a rate of 5 miles per hour each second for 4 seconds. What is the final velocity of the truck?

•A 60cm nichrome wire is used to connect a 15Ω resistor to a battery causing a current of 4 Amperes. If the 60cm nichrome wire is replaced with a 30cm nichrome wire, will the current increase, decrease, or remain the same?

Figure 1: Sample worksheet questions. Half the students were given instructions to use the reference tables and the other half were told to answer as if they had never taken a physics class.

	with reference tables	Pretending to have never taken physics
accelerating truck question	51%	59%
nichrome wire question	37%	63%

Figure 2: Percentage of students who answered the two questions shown in Figure 1 correctly for each version of the directions

(Some) successes

It is distressing that after approximately 150 hours teaching physics to the same group of kids that I failed to make meaningful headway with so many of them; however, I saw how that does not have to be the case. One of my colleagues in biology did an enormous amount of project-based learning. His students chose, designed, and executed projects where they actually did and learned science. They went to class in a room filled with things growing, swimming, and smelling. One of my colleagues in social studies had his students read original historical documents and contrast points of view of different figures of the time. His students had lively relevant debates during class time. Even I had some successes. For whatever reason, students had a real good time playing with scotch tape and learned a foundation for electrical charge. Some students enjoyed the whole year and the way I taught physics enough to openly enjoy and value the experience. I felt genuinely good about what could happen.

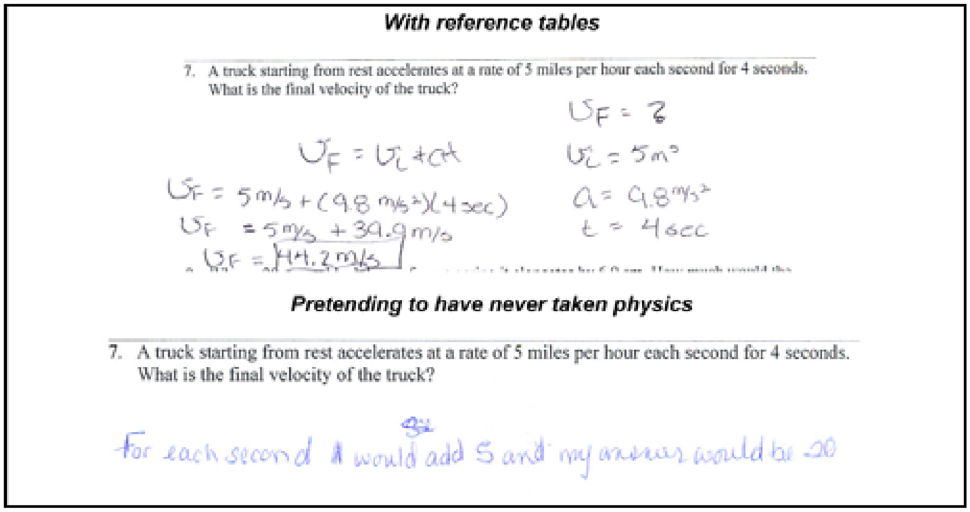


Figure 3: Sample student responses to accelerating truck questions for each version of the worksheet directions

After an exhausting and trying year, I was asked if I want to do it again. My feeling right now is definitely yes (assuming I could convince my wife to let me). I see that it is possible to work around the system and make a meaningful difference in something that is of such great importance. I just wish we could rethink the system.

Richard Steinberg is a Professor in the School of Education and the Department of Physics and Program Head of Science Education at City College of New York. Results described here are being prepared for publication.

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