APS physics

Forum on Education

American Physical Society

Summer 2008 Newsletter

Larry Woolf, Editor

IN THIS ISSUE

From the Chair, Ernest Malamud 2
From the Editor, Larry Woolf 3

Announcements

Forum on Education News 4
Video Analysis Workshops for College and University Faculty, Robert Teese 4
Introducing ALPhA, Michael Crescimanno 5
New Web-Based Collection of Open Source Physics Resources, Bruce Mason 5

Articles

Physics Textbook Writing: Medieval, Monastic Mimicry, Craig Bohren 5
Thoughts about the Career of a Graduating PhD in Physics, Martin Gutzwiller 8
The APS/AAPT Conference on Graduate Education in Physics, Janet Tate 11
Information Fluency and Physics Curriculum: Faculty/Librarian Collaboration, Pat Viele 12
Computer-based Tutorials to Develop Expertise in Introductory Physics Students, Chandralekha Singh 13
From the Desk of the NIH Director: Special Edition on Science Education, Elias A. Zerhouni, 16

APS March and April 2008 Session Summaries

Invited Education Sessions at the 2008 APS March Meeting

Undergraduate Nanotechnology and Materials Education I, Larry Woolf 18
Undergraduate Nanotechnology and Materials Education II, Peter Collings 19
Physics Demonstrations and Strategies for Teaching and Public Outreach, James McGuire 20

Invited Education Sessions at the 2008 APS April Meeting

How to Communicate Physics to the General Public using Books and Articles, Art Hobson 21
Physics Demonstrations and Strategies for Teaching and Public Outreach, Jack Wiegers 21
Undergraduate Education in Nuclear Physics, Conrad Beausan 22
The US Particle Accelerator School, Ernest Malamud 23
Why We Should Double the Number of Undergraduate Degrees in Physics, Ted Hodapp 23
Excellence in Physics Education Award, Larry Woolf 24
Programs to Prepare Teaching Assistants to Teach, Peter Shaffer 25

Teacher Preparation Section

From the Editor of the Teacher Preparation Section, John Stewart 25
2008 PTEC Confererence: Master Teachers: Change Agents for Teacher Preparation, Gabe Popkin 26
Doing the Right Thing (and in the Right Place): Starting a Teacher Preparation Program at a Research University, Laurie E. McNeil 27
Improving Physics Education through a Diverse Research and Learning Community at Florida International University, Laird Kramer, Eric Brewe, and George O'Brien 29
Contributing to Teacher Preparation through "Broader Impacts" Activities, Monica Plisch 32

Executive Committee of the Forum on Education 34

A Message from the Chair

Ernest Malamud

The Forum on Education (FEd) is doing well. We just passed a milestone. Somewhat over 10% of the total APS membership belongs to the Forum on Education and that percentage is increasing. We now have over 4,600 members. I believe this represents increasing interest and involvement in efforts to improve physics education by APS members.

Larry Woolf, Editor of this issue, is breaking new ground. Recognizing that only a fraction of our large membership is able to attend FEd sessions at the APS spring meetings, Larry is giving these excellent and interesting talks a wider distribution. Brief session descriptions in this newsletter are linked to the talks themselves. We would welcome your feedback on whether you feel this should become a regular feature of our summer newsletter.

Where do our members come from?

Of 4,688 FEd members, 604 (13%) are foreign members and 4,084 (87%) are domestic members. We have members from 69 different countries and there are FEd members in all 50 states (plus Puerto Rico and Washington DC). This resource could be mustered in a campaign addressing a particular physics education issue.

Let's look in more detail at the 84% of our members who indicate affiliation (the other 16% are labeled in the APS database as "no company provided"). We have members from 1,241 different institutions. I was surprised at how many different institutions are represented. Many institutions have only one FEd member. Here is an opportunity for you to help increase our membership by talking to your colleagues and suggesting that they join the FEd.

The table shows a further breakdown and a comparison with the APS as a whole.

Type of Institution	APS Members	%	FEd Members	%
Company	3,140	8.6 %	242	6.2 %
Government	789	2.1 %	57	1.5 %
Laboratory	5,025	13.7 %	326	8.4 %
University	27,737	75.6 %	3,246	83.9 %
TOTAL	**36,691**		**3,871**	

It is not surprising that the academia percent is higher than for APS as a whole. More FEd membership from companies (primarily industry) would be welcome. Industry has a vital interest in the development of a technically trained and scientifically literate work force and many industries run excellent outreach programs. Should we have a member drive aimed specifically at APS members who work in industry?

Perhaps we should also strive to increase our membership in the national labs who run a wealth of public outreach programs. There are even smaller numbers from Science Centers, reflecting, of course, the small number of APS members in these institutions. Nevertheless, a great deal of informal science education and outreach takes place in science centers especially aimed at middle school children and the general public, so it would be useful to have more members from that segment of the education community.

Sessions at Meetings

The FEd has developed a strong presence at the APS spring meetings. At the March 2008 meeting in New Orleans we had three invited paper sessions, one focus session and one contributed paper session. At the April Meeting in St. Louis the totals were three invited sessions and four additional invited sessions co-sponsored with other units, two focus sessions, and two contributed paper sessions. In addition at both meetings there were interesting posters. With the convenience of short session summaries and links in this newsletter, I hope you take the time to browse through these talks. You may find items of interest and of use to you.

In 2009 FEd members will gather at two APS spring meetings: March 16-20, 2009 in Pittsburgh and May 2-5, 2009 in Denver. We are looking forward to a great set of sessions that will attract involved and participating audiences. The sessions will cover the wide range of topics that comprise physics education. Peter Collings, our Program Committee Chair for the 2009 spring meetings, will welcome your suggestions.

Areas of interest to FEd members

Members of the APS Forum on Education (FEd) are physicists with interests in all aspects of Physics Education. These include improving instruction at the K-12, undergraduate and graduate levels, teacher preparation programs, physics education research, physics on the road programs that bring physics to local communities, education outreach and informal science education. Members of the Forum are active in the joint APS/AAPT initiative to double the number of undergraduate physics degrees. My own background is in informal science education; I am the founding director of a successful hands-on science center, SciTech, in Aurora, Illinois. During the next year I personally will emphasize sharing of ideas and approaches between the important sectors of our physics education community that do outreach programs.

Working with AAPT

We will continue to work closely with AAPT. I am pleased at the effort begun by Wolfgang Christian when he was FEd Chair to

have an invited or plenary session once a year at an AAPT meeting, jointly sponsored by an APS Division and the FEd. This began in 2004 with a DPB/FEd session at the summer AAPT meeting in Sacramento, which I put together, and then continued in 2005 in Salt Lake City by DAMOP, in 2006 in Syracuse by DNP and most recently with DPF presenting talks at the AAPT winter meeting in Baltimore. We look forward to continuing this tradition with a session at the July 2009 AAPT meeting in Ann Arbor sponsored jointly by DPP and the FEd.

Become involved

There are many ways to join 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 and 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.

Kudos

• Congratulations to Paula Heron, Lillian McDermott, and Peter Shaffer for winning this year's Excellence in Physics Education Award and to our two new APS Fellows: Paula Heron and Luz Martinez-Miranda.

• Thanks to David Haase for his leadership of the Forum the past year.

• Special thanks to our hard-working Secretary-Treasurer Bruce Mason, who has been elected to a second three-year term. The Secretary-Treasurer is the key to a well-run APS unit.

• And thanks to outgoing members of the Executive Committee for their important contributions.

I look forward to working with all of you to strengthen physics education in our country.

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

Larry Woolf

The goal of the Forum on Education (FEd) newsletter is to provide useful and thought-provoking articles over a wide range of physics education topics. To that end, this issue includes articles ranging from computer based tutorials for introductory physics students to errors propagated in physics textbooks, from information literacy to education outreach, as well as two very different perspectives on the graduate education of a physicist: a summary of a conference on graduate education and a personal reflection based on a varied life in industrial physics. Standard fare will also be recognized including an article from the chair, announcements, Forum on Education news, and articles on teacher preparation.

The FEd encourages submissions of articles or letters about physics education topics of concern to members, and there are a variety of pathways that are exemplified in this newsletter. Pat Viele expressed concern about information literacy in physics education to FEd members and was then invited to write an article. Similarly, an article by Chandralekha Singh is included because she informed us of her desire to share her tutorial efforts. Each of the other articles has their own story. As a major fan of Craig Bohren's popular books as well as textbooks, all of which are truly unique, I asked that he write an article about his views on textbooks. After finding his letter to the editor in the March 2008 issue of Physics Today thought provoking, I requested that Martin Gutzwiller expand on his thoughts. FEd executive committee members suggested that I ask Janet Tate to review the results of the conference on graduate education. The final article is a reprinting of an inspirational memo by the National Institutes of Health (NIH) director, Elias A. Zerhouni, to all NIH grant recipients about education resources and roles scientists can play in revitalizing K-12 science education. This memo includes a discussion of a wonderful guide for scientists *(Scientists in Science Education)* who want to become involved in K-12 education outreach. This guide is a greatly expanded version of an article that appeared in the Fall 1998 FEd newsletter and is one of the most downloaded files from the newsletter archive. So if you have ideas for articles or letters, or would like to suggest others whose opinions, programs, or experiences would be appropriate for future newsletters, please contact one of the newsletter editors.

One of the main roles of the Forum on Education is to organize physics education related sessions at the March and April meetings. However, only those who attend the sessions learn about the results presented. To increase the diffusion of this information, I asked each FEd invited session organizer to write a summary of their session and to request that their presenters provide an electronic version of their presentation. I am grateful to all of the session organizers and presenters for spending the time and effort to provide these. (Not all presentations are represented either because of the desire of the presenter not to post

their presentation, or because there was no electronic version used.) So if you could not attend a session or a meeting, you can now read about the session as well as view the slides presented in most of the presentations. Whether this new feature becomes a staple, expands, or contracts in future summer newsletters will depend on feedback from FEd members as well as the desire of future newsletter editors.

Larry Woolf (Larry.Woolf@ga.com) is a materials/optical physicist and program manager at General Atomics and the vice-chair of the FEd. He has been active in many aspects of K-12 science education outreach and curriculum development for over 15 years. For more details, see: < http://www.sci-ed-ga.org >

Forum on Education News

FEd Program Committee

If you have suggestions for topics for FEd sessions at the March or April 2009 meetings, please contact Peter Collings (pcollin1@swarthmore.edu), chair of the Program Committee, as soon as possible.

FEd Nominating Committee

If you would like to become a member of the FEd Nominating Committee, which nominates candidates for the FEd Executive Committee or would like to nominate someone to be a candidate for the FEd executive committee, please contact Ernest Malamud, chair of the Nominating Committee, at Malamud@foothill.net.

FEd Fellowships

Each year the Forum on Education nominates APS members for Fellowship. If you have a colleague who has in their career made substantive developments in Physics Education (undergraduate, graduate, K-12, informal science education, mentoring, education policy, textbooks, etc.) please consider nominating her or him for Fellowship.

The Fellowship website, with information and instructions, is http://www.aps.org/programs/honors/fellowships/ The next deadline for Fellowship nominations will be in late March or early April, 2009.

The members of the 2008 FEd Fellowship committee are:

Paula Heron, University of Washington
Luz Martinez-Miranda, University of Maryland
Bruce Sherwood, North Carolina State University
Howard Matis, Lawrence Berkeley Laboratory
David Haase, North Carolina State University (chair)

Video Analysis Workshops for College and University Faculty

Bob Teese

Students find video capture and analysis both educational and compelling. Current video analysis tools are powerful as well as educationally effective for advanced physics majors as well as introductory physics students.

The LivePhoto Physics project is offering NSF-funded workshops for university and college faculty interested in using digital video analysis in student research, lectures, tutorials, homework assignments, and laboratories. These 3-day and 5-day workshops will cover capture and analysis techniques for a range of topic areas such as mechanics, thermal physics, wave propagation, electricity, magnetism, and optics. In addition, the literature on the impact of digital video analysis on student learning will be reviewed. A collection of video-based curricular materials and video clips will be provided to participants. Follow-up activities and on-line communication will allow participants to share videos, activities and ideas for teaching.

There will be no tuition or fees. Room and board for faculty and instructional staff from US institutions will be provided, and those with demonstrated need may also apply for travel grants. The workshop leaders are Bob Teese (Rochester Institute of Technology), Priscilla Laws (Dickinson College), Pat Cooney, and Maxine Willis.

Three-day workshops will be held **July 16-18, 2008** in Edmonton, Alberta, Canada and in **July, 2009** in **Ann Arbor, MI**. A **five-day workshop** will be held **June 8-12, 2009** in **Rochester, NY**. **For more information**, visit http://livephoto.rit.edu/workshops/.

Robert Teese (rbtsps@rit.edu) is in the Department of Physics at the Rochester Institute of Technology.

Introducing ALPhA

Michael Crescimanno

Developing a 'new' (for your institution) undergraduate laboratory experiment? Updating an old one? Have few or many years experience with the advanced laboratory? Now you have a national community of know-how and experience behind you. That, in short, is the Advanced Laboratory in Physics Association, otherwise known as ALPhA. Our community is a warehouse of tried and true best practices in experiment and pedagogy. Come and be part of the exchange by joining the searchable listserv and other materials that can be obtained through the ALPhA website http://www.advlab.org/ and that are also listed under comPADRE at http://www.compadre.org/AdvLabs/.

Information on ALPhA may also be obtained from Professor Gabe Spalding, ALPhA President (Illinois Wesleyan University) at gspaldin@titan.iwu.edu, or from Professor Steve Wonnell, ALPhA Treasurer & Webmaster (Johns Hopkins University) at Wonnell@pha.jhu.edu.

Michael Crescimanno (mcrescim@cc.ysu.edu) is in the Department of Physics and Astronomy at Youngstown State University.

New Web-Based Collection of Open Source Physics (OSP) Resources

Bruce Mason

The Open Source Physics (OSP) project and the ComPADRE digital library are pleased to announce the creation of a new web-based collection of OSP resources. The OSP Collection provides curriculum resources that engage students in physics, computation, and computer modeling. Computational physics and computer modeling provide students with new ways to understand, describe, explain, and predict physical phenomena. The materials in the collection connect computational simulations, models, and tools with curricular resources. Registered users of the library (registration is free) can build personal collections of materials, comment on resources, and submit materials for consideration by the OSP Editors.

The OSP collection can be viewed at http://www.compadre.org/osp. More information about the Open Source Physics project is available at http://www.opensourcephysics.org/. OSP is supported in part by NSF grants DUE-0126439 and DUE-0442481, and ComPADRE is supported in part by NSF grants DUE-0226192 and DUE-0532798.

Bruce Mason (bmason@ou.edu) is in the Department of Physics and Astronomy at the University of Oklahoma and is the Secretary-Treasurer of the Forum on Education

Physics Textbook Writing: Medieval, Monastic Mimicry

Craig Bohren

Abstract: Textbooks taken in the round are repositories of errors faithfully transmitted from generation to generation. For example, erroneous statements about the speed of light and supposed limitations on the refractive index and its dependence on mass density are pervasive. The history of science in textbooks often bears little resemblance to actual history. The more elementary the textbook, the more scrupulous and knowledgeable its authors must be because most beginning students cannot be expected to know when they are being fed scientific or historical piffle, for which there is no excuse given the several journals devoted to exposition and criticism and the historical resources readily available on the Internet.

The best advice to anyone who would write a physics textbook, especially an introductory textbook, is to adopt the working hypothesis that everything in previous textbooks is wrong. But that is not what usually is done. Like a medieval monk cloistered in a cell decorating illuminated manuscripts but leaving dogma intact, the writer of textbook *N* dutifully copies what is in textbook *N*-1, adding a few arabesques but blithely transmitting errors unto the *N*th generation. This advice may seem extreme so I'll soften it a bit by saying that almost every assertion in textbooks in the form of an invariable, unqualified mantra, especially if it asserts supposed limits, is wrong. And the more times the mantra is repeated in print, the more likely it is to be wrong. There are so many examples that it is difficult to know where to begin, but among my favorites are erroneous treatments of refractive indices. I won't indict any offending textbooks. You can find them for yourselves. What Stephen Jay Gould (1991, Ch.10) calls the "cloning of contents" because "authors of textbooks copy from other texts and often do not read original sources" is not unique to physics, and he gives an amusing example from evolutionary biology. He notes that "good teaching requires fresh thought…rote copying can only indicate boredom and slipshod practice."

The nearly universal textbook statement is that *c/n* is the "velocity of light" in a medium with refractive index *n*, which must be greater than 1, the implication being that if it were not Einstein would be dethroned. Well *c/n* is not *the* "velocity of light", only

one among many, the *phase velocity* of a plane harmonic wave. Let's set aside that such a wave cannot exist because it would have to occupy all space and exist for all time. The phase velocity cannot be determined by time-of-flight measurements. It is neither the velocity of a palpable object nor of a signal. Leaf through the three-volume compendium of refractive indices edited by Edward Palik (1998) and you will discover that it is nearly impossible to find a material for which n is *not* less than 1 at some frequencies. And these are not exotic materials. Try table salt.

When students stumble on refractive indices less than 1, they sometimes are placated with, "Don't fret. The group velocity can't be greater than c". They don't know what the group velocity is, but invoking it makes them go away. Alas, the cure is worse than the ailment because the group velocity not only can be greater than c, it can be negative and *less* than $-c$. There are in fact many "velocities of light" (Smith 1972, Bloch, 1977).

Anguish over supposedly nonphysical refractive indices less than 1 was laid to rest more than a century ago by Arnold Sommerfeld. English translations of excerpts from his 1907 paper, his entire 1914 paper, and a 1915 paper by Leon Brillouin, are in Brillouin's 1960 book. Although the mathematical analysis in these papers, especially Brillouin's, is formidable, the physical arguments by Sommerfeld, who was reputed to be a superb teacher, can be followed by those innocent of mathematics. He showed that, subject to the restriction of causality—you can't squeal before you are hurt—no *signal* can be transmitted faster than c in any medium. Thus for about a century it has been inexcusable for anyone to assert that n is constrained to be greater than or equal to 1.

This has nothing to do with "negative refractive indices", a better but less newsworthy term for which is "negative phase velocities" (see, e.g., Lakhtakia et al., 2003).

Now let us turn to an even worse textbook botch of refractive indices, the notion that light "slows down" in "denser media". Even Whittaker (1987), in his history of electromagnetic theory, passes this on. On page 11 of Volume 1, in his discussion of Descartes's corpuscular theory of refraction, Whittaker notes that "These equations imply that…the velocity is greater in the…denser medium. As we shall see, this consequence of the corpuscular theory…is in contradiction with experimental facts." No it is not. There is no necessary relation between mass density (or molecular number density) and phase velocity (c/n). This was pointed out more than 50 years ago by E. Scott Barr (1955) in an outstanding expository paper. His message is succinctly, clearly, forcefully, and humorously conveyed with only one figure and its caption: "Does index of refraction vary directly with density?" This figure shows the refractive index (in the visible) of many liquids versus density, the points connected to answer the question in the caption: NO. But Barr didn't go far enough because it is easy to find examples that more dramatically demolish fatuous notions about refractive indices (at a given frequency) being greater the greater the density. My favorite example is gold, the refractive index of which in the visible is about one-fifth that of air despite gold being 20,000 times denser.

The non-existence of a universal monotonic relation between refractive index and density can be understood by coming to grips with the concept of refractive index as a phase-shift parameter. It specifies the difference in phase between two plane harmonic waves with the same frequency and propagated the same distance, one in free space, the other in a material medium. The origin of this phase shift is excitation of *charges* in the medium by an electromagnetic wave. Electromagnetic fields act on charges; masses go along for the ride.

Notions about the proper behavior of refractive indices originated hundreds of years ago when the only light sources were lamps or sunlight, and material samples (e.g., glass, water) were transparent. But generalizing on the basis of a tiny fraction of the electromagnetic spectrum and a restricted class of materials is like pronouncing on the diversity of species solely on the basis of observations made in Kansas.

To criticism that I am unfair because by "denser medium" is meant "optically" denser I have two ripostes. The qualifier "optically" rarely appears, and there is no good reason to redefine refractive index as optical density, especially given the connotations of density and the vagueness of the term optical density [which according to *The MacMillan Dictionary of Measurement* (1994) is an "imprecise term for transmittance"]. Baptizing refractive index as optical density, and then saying that the (phase) velocity of light is lower in an optically denser medium is logically equivalent to saying that the medium with the higher refractive index has a higher refractive index. True, but not very profound.

Our illustrious predecessors cannot be blamed for arguing about whether light slows down or speeds up in denser media. They didn't know better. But we do—or should. This is a controversy to be buried along with the ether and phlogiston, not kept alive in textbooks except as a scientific curiosity, a pothole on the road to understanding.

When it comes to the history of science as presented in textbooks, error propagation is rife. Any historian of science can attest that the history of physics in textbooks is mostly, as Henry Ford said, "bunk". To be fair, it often is very difficult to determine who did what first, and hence attribution of laws, constants, theorems, and measurements is almost always wrong. This inspired Stigler's (1999, Ch. 14) law of eponymy, "No scientific discovery is named after its original discoverer", and Rothman's (2003, p.xiii) "Infinite Chain of Priority: Somebody Else Always Did it First". For example, who first determined the law of refraction. Harriot, Descartes, Snel? They were latecomers, preceded by around 600 years by Ibn Sahl (Rashed, 1990). Many results of geometrical optics are 17th century rediscoveries of what was known to Arab scientists 1000 years ago.

Readers may be shocked by my apparent misspelling of Snel. As it happens, this is the correct spelling, easily verified with the *Dictionary of Scientific Biography.* Why has Snel been misspelled Snell tens of thousands of times? Monastic copyists at work again.

Although it is excusable to get attributions wrong, it is not to pass on what you have not read yourself. For what it is worth, I cannot recall a single instance in which I read in a textbook that scientists said something, only to discover in their original papers that they did not. Again, a few examples will suffice. To judge by textbooks the equations of the electromagnetic field were written down in their present form by Maxwell. Yet if he were to rise from the dead and be presented with his eponymous equations he would not recognize them. They are the work of Oliver Heaviside (see e.g., Nahin, 2002). But a truly egregious example of rewriting history is Newton's law of cooling in the form, $qh\Delta T$,where q is the energy flux, h the "heat transfer coefficient" and ΔT a temperature difference. I have seen books in which not only is this called Newton's law of cooling, he is cited. So I read the cited reference and discovered that Newton's law of cooling according to Newton is an exponential decrease of temperature with time of a cooling body, which can be obtained (but was not by Newton) from this supposed law by making several assumptions and approximations (Bohren, 1991). And this equation incorrectly attributed to Newton and called a law is worse than merely historically inaccurate. Unless accompanied by conditions on h, it is not a law (i.e., verifiable) but rather a *definition* of h. Because of this and many other experiences, I do not believe any historical statements in textbooks even if accompanied by complete bibliographical information or even direct quotations until I have verified them for myself. I have been deceived too many times.

Given the ready availability of the multi-volume *Dictionary of Scientific Biography*, contributors to which are not infallible but at least take pride and care in their entries, and the Internet, where one can find many classical scientific papers, there is no excuse for historical bosh in textbooks. Their authors are under no obligation to spice them up with historical tidbits, but if they choose to do so, they have an obligation to get them right. And they also have an obligation to be honest, to note that almost all scientific discoveries were *not* made by a single scientist. Who gets the credit depends to a large extent on luck, timing, publicity, and nationalism. The electron, for example, had many fathers, despite which J. J. Thomson is lauded as its sole discoverer. Yet "the electron was not discovered by any particular scientist…Several physicists, theoreticians and experimentalists provided evidence that supported the electron hypothesis" (Arbatzis, 2001, p. 188). The norm in science is multiple origins in space and time of discoveries. Moreover, new ideas are not instantaneously accepted because of alleged crucial experiments. But you'd never gather this from the potted histories in textbooks.

There is no excuse for not getting most of the physics right given the many years of publication of journals such as *American Journal of Physics*, *European Journal of Physics*, *The Physics Teacher*, and *Journal of Chemical Education*. Many papers in these journals are devoted to exposing and criticizing textbook errors. One outstanding example is by Gearhart (1996), who finds that only 6 out of 27 introductory textbooks treat the specific heats of gases and the equipartition theorem correctly. And a remarkably perceptive and thorough criticism of textbook presentations of the photoelectric effect is given by Leadstone (1990), whose sentiments echo my own: "Textbook inadequacies are the rule rather than the exception, and continue to be propagated with remarkable fidelity." In the same collection a superb essay by French on the role of history in physics teaching includes a figure showing the steady decrease in received frequency of a signal from Sputnik I as it passed overhead, neatly refuting yet another blunder portraying the Doppler effect as an increase followed by a decrease of frequency.

Contrary to what one might think, the more elementary the textbook the more scrupulous and knowledgeable their authors must be. Much time must be spent carefully reading many papers, including (gasp!) original papers of historical importance, weighing each word, being careful not to teach anything that later has to be untaught. Readers of technical monographs can be expected to fend for themselves. But in writing an introductory textbook, authors should keep in mind the words of Thomas Cardinal Wolsey: "Be very, very careful what you put into that head, because you will never ever get it out." That "head" belonged to Henry VIII, but also likely belongs to most beginning students.

References

1. Arbatzis, Theordore, 2001: The Zeeman effect and the discovery of the electron, in *Histories of the Electron*, Jed Z. Buchwald and Andrew Warwick (Eds.), MIT Press.

2. Barr, E. Scott, 1955: Concerning index of refraction and density. *American Journal of Physics*, 23, 623-624.

3. Bloch, S. C., 1977: Eighth velocity of light. *American Journal of Physics*, 45, 538-549

4. Bohren, Craig F., 1991: Comment on "Newton's law of cooling—a critical assessment" by Colm T. O'Sullivan [*Am. J. Phys.*, 58, 956-960 (1990)]. *American Journal of Physics*, 50, 1044-1046.

5. Brillouin, Leon, 1960: *Wave Propagation and Group Velocity*. Academic Press, New York.

6. French, A. P., 1990: The role of history in physics teaching, in *Physicists Look Back: Studies in the History of Physics*. John Roche (Ed.), Adam Hilger, Bristol.

7. Gearhart, Clayton A., 1996: Specific heats and the equipartition law in introductory textbooks. *American Journal of Physics*, 18, 213-221.

8. Gould, Stephen Jay, 1991: *Bully for Brontosaurus*. W. W. Norton, New York.

9. Lakhtakia, Akhlesh, Martin W. McCall, and Werner S. Weiglhofer, 2003: *Negative phase-velocity mediums, in Introduction to Complex Mediums for Optics and Electromagnetics*, Werner

S. Weiglhofer and Akhlesh Lakhtakia (Eds.), SPIE Press, Bellingham, Washington.

10. Leadstone, Stuart, 1990: The photoelectric effect—a suitable case for surgery?, in *Physicists Look Back: Studies in the History of Physics*. John Roche (Ed.), Adam Hilger, Bristol.

11. Nahin, Paul J., 2002: *Oliver Heaviside*. Johns Hopkins University Press, Baltimore, Maryland.

12. Palik, Edward D. (Ed), 1998: *Handbook of Optical Constants of Solids*. Academic, San Diego.

13. Rashed, Roshdi, 1990: A pioneer in anaclastics: Ibn Sahl on burning mirrors and lenses. *Isis*, 81, 464-491.

14. Rothman, Tony, 2003: *Everything's Relative and Other Fables from Science and Technology*, John Wiley & Sons.

15. Smith, Richard L, 1970: The velocities of light. *American Journal of Physics,* 38, 978-984.

16. Stigler, Stephen M., 1999: *Statistics on the Table*. Harvard University Press.

17. Whittaker, Edmund, 1987: *A History of the Theories of Aether and Electricity: I. The Classical Theories*. Tomash/ American Institute of Physics.

Craig F. Bohren is Distinguished Professor Emeritus of Meteorology, Pennsylvania State University, the co-author (with Donald Huffman) of Absorption and Scattering of Light by Small Particles, (with Eugene Clothiaux) Fundamentals of Atmospheric Radiation, (with Bruce Albrecht) Atmospheric Thermodynamics, and the author of two popular science books, Clouds in a Glass of Beer *and* What Light Through Yonder Window Breaks? *bohren@ems.psu.edu*.

Thoughts about the Career of a Graduating PhD in Physics

Martin C. Gutzwiller

Abstract: The preparation for the PhD in physics seems quite narrow for various reasons. It is then essential for the student to experience scientific life not only in a different environment, but also in another area of physics.

The education of a young scientist is well defined. The minimum is 4 years of undergraduate and at least 4 years of graduate studies, to be completed with a PhD thesis. Its theme is generally suggested and then supervised by a professor who is a specialist in the matter. Nowadays the young person will be encouraged to continue his/her work as a post-doctoral researcher in an available university.

For many physicists, this postdoctoral continuation is repeated several times, until a more permanent (and better paid) job in the same specialty is found. Sometimes it looks as if the main recommendation for such a job is the stubborn pursuit of the main topic in the PhD thesis. My scientific life (from about 1950 to 2000) looks as if I had tried to change my interests in the beginning as often as possible. In spite of the changed conditions in today's physics, I still insist on the great importance for every student to become aware of various special fields, and try out one or two. The work in different areas of physics requires different skills, and the atmosphere in a government or industry laboratory does not compare at all with the universities. A young person has to have some practical experience before deciding her/his lifestyle. The best time is right after the batchelor's degree, without a foregone conclusion to get a PhD thesis. After the PhD degree, a challenging research job for several years will show another part of the world. Teaching in a good university is still accessible when in one's thirties.

The up and down in my scientific life would sound like a self-serving recommendation. But the main reason for my insistence comes from the deep change in the life of physics over the second half of the 20-th century. The Second World War had brought physics in America to the top of the sciences world-wide, no less! Physics departments in the universities, however, and even research in the government laboratories had not increased to the same extent. Industry came to the conclusion that hiring physicists could be quite helpful. Jobs became available in unforeseen areas.

The first event to change all that was "Sputnik", the first artificial satellite to circle the Earth, launched by the Soviet Union in fall 1957. President Eisenhower launched a crash program, and physics got everything it wanted, in jobs and equipment for universities, government, and industry. These sudden movements were soon taken over by European institutions that had recovered from WWII. The 1960's were roaring times "physically", and politically as well! The universities held on stubbornly to their increase.

The second event was not so obvious, but it started toward the end of the 1960's, and settled down in the 1970's. It is more subtle, but very profound. Particle physics was promoted already during WWII to explain the structure of the nuclei. After the war, much bigger accelerators were built in the hope of better understanding the nuclear structure. But by the 1970's any such explanation was beyond the usual theoretical quantum field theory. At the same time the cost of the machines for the necessary experiments ran into unreasonable sums that could be used for other pursuits in the sciences.

Right now, or if a round figure is required, let us say since the year 2000, the foundations of physics seem impenetrable. The big experiment at CERN still hopes to find something understandable. For over 20 years, however, theoretical explanations are off in

some speculative garden where nothing can be secured by experiment. The research toward the deepest foundations in physics has proved to be beyond our human effort. Even the "standard model" for particle physics is beyond mathematical analysis in depth.

For many readers it may look outrageous to interpret the history of physics in this radical way. Such a viewpoint appears more acceptable if physics is compared with its two neighbors on the left, mathematics and astronomy, as well its neighbors on the right, chemistry, geography-geology-geophysics. These four companions have been alive in humanity for thousands of years. Their scientific territories have grown in modern times while remaining in the human sphere of accessibility and interest, quite unlike physics.

The professional life of an individual in the "hard" sciences lasts about 50 years, from age 20 to 70. The student has to absorb the ever increasing knowledge, and to learn the methods as well as invent new ones in the progress of science. Teaching becomes a central and enjoyable occupation, not only daring experiments and grandiose explanations. It is tempting to continue this activity for the remaining life. But modern science requires more than pure knowledge. New ideas have to be worked out, their ramifications explored, possible applications tried out, and connections with other fields established. The usefulness, the cost, the distribution, and perhaps even social consequences have to be evaluated. These additional activities cannot be neglected; they require special talents that demand a grown up person with a wider view of the world.

Unfortunately, all these normal activities for physicists may lead to the most extravagant problems, such as the two main types of atomic bombs, and even to the intense radiation phenomena with their destructive intentions. The more down-to-earth mechanics and thermodynamics, once they got into the hands of the physicists in the 19th century, turned into automated weapons and their horrible results. The number of physicists working in these fields is considerable. By contrast, chemical warfare was limited by the required conventions, although it had been tried a few times.

The professors in physics should occasionally lead their students outside the strict teaching plans. They have to develop a deeper insight and a broader understanding concerning the transition from the "natural philosophy" of Newton to modern "physics." The 19th century ended in the unified concept of electro-magnetism. The idea of the atom had been sponsored by the chemists for a long time, and the physicists finally proved it in their own fashion. Relativity and quantum mechanics then lead to nuclear physics. Particle physics was supposed to explain the structure of the nuclei. But that never happened; since 1950, nuclear physics is a purely empirical science.

In the spring of that year I graduated from the Swiss Federal Institute of Technology in Zurich (ETH of Einstein fame). The year before I had spent 6 months to write the required "Diplom-Arbeit". I had asked Wolfgang Pauli to be my supervisor, and he asked his post-doc, Felix Villars (later at MIT where he started a new program on physics in the life sciences), to discuss my work as needed. I was supposed to calculate the anomalous magnetic moment of the proton-neutron with the coupling by a charged, vectorial pi-meson. After Schwinger and Feynman had obtained the anomalous magnetic moment of the electron, it was natural for a beginning graduate student to try his hand on the proton-neutron problem.

The ETH still lived as before WWII, and was organized like its famous French model. The department of mathematics and physics had 10 full professors of mathematics, 2 in physics (Pauli and Scherer), and 1 in astronomy. They gave all the required courses; quantum mechanics was not taught. I had to learn it from working through some famous textbooks all by myself. Sommerfeld was the easiest, Pauli and Dirac were the hardest. There was plenty of time to study hard, and not to fool yourself, even if you could quote whole sentences. This experience gave me courage and conviction when I had learnt some new specialty of physics. Like a dog, there is pleasure in chewing on a bone to get the finest piece of meat.

After the Diplom, I could have started on a PhD thesis. But there were no scholarships or assistantships available, and I decided to earn some money. I got a job helping to install the first microwave telephone link between Zurich and Geneva. By summer 1951, I got a scholarship at the physics department of the University of Kansas. Max Dresden's first job was there, and I much appreciated the spirit at KU. I continued working in quantum field theory, and was searching for a job in 1953. Although I had an immigration visa, times were not good for foreigners, and I ended up at the geophysical laboratory of Shell Oil Company in Houston, Texas.

Research was dominated by the geologists and the chemists. Publishing any new results was quite limited. Nevertheless the laboratory had a dozen young physicists directly from the universities, where they had done a PhD thesis in an esoteric topic. They were asked to get familiar with down-to-earth problems, and participate in work already on the way. I was asked to study dislocations, well known one-dimensional singularities in a crystal lattice. They are responsible for crystal growth and plastic flow. Calcites and dolomites under high pressure were studied in the laboratory.

After a couple of years, I was asked to get familiar with the magnetism of sedimentary rocks, i.e., very small special crystals inside a non-magnetic rock. Then I got involved in the propagation of waves in layered formations. Of particular interest was dropping a heavy steel plate on a hard dry ground, a time-dependent excitation on a surface with mixed boundary conditions! This was before the times of Fortran, on machines with very poor memories. The on-going experiments had a close relation with these problems.

Another industrial giant, IBM, had opened a research laboratory near Zurich, and I was eager to bring my family back to Switzerland. The freedom of work there was remarkable, and I was allowed to publish some of my results from Houston. Whatever results I now found were to be published, as long as I did not lose myself in esoteric physics. I was inspired to study magnetism in

metals. I formulated the problem as in quantum field theory, with a projection that prevented the electrons from crowding on a lattice site. That idea is still appreciated to explain high-temperature superconductivity.

After 3 years my whole family went back to the USA in 1963. I had a chance to work at the original IBM lab on the campus of Columbia University, and teach a course in the engineering department. I started a new project, when I became convinced that the limit between classical and quantum mechanics had not been properly examined. Feynman had found a method using his path-integral. He had tested it only in very special cases, not even including the H-atom. The most important information for the spectrum were the classical periodic orbits (PO). I was inspired by the founder of the laboratory, an astronomer computing planetary orbits, and particularly the lunar trajectory. It was based on a single PO in a special case of rotating the coordinates with the Sun. The classical PO's produced approximate quantum spectra for various atomic and molecular problems. That led me straight into classical as well as quantum chaos. Chaos and the history of physics and astronomy became my work and hobby until 2000.

This discovery happened as I turned 45, 20 years after my graduation from the ETH. I continued some other work. I mostly enjoyed meeting a whole new bunch of colleagues who found new features and mathematical riddles in quantum chaos. Many have dedicated their lives to this wide open field. I often miss their connection with physics, in favor of an abstract mathematical model. There are also solid–state physicists, chemists and engineers of various kinds, for whom vibrations in some "crooked" body are important. Gadgets of that type are very popular in the effort to miniaturize computers, etc. I enjoy very much talking to them, because it puts me in direct relation with everyday objects.

Frankly, I wish that more of my younger colleagues could also profit from the boom of research in the last 50 years. But the world of physics has changed profoundly. The great industries stopped the boom more than 20 years ago. IBM got rid of many people my age (late 60's) with a mixture of threat and promise (which they have kept now for 15 years!). Progress now comes from highly specialized skills, always directed toward imaginable goals. Shell is hiring geologists and chemists as before, but needs many engineer-scientists with education in special fields and down-to-earth skills. There should be some space for bright young people who want to work.

The boom in the universities had its ups and downs, but the teaching staff has remained very large, whereas the government laboratories are less lucky. Both are hit hard by the second great event in physics of the last 50 years. The short history of physics shows how it concentrated on the very foundations of the hard sciences. This special role for physics has come to a halt now since 30 years. The insight we have gained has led us into a vast morass. Even my short experience with calculating the magnetic moment of the proton in 1949, is still unsolved theoretically, even computationally.

I wonder sometimes how many physics professors in the universities are worried for the future of their students. The boom of the last 50 years has lead into a vast and confusing territory of high-energy particles and all the associated areas like cosmology, both in experiments and theory. Special efforts are required so that the students do not simply hold out for a teaching position at a university. I also wonder sometimes what will happen with physics at extremely low temperatures. It does not require nearly as many people and facilities, and our understanding does not end up in a morass.

A last general impediment for students to find some work is the increasing specialization of their professors. Many have been in the same field for a long time, and their competence in other areas is limited. The list of open jobs each month at the end of Physics Today always gives tight descriptions. What about a list for recent PhD's specifically to work in another field?

I have tried to paint a picture of the present state of physics, historically and philosophically. The consequences for students are not obvious from the attitudes and experiences of their professors. The effective training in a particular specialty creates engineers and technicians rather than individuals with the capacity to work in different areas. The universities have to find ways for broadening the mind of their PhD students, and create opportunities where this aim can be realized. It may be harder now after 50 years of boom with the added difficulty of large areas of physics slowly phasing out.

Martin Gutzwiller is an IBM Research Staff Emeritus, and is an Adjunct Professor of Physics at Yale University. His current interests are physics, history, and philosophy. He can be reached at MoonGutz@aol.com

The APS/AAPT Conference on Graduate Education in Physics

Janet Tate

The Directors of Graduate Studies (DGS) from 70 of the nation's PhD-granting institutions met for a day and a half at the American Center for Physics in College Park, MD in February 2008 to discuss trends and practices in graduate education in physics. Also represented at the conference were several of the professional societies (AAPT, APS, AIP, and the European Physical Society), the NSF, industry, and the Sloan Foundation. Three graduate students from the APS Forum on Graduate Student Affairs also participated to supply the student perspective.

Motivation for such a meeting came from the AAPT/APS Task Force on Graduate Education, whose 2006 report indicated that the physics graduate curriculum has been static for many years, and from the Rising Above the Gathering Storm report in 2005, which sounded alarms about the state of science education in general and the implications for US competitiveness. A survey of Physics DGS indicated that two-thirds of the responding departments are considering or are implementing significant changes to their graduate programs, and that all were very interested in finding out about what works and what doesn't in other departments.

In her remarks during a panel session, APS Executive Director Judy Franz noted that opportunities for graduate study in physics in Europe and Asia are far more exciting and attractive than in the past, which means that the US faces much stronger competition than before. She encouraged departments to be conscious of the diverse careers that physics PhD graduates ultimately pursue, and also to take steps to increase the diversity of students and faculty.

Past AAPT president Ken Heller encouraged participants to "discuss our questions, qualms, and insights," and many of those were aired. One topic of discussion was broadening the core courses to encourage the interdisciplinary research aspirations of students and faculty. Biological physics, as an example, is an exciting field that attracts talented students who are disappointed to find that the traditional physics core delays or even precludes the biology courses they need to pursue their research. Will physics accommodate them, or will they find their homes in a biology-oriented department? Will physics cede "Energy" to environmental sciences? Randy Kamien of the University of Pennsylvania described a remodeled physics program that allows biological physics to flourish.

Question: What do we really teach in those courses with 50-year old names and texts whose first editions are also approaching retirement age? Has the content evolved and is it relevant to modern research? Is the content taught using modern tools and strategies? Regular examination of course content and delivery by departments is essential, and on a national level, a follow-up to this conference would be useful.

Qualm: Do physics graduate programs subtly or even overtly dismiss non-academic career choices as second class? The graduate students thought so, and many faculty wanted to improve the mentoring of students with aspirations outside of academia. Departments can enhance contact with broader physics interests, including encouraging entrepreneurship, fostering student/industry contacts, and inviting non-academic scientists to speak in the department.

Insight: Mentoring and tracking of students, explicit attention to the departmental climate, and providing opportunities for students to develop the communication, interpersonal and teamwork skills that will be essential in any career, are key elements in successful programs. There are many examples of exemplary practices that are being gathered into the final conference report.

Vincent Rodgers of the University of Iowa, noting the abysmal lack of representation of ethnic minorities in the population of physics PhDs, described a program in which highly talented students are brought together for a summer to solve cool physics problems under the dedicated tutelage of physicists like himself. The recipe is simple: challenge students, keep expectations high, provide a supportive and collaborative environment. Good things happen, and step by step, a few new recruits are found. Keivan Stassun described the successful Fisk-Vanderbilt bridge program where students study for the MS degree in a carefully structured collaborative environment at Fisk and are groomed for transition to the PhD program at Vanderbilt. Margaret Murnane of the University of Colorado/JILA reiterated the recommendations of the APS Committee on the Status of Women in Physics to create a climate that is welcoming to women, and stressed that the flexibility and awareness that is necessary achieve this improves the climate for all. She also encouraged broadening the curriculum and throwing out unnecessary hurdles to research progress.

As expected, an important outcome of the conference was the opportunity to connect with peers and exchange ideas and receive that added spur to keep pushing to improve graduate education locally and nationally. The need for regular exchanges among DGS was evident, with participants suggesting a national listserv and convening the Graduate Education in Physics conference every 3-5 years.

The presentations of the slate of speakers and summaries of the discussions are available at the conference website http://www.aps.org/programs/education/conference.cfm, where you will also find resources relating to TA training, ethics courses, diversity issues, and a compilation of comprehensive exam procedures. A formal report will be posted this summer. The conference was partially supported by a grant from the National Science Foundation.

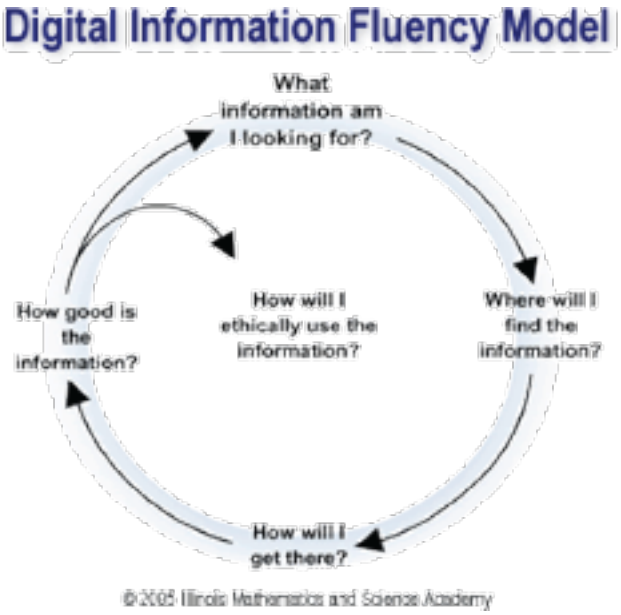
Janet Tate is a Professor in the Department of Physics, Oregon State University, Corvallis, OR 97331-6507. She can be reached at tate@physics.oregonstate.edu

Information Fluency and Physics Curriculum: Faculty/Librarian Collaboration

Pat Viele

Abstract: Much has been written about the importance of information fluency. Information fluency is defined as the ability to locate, evaluate and use information effectively, efficiently and ethically. In this brief article, I will summarize some ways one might add information fluency to the physics curriculum.

They say one picture is worth a thousand words. Below is a graphic that gives one a sense of what information fluency is all about. The diagram is relevant to all information sources, not just digital materials.



No one likes busy work. The most effective way to integrate information fluency into a student's life is to connect lesson plans to a specific subject assignment. Assignments can be as simple as asking students to evaluate a web page or as complex as a semester long seminar class with formal assignments. Lessons can start as early as middle school and go up to graduate level.

A sample of a web page evaluation sheet can be found on eCommons Cornell. (1) Brigham Young University has a formal class called "Writing in Physics" for their senior physics majors who must write a mini-thesis. (2) The physics department at the University of Buffalo asked librarian A. Ben Wagner to design a course for physics graduate students. The class description is included in the poster that I did for the "Graduate Education in Physics: Which Way Forward?" conference (3)

Each state has established its own standards for information fluency. The web site, 21st Century Information Fluency Skills, written by the Illinois Mathematics and Science Academy, is an excellent source of definitions and examples of curriculum. (4)

To better understand the questions that physics faculty have, I monitor several listservs: PHYSOC, OPHUN-L, PHYS-L, and PHYSHARE. One discussion thread was about the difficulties that physics students have dealing with physics word problems. I was able to share with faculty the logical problem solving strategy developed at the University of Minnesota. (5)

Like many institutions, Cornell offers professional development courses for teachers. I am included in the Research Experience for Teachers (RET) and other workshops that are offered by Cornell for science teachers at all levels. I help teachers find and evaluate background information for their lesson plans. The RET participants write up lesson plans that are readily available to all. BUT, unless one knows where to look (6), the lesson plans are lost in cyberspace.

The Professional Concerns Committee for AAPT sponsored a number of cracker barrel discussions for various constituencies. Based on expressed needs, I am gathering web pages that would be useful in addressing the concerns. I have been using Connotea, a free service of the Nature Publishing Group, to facilitate communications among researchers. One can sort the contents of my Connotea page (7) by any of the "tags" or keywords listed on the left side of the screen. For example, I have been collecting materials about women in science, professional development opportunities for physics faculty, and lesson plans. Because physics classes do not typically have a writing component, I have collected some examples of alternative writing assignments on Connotea. A person who is preparing to write a term paper, give a poster session, or an oral presentation on a topic needs to find good information. Information fluency skills can save a lot of time. I have compiled a list of resources that would be helpful in the process of integrating information fluency skills into the physics curriculum. (8)

There are 245 members of the Physics, Astronomy and Mathematics (PAM) section of the Special Libraries Association (SLA). About 650 librarians worldwide belong to the PAM listserv. In many cases, a science librarian must serve faculty and students in several different sciences. Our mission is to support the teaching and research activities of our faculty and students. Our activities include collection development, reference services and instruction. The Internet has changed the information landscape drastically. We librarians participate in initiatives like arXiv, the National Science Digital Library (NSDL), and digital books projects. For example, Cornell University has a collection of digitized mathematics books available on-line. (9) At the annual meeting of SLA in June 2008, Bruce Mason and I will be presenting to the physics round table. Our goal will be to recruit science librarians to reach out to re-

gional groups of APS and AAPT to spread the word about compADRE as well as other excellent on-line materials. Faculty and librarians share many of the same goals. By working together, I feel we can lighten the load and increase effectiveness.

Over the past seven years, I have presented on the topic of information fluency at many AAPT meetings. By working with the Forum on Education, I hope to share what I have learned with a wider audience.

References

1.Viele, Pat. Sample Web Page Evaluation Sheet http://ecommons.library.cornell.edu/handle/1813/1486

2.Brigham Young University PHYSCS 416A Writing in Physics http://gardner.byu.edu/416w/

3.Viele, Pat. Information Fluency and Graduate Physics Education http://www.aps.org/programs/education/upload/Vieleposter.ppt

4. 21st Century Information Fluency Skills http://21cif.imsa.edu/

5. A Logical Problem Solving Strategy http://groups.physics.umn.edu/physed/Research/CRP/psintro.html

6. Teacher Developed Lesson Plans http://www.ccmr.cornell.edu/education/modules/retmodules.html

7. Pat Viele's Connotea Collection http://www.connotea.org/user/pviele

8. Information Fluency and Physics Graduate Students http://ecommons.library.cornell.edu/handle/1813/9442

9. Cornell University digital mathematics books http://astech.library.cornell.edu/ast/math/additional/Digital-Books.cfm

Pat Viele has been the physics and astronomy librarian at Cornell University since 1994. She is a member of APS and AAPT. Pat is serving as the chair of the Committee on Professional Concerns for AAPT this year and is a member of the Sub-committee on Classification and Information Retrieval for AIP Publishing. She can be reached at ptv1@cornell.edu

Computer-based Tutorials to Develop Expertise in Introductory Physics Students

Chandralekha Singh

Abstract: Computer-based learning tools can be exploited to make physics teaching and learning interactive, self-paced, and meaningful. We are developing and evaluating interactive problem-solving tutorials to help students in the introductory physics courses learn effective problem-solving strategies while learning physics concepts.

Introduction

The diversity of students' preparation and backgrounds in introductory physics courses for science and engineering majors has increased significantly. Even a conscientious instructor cannot gear the level of classroom instruction for all students and perhaps focuses on an average student. Those with inadequate preparation may struggle to learn basic concepts and skills. Insufficient background is detrimental for learning physics because of the hierarchical knowledge structure of the discipline and the need for learning strategies for solving problems effectively.

Technology can be exploited to help students learn if it is used in a pedagogical manner commensurate with the need and prior knowledge of students. Online homework systems such as WebAssign, LON-CAPA, and Mastering Physics are already being exploited extensively in introductory physics courses to grade students' homework.[1] Here, we describe computer-based tutorials which are self-paced and focus on helping students with a wide range of content knowledge and skills, including those at risk. Textbook publishers are increasingly providing tutorials with their online homework systems.

The computer-based interactive problem solving tutorials that we have been developing for introductory physics combine quantitative and conceptual problem solving. They focus on helping students develop a functional understanding of physics while learning useful skills.[2] If only quantitative problems are asked, students often view them as "plug-and-chug" exercises, while conceptual problems alone are often viewed as guessing tasks with little connection to physics content. The interactive tutorials combine quantitative and conceptual problem solving and provide guidance and support for knowledge and skill acquisition. They help students tackle quantitative problem solving not merely as a mathematical exercise but as a learning opportunity. They provide a structured approach to problem solving and promote active engagement while helping students develop self reliance.

Effective Problem Solving Strategies and Tutorials

Effective problem solving begins with a conceptual analysis of the problem, followed by planning of the problem solution, implementation and evaluation of the plan, and last but not least reflection upon the problem solving process. As the complexity of a physics problem increases, it becomes increasingly important

to employ a systematic approach. In the qualitative or conceptual analysis stage, a student should draw a picture or a diagram and get a visual understanding of the problem. At this stage, a student should convert the problem to a representation that makes further analysis easier. After getting some sense of the situation, labeling all known and unknown numerical quantities is helpful in making reasonable physical assumptions. Making predictions about the solution is useful at this level of analysis and it can help to structure the decision making at the next stage. The prediction made at this stage can be compared with the problem solution in the reflection phase and can help repair, extend and organize the student's knowledge structure. Planning or decision making about the applicable physics principles is the next problem solving heuristic. This is the stage where the student brings everything together to come up with a reasonable solution. If the student performed good qualitative analysis and planning, the implementation of the plan becomes easy if the student possesses the necessary algebraic manipulation and mathematical skills.

After implementation of the plan, a student must evaluate his/her solution, e.g., by checking the dimension or the order of magnitude, or by checking whether the initial prediction made during the initial analysis stage matches the actual solution. One can also ask whether the solution is sensible and, possibly, consistent with experience. The reflection phase of problem solving is critical for learning and developing expertise. Research indicates that this is one of the most neglected phases of problem solving. Without guidance, once a student has an answer, he/she typically moves on to the next problem. At reflection stage, the problem solver must try to distill what he or she has learned from solving the problem. This stage of problem solving should be used as an opportunity for reflecting upon why a particular principle of physics is applicable to the problem at hand and how one can determine in the future that the same principle should be applicable even if the problem has a new context.

Description of the Tutorials

The development of the computer-based tutorials to help students learn effective problem solving strategies is guided by a learning paradigm that involves three essential components: modeling, coaching, and weaning.[3] In this approach, "modeling" means that the instructor demonstrates and exemplifies the skills that students should learn (e.g., how to solve physics problems systematically). "Coaching" means providing students opportunities, guidance and practice so that they are actively engaged in learning the skills necessary for good performance. "Weaning" means reducing the support and feedback gradually so as to help students develop self-reliance.

Each of the tutorials starts with an overarching problem that is quantitative in nature. Before using a tutorial, students use a pre-tutorial worksheet that divides each quantitative problem given to them into different stages involved in problem solving. For example, in the conceptual analysis stage of problem solving, the worksheet explicitly asks students to draw a diagram, write down the given physical quantities, determine the target quantity, and predict some features of the solution. After attempting the problem on the worksheet to the best of their ability, students access the tutorial on the computer. The tutorial divides an overarching problem into several sub-problems, which are research-guided conceptual multiple-choice questions related to each stage of problem solving. The alternative choices in these multiple-choice questions elicit common difficulties students have with relevant concepts as determined by research in physics education. Incorrect responses direct students to appropriate help sessions where students have the choice of video, audio or only written help with suitable explanations, diagrams, and equations. Correct responses to the multiple-choice questions give students a choice of either advancing to the next sub-problem or directs them to the help session with the reasoning and explanation as to why the alternative choices are incorrect. While some reasonings are problem-specific, others focus on more general ideas.

After students work on the implementation and assessment phase sub-problems posed in the multiple-choice format, they answer reflection sub-problems. These sub-problems focus on helping students reflect upon what they have learned and apply the concepts learned in different contexts. If students have difficulty answering these sub-problems, the tutorial provides further help and feedback. Thus, the tutorials not only model or exemplify a systematic approach to problem solving, they also engage students actively in the learning process and provide feedback and guidance based upon their need.

Each tutorial problem is matched with other problems (which we call paired problems) that use similar physics principles but which are somewhat different in context. Students can be given these paired problems as quizzes so that they learn to generalize the problem solving approach and concepts learned from the tutorial. The paired problems play an important role in the weaning part of the learning model and ensure that students develop self-reliance and are able to solve problems based upon the same principle without help. These paired problems can also be assigned as homework problems and instructors can inform students that they can use the tutorials as a self-paced study tool if they have difficulty in solving the paired problems assigned as homework related to a particular topic.

We have developed computer-based tutorials related to introductory mechanics, electricity, and magnetism. Topics in mechanics include linear and rotational kinematics, Newton's laws, work and energy, and momentum. Topics in electricity and magnetism include Coulomb's law, Gauss's law, potential and potential energy, motion of charged particles in a constant electric field, motion of charged particles in an external magnetic field, Faraday's law, and Lenz's law.

Figure 1 shows screen capture from a conceptual question from a tutorial which starts with a quantitative problem in which two blocks with masses m_1 and m_2 are in contact on a frictionless horizontal surface and a horizontal force F_H is applied to the block

with mass m_1. Students are asked to find the magnitude of force exerted by the block with mass m_2 on m_1. We have found that this problem is sufficiently challenging for students in both algebra and calculus-based introductory physics courses that most students are unable to solve it without help. In the tutorial, the quantitative problem is broken down into several conceptual problems in the multiple-choice format that students have to answer. Hints are provided as needed.

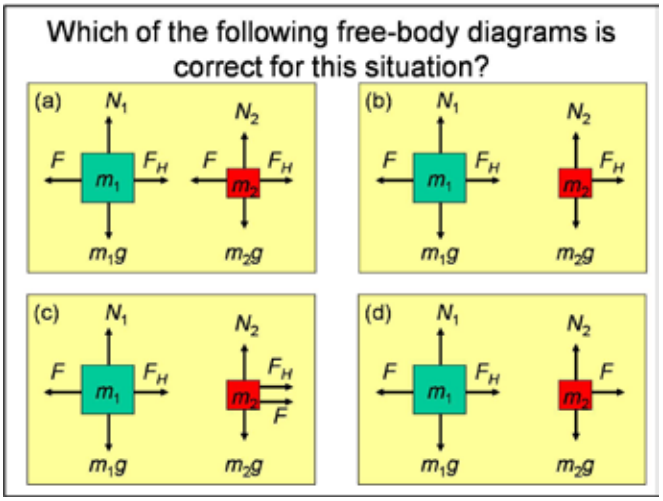


Figure 1. An example of a multiple-choice question related to the free body diagram.

In a case study, we compared three different groups who were given different aid tools: Group (1) consisted of students who used the tutorials as an aid tool. Group (2) consisted of students who were given the solved solutions for the tutorial problems that were similar to the solutions in the textbook's solutions manual. However, the solutions were not broken down into the multiple-choice questions with alternative choices targeting common misconceptions as was done in the tutorials. Group (3) consisted of students who were given the textbook sections that dealt with the relevant concepts as the aid tool and were asked to brush up on the material for a quiz on a related topic. Performance on paired-problems showed that Group (1) outperformed Groups (2) and (3).

The computer-based self-paced tutorials that combine quantitative and conceptual problem solving are suited for a wide variety of students in introductory physics. They engage students actively in the learning process and provide feedback based upon their needs. They can be used as a self-study tool by students. The paired problems can be incorporated into regular quizzes or assigned as homework problems. This work was supported by NSF grant DUE-0442087.

References

1 For example, see http://www.webassign.net, http://www.masteringphysics.com, http://loncapa.msu.edu

2 C. Singh, "Interactive video tutorials for enhancing problem solving, reasoning, and meta-cognitive skills of introductory physics students", *Proceedings of the 2003 Physics Education Research Conference*, edited by J. Marx, S. Franklin and K. Cummings, AIP Conf. Proc., volume 720, Melville, New York, 177-180, 2004. Also, see http://www.phyast.pitt.edu/~cls/interactive

3 A. Collins, J. Brown, and S. Newman, *Cognitive Apprenticeship: Teaching the crafts of reading, writing and mathematics*, in L. B. Resnick (Ed.), "Knowing, learning, and instruction: Essays in honor of Robert Glaser," Hillsdale, NJ: Lawrence Erlbaum., 453-494, (1989).

Chandralekha Singh (clsingh@pitt.edu) is an Associate Professor in the Department of Physics and Astronomy at the University of Pittsburgh. She has been conducting research in physics education for more than a decade.

From the Desk of the NIH Director: Special Edition on Science Education

Elias A. Zerhouni

*[**Ed. Note:** This Desk-to-Desk communication from the Director of the National Institutes of Health (NIH) is reprinted with the permission of the NIH].*

You may have read the recent news stories about the disappointing performance of U.S. students on an international science and math exam.[1] The future of biomedical research and the health of this nation both hinge on getting young people excited about science and health. Unfortunately, too many of them are leaving school without the analytical skills they need to be successful in today's economy, much less to become competitive researchers. Here at NIH, we are taking a multifaceted approach to engaging students from diverse populations in science and inspiring some of them to choose careers in research. However, there is only so much that we can do from Bethesda. Our best hope for making a broad impact on the children of this nation would be to have a grassroots movement of scientists across the country, rallying for improved science education in their own communities.

At the end of this Desk-to-Desk, I will suggest ways that you might use the tools developed at NIH to partner with local teachers and officials, and help revitalize American science education. I hope that many of you rise to this challenge. If those of us already passionate about science don't carry the torch, who will?

Our Children's Science Education: What You Should Know

Science education has been a concern in this country since the launch of Sputnik in 1957. Seeing our biggest adversary beat us into space lit a fire under American policy makers, educators, and the public. However, as detailed in books such as Thomas Friedman's *The World Is Flat* and the National Academy of Science's *Rising Above the Gathering Storm*, that fire desperately needs to be rekindled. [2], [3] American leadership in science and technology is once again at risk.

The performance of U.S. students is behind most other rich nations in the world—and quite a few that aren't rich. A 2003 study by the Programme for International Student Assessment (PISA) compared the problem-solving abilities of 15-year-old students from 40 nations around the world. (See the graph below.) The U.S. placed 29th. More than half of our children scored in the range that suggests they will have serious difficulties as they enter the workforce or even try to face the normal challenges of adulthood. American students were less than half as likely as students in the top-performing nations to achieve the highest level of problem-solving performance. (For more about the PISA and other education assessments, please see Appendix I in the new guide (Scientists in Science Education).

I believe that we scientists can agree that this is not what we want for our children, for our nation, or for the future of our field.

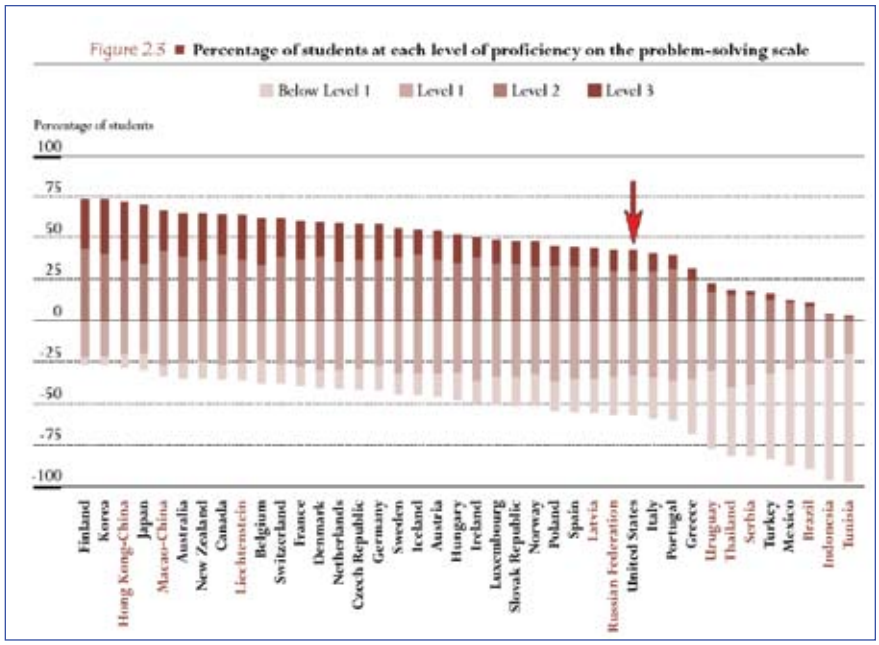


Figure from *Problem Solving for Tomorrow's World*. Countries are ranked in descending order of percentage of 15-year-olds at the two highest levels of proficiency (Levels 2 and 3, above the 0 line). Organization for Economic Cooperation and Development (OECD) member nations are depicted with a black font and non-members with a colored font. A larger version of this graph is available at the Web site http://science.education.nih.gov/pisa. The entire report can be downloaded at the Web site http://www.oecd.org/document/54/0,3343,en_32252351_32236173_34002550_1_1_1_1,00.html.

Science Isn't Just for Scientists!

Obviously, the next generation of biomedical researchers needs to be taught science, but why worry about everyone else? There are a few good reasons. Economists have estimated that as much as half of the post-World War II growth in GDP in the U.S. is attributable to technological progress that resulted from research and development. The world economy is changing, and with it, the skills that will be demanded in the promising jobs and the productive workforce of tomorrow. The international competition for a greater share of the wealth is heating up.[4] It is important for our citizens to

understand more math and science than they ever have in the past, if we dream of continuing the American tradition of leadership.

Labor economists are now warning that more than half of our children may leave school without the skills they need to enter the middle class.[5] Business reports such as *Building a Nation of Learners and Tapping America's Potential* are suggesting that many companies are having increasingly difficult times finding the employees with the critical-thinking, problem-solving, and communications skills they need to do their jobs. [6], [7] A rigorous education in math and science can help prepare all students for good jobs, even those who will never wear a white lab coat. I encourage each of you to familiarize yourself with the National Academy of Science's recent report *Rising Above the Gathering Storm*, which discusses many of these issues.[3]

Science Literacy and the Burden of Illness

Improving science education may improve not only a child's economic prospects, but his or her health status as well. Children who learn about health and the science that underpins it will be better equipped to make smart choices—about diets and exercise, about smoking and drugs, and about choosing lifestyles that will help keep them mentally and physically fit. They will grow into adults better able to pick the insurance plans and choose the treatment plans that best suit their needs and the needs of their families. Better science education is one key to a more participatory style of healthcare, which will engage individuals and communities in building a healthier society, understanding and minimizing health disparities, and reducing the suffering and costs associated with chronic disease for all Americans. We are working on this with our sister agencies in HHS and will be announcing some bold, new initiatives soon.

Promoting Science, Health, and Science Education: NIH Curriculum Supplements

To many laypeople, science and technology are essentially one and the same. Many don't understand that science isn't about the high-tech devices we use or even what we choose to study. It is a way of *knowing*. It is a method of making sense of our world and of our universe. Science builds models of what is and tests hypotheses about what *will* be. At NIH, we use the tools of science to investigate human health and disease, and to improve the human condition. But we also recognize that the same thought processes we use can also propel our society, culture, and economy, making a brighter future for our children and our children's children.

Therefore, although we focus our primary efforts on efficiently finding and funding the best research today and work to ensure the health of the scientific enterprise of tomorrow, we also make strategic investments in broader K-12 science education. An excellent example is the *NIH Curriculum Supplement Series*-16 free, interactive modules for elementary, middle, and high schools that combine the latest science from our institutes and centers with state-of-the-art instructional approaches. The supplements are available free to educators at the Web site http://science.education.nih.gov/supplements. The supplements have been aligned to state and national science education standards so that teachers can fulfill their requirements, as they introduce students to the science surrounding important human health problems. More than 300,000 supplements have been distributed to date, each in response to a request from an educator. (Take a look at a map illustrating how the NIH curriculum supplement requests correspond to population density across the U.S. at this Web site http://science.education.nih.gov/map.) While we are thrilled by the broad interest, we would love to see them in even wider use. There is always an "activation energy" required when trying something new, and even good teachers can be intimidated by working state-of-the-art science into their curriculum for the first time—especially in urban and rural environments where the appropriate tools and support may not be as readily available. That is where we hope you can help!

What Can You Do to Help?

Take a few minutes to explore the demonstration page we created for the NIH Curriculum Supplements, http://science.education.nih.gov/demos. It features one supplement for elementary school, one for middle school, and two for high school. Each will take you no more than 5 to 10 minutes and will show you how different the approach of the supplements is from what you probably experienced in grades K-12. If you like the samples, tell your child's science teacher or school principal about the free *NIH Curriculum Supplements Series* and how well the lessons portray the scientific process. Better yet, find the supplement that is closest to your research. Offer to assist the teacher with that supplement by giving a demonstration related to one of the activities or serving as the teacher's "personal science resource" while he/she works through the lesson plans.

Read over the new guide Scientists in Science Education. The guide was written by scientists and educators to help you—whether you are considering devoting an hour to a local "career day" or a hundred hours to reviewing your state's science education standards. It has some simple suggestions for making the most of your time. It includes some references if you would like a deeper understanding of the performance of U.S. students, the importance of "inquiry" in modern science education, the roles of national and state science education standards, and the No Child Left Behind Act.

Thank you for all you are doing to advance medical science today and to ensure the vitality of the American scientific enterprise in the years to come. Please let me know if you have any comments on this Desk-to-Desk or on NIH's science education efforts. I am especially interested in hearing about your own experiences in promoting science education in your community—using the NIH curriculum supplements or however else you choose to get involved. Please contact Bruce Fuchs, director of the NIH Office of Science Education, if you have questions about our science education efforts or if you need help with the science education projects you are considering (bruce.fuchs@nih.gov).

We look forward to hearing from you soon.
I invite you to share any comments you have with me, directly, at zerhounidirect@nih.gov.

For information about NIH programs, useful health information, and additional resources, see the NIH web site at www.nih.gov. An archive of the Director's Newsletter is available at http://www.nih.gov/about/director/newsletter/archive.htm.

References

1. Gold, M. U.S. Teens Trail Peers Around World on Math-Science Test. *Washington Post*, Dec. 5, 2007: A07.

2. Friedman, T.L. *The World Is Flat*. New York: Farrar, Straus and Giroux, 2006.

3. National Academy of Sciences, National Academy of Engineering, Institute of Medicine. *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future.* Washington, D.C.: National Academies Press, 2007. Available at http://www.nap.edu/catalog/11463.html#orgs.

4. Domestic Policy Council (White House Office of Science and Technology Policy). *American Competitiveness Initiative*. February 2006. Available at http://www.ostp.gov/html/ACIBooklet.pdf.

5. Murnane, R.J., and F. Levy. *Teaching the New Basic Skills: Principles for Educating Children to Thrive in a Changing Economy*. New York: The Free Press, 1996.

6. Business-Higher Education Forum. *Building a Nation of Learners: The Need for Changes in Teaching and Learning to Meet Global Challenges, 2003*. Available at http://www.bhef.com/publications/2003_build_nation.pdf.

7. Business Roundtable (and 14 others). *Tapping America's Potential: The Education for Innovation Initiative, 2005*. Available at http://www.tap2015.org/about/TAP_report2.pdf.

Elias A. Zerhouni, M.D., is Director of the National Institutes of Health.

Invited Education Sessions of the 2008 APS March Meeting

Session J7: Undergraduate Nanotechnology and Materials Physics Education I

Larry Woolf , General Atomics

NCLT Contributions to Nanoscience Education at the Undergraduate Level

Robert Chang, Northwestern University
http://www.nanoed.org/seminar/docs/NCLT%2520APS%2520march-08.pdf

Robert Chang started the session describing the activities of the National Center for Learning and Teaching in Nanoscale Science and Engineering, whose mission is to build national capacity in Nanoscale Science and Engineering Education. Some of the accomplishments of the center include the construction of an online education resource repository [www.nclt.us], and the development of units, courses, and simulations for undergraduate education, including a Nanoconcentration in Physics. The Center also houses an archive of seminars on various nanoscale science education topics and includes a potential venue for universities to post their courses and degree programs.

A Cutting-Edge Education: Incorporating Nano into the Undergraduate Curriculum

Greta Zenner, University of Wisconsin, Madison
http://mrsec.wisc.edu/Edetc/people/Zenner_APS_Mar08.ppt

Greta Zenner then described the education activities of the Materials Research Science and Engineering Center on Nanostructured Interfaces. They have developed numerous teaching modules, labs, and education resources devoted to nanotechnology concepts, and many of these materials have been integrated into key introductory and advanced undergraduate courses at UW and other institutions, including small liberal arts colleges and community colleges. This effort has taken place through both the creation of new courses and the modification of existing courses to include cutting-edge content based on current research and emerging applications in nanotechnology.

Integrating Condensed Matter Physics into a Liberal Arts Physics Curriculum

Jeffrey Collett, Lawrence University
http://www.lawrence.edu/fast/collettj/March_08.pdf

Next, Jeffrey Collett discussed the injection of nanoscale physics into recruiting activities and into the introductory and the core portions of the undergraduate curriculum. He described the use of inexpensive scanning tunneling (STM) and atomic force (AFM) microscopes to introduce students to nanoscale structure early in their college careers. The STM is used in introductory modern physics to explore quantum tunneling and the properties of electrons at surfaces. An interdisciplinary course in nanoscience and nanotechnology course, team-taught with chemists, looks at nanoscale phenomena in physics, chemistry, and biology.

Engaging Undergraduate Students in Interdisciplinary Courses in Nanotechnology

Fiona Goodchild, University of California, Santa Barbara

FGoodchild APS08.ppt

Fiona Goodchild described two new courses designed and taught by research faculty and education staff at the California Nanosystems Institute (CNSI) at UC Santa Barbara for both undergraduate and graduate students. The first course, INSCITES, aimed at first and second year students who are interested in the impacts of science and technology in society, is team taught by three Graduate Teaching Scholars from across engineering, science and social sciences. The second course, entitled the Practice of Science is focused on science and engineering majors interested in scientific research and related career opportunities; it focus on the nature of scientific discovery, the role of graduate researchers and faculty, the challenges of collaboration across disciplines and the mechanisms for funding research in academia and industry.

Educating the Workforce for the Nanotechnology Industry at CNSE

Pradeep Haldar, University at Albany

The final speaker in this first session was Pradeep Haldar from the College of Nanoscale Science and Engineering (CNSE) of the University at Albany, the first college in the world dedicated to research, development, education, and deployment in the emerging disciplines of nanoscience, nanoengineering, nanobioscience, and nanoeconomics. CNSE's NanoTech complex is a $4.2 billion, 450,000-square-foot facility that has attracted over 250 global corporate partners and is the most advanced research complex of its kind at any university in the world. The proposed undergraduate curriculum constitutes a four-part educational program comprised of a 'Foundational Principles' component, a 'Core Competency' component, a 'Concentration' component and a 'Capstone Research/Design' component.

Session Q7: Undergraduate Nanotechnology and Materials Physics Education II

Peter Collings, Swarthmore College

The Role of Engineering Design in Materials Science and Engineering Curricula

Emily Allen, San Jose State University

http://www.engr.sjsu.edu/~eallen/Presentations/APS_Mar08.ppt

Materials science and engineering programs have the dual requirement of educating both future scientists and future engineers. Graduating B.S. students need to be ready for engineering practice, yet may also be readied for graduate study and research. Design activities occur in many aspects of the profession and may be practiced by both scientists and engineers, however it is engineering curricula, not science curricula, that tend to focus explicitly on design. Accredited programs within colleges of engineering are required to emphasize engineering practice and design, while still providing the necessary conceptual development of the underlying science.

What Quantum Dots Can Do For You

Gregory Salamo. University of Arkansas

The study of nanosize materials is an emerging area of research that requires a background in both chemistry and physics. Quantum dots can be made cheaply, thereby providing a base from which to study both process engineering and the science of these materials. A simple question such as "Can we engineer greater homogeneity of dot shape and size?" provides an opportunity for students to gain the complementary skills associated with design and basic research. By teaming undergraduates from different majors and by working with industry on problems they face, undergraduates leave with a broad and realistic education in nanoscience.

An Interdisciplinary Program in Materials Science at James Madison University

Chris Hughes, James Madison University

http://csma31.csm.jmu.edu/physics/hughes/MarchMtgTalk08.swf

As part of a program in materials science that is now a decade old, James Madison University established a Center for Materials Science, which provides seed money for research, support for students, and motivation for departments to participate in the program. Courses exist at both the introductory and intermediate level that are cross-listed between departments, and students are encouraged to participate in materials science research. This program has invigorated on-campus research and forged links between faculty in several departments. In addition, this research across departments provides an opportunity for it to feed back directly into the classroom.

Use of Clickers and Sustainable Reform in Upper-Division Physics Courses

Michael Dubson, University of Colorado

http://www.colorado.edu/physics/EducationIssues/talks_posters/2008APSTalkDubson.ppt

Course reform at the introductory and intermediate level began with the introduction of clicker questions in lecture, peer instruc-

tion, and an added emphasis on conceptual understanding and qualitative reasoning. Such conceptual training improves rather than dilutes traditional, computationally intensive, problem-solving skills. This reform is now being extended into upper-division courses. In order to be successful, such a reform must start with a department-wide consensus and agreed-upon measures of success.

Thinking Like A Physicist: Condensed Matter and Materials Physics in the *Paradigms in Physics* Curriculum at Oregon State University

Janet Tate, Oregon State University
http://www.physics.oregonstate.edu/~tate/MarAPS2008_Tate_Paradigms.pdf

The *Paradigms in Physics* program at Oregon State University organizes the upper-level undergraduate physics curriculum in a way that intentionally blurs traditional sub-disciplinary boundaries and makes use of many interactive pedagogical techniques. Condensed matter physics and materials science content appear in many places in the early curriculum, culminating in a capstone course in solid state physics. A mix of analytic, computational, and research approaches are employed.

Session U7: Physics Demonstrations and Strategies for Teaching and Public Outreach

Jim McGuire, Tulane University

Bringing Nano to the Public Through Informal Science Education

Wendy Crone, University of Wisconsin–Madison.

Prof. Crone reported on tested methods for effectively communicating concepts about nanoscale science and engineering. Her talk gave an introduction to the informal science education field, discussed the art of honing your message into clear and realistic learning goals, described methods for understanding your audience and their background, and helped researchers to appreciate the limits of what can be learned in one experience. It also reviewed what the public currently understands about nanoscale science and engineering and the challenges that these (mis)understandings create for museums and researchers. These insights were developed through her experience directing a internationally recognized education development enterprise focused on the theme of "Exploring the Nanoworld" for 6 years with the UW Materials Science Research and Engineering Center (MRSEC) on Nanostructured Materials and Interfaces. The MRSEC Interdisciplinary Education Group website is located at: www.mrsec.wisc.edu/nano Email: crone@engr.wisc.edu

Preparing minority undergraduate students for successful science careers

Murty A. Akundi, Xavier University of Louisiana

In the view of Jim McGuire, session chair, Xavier of New Orleans has a reputation as the leading historically black college producing African American undergraduates in science. Xavier has been #1 among the minority serving institutions in graduating the highest number of physics graduates for the past 10 years. They are also # 1 in physical sciences and sending most students to medical schools. Email: makundi@xula.edu

"Wow" is good, but "I see" is better–techniques for more effective Physics demonstrations

Stephen Collins, Lusher Charter School, New Orleans
http://socraticbrain.com/demoTechniquesAPS.ppt

Lusher focuses on a high-academic college-preparatory curriculum, with early college credit classes through Tulane University and Advanced Placement courses, incorporating the arts throughout the curriculum. Mr. Collins discussed educational best practices in the context of science demonstrations, and modeled the techniques for the audience. A series of demonstrations utilizing a microwave oven were used as examples through which the audience was engaged in predicting outcomes, observing, measuring, and analyzing. Email: mrstephencollins@gmail.com

Gravity–The Engine of the Universe

John Thacker, LIGO and Covington High School, Covington, LA

The LIGO (Laser Interferometer Gravitational-Wave Observatory) Science Education Center has over 40 interactive, hands-on exhibits that relate to the science of LIGO. The center hosts field trips for students, teacher training programs, and tours for the general public. One may explore science concepts such as light, gravity, waves, and interference; learn about LIGO's search for gravitational waves; and interact with our scientists and engineers. Email: thacker_j@ligo-la.caltech.edu

Sparks Fly with Physics

Robert McGuire, Sci-Port Discovery Center.

Sci-Port is a private, non-profit organization with a rotating governing board of community leaders and a staff of scientists, educators and business professionals. The center opened November 21, 1998 on the Shreveport-Bossier City downtown riverfront. Since opening, people of all ages have explored the fun of sci-

ence, technology and math provided by Sci-Port's programs, exhibits and educational environments. Sci-Port's partnerships with school systems, effective collaborations with community organizations and diverse public/private support have established the science center as a cornerstone in the economic and educational development of the southern region and a leader of informal science education in the state of Louisiana. Email: rmcguire@sciport.org

Invited Education Sessions of the 2008 APS April Meeting

Session B4: How to Communicate Physics to the General Public Using Books and Articles

(co-sponsored by the Forum on Physics and Society and the Forum on Education)

Art Hobson , University of Arkansas

Writing about, and teaching, physics for non-scientists

Art Hobson, University of Arkansas
http://www.aps.org/meetings/multimedia/april2008/upload/April2008-B4-1-Hobson.pdf

Physicists must communicate their knowledge to the general public because, as the American Association for the Advancement of Science puts it, "without a scientifically literate population, the outlook for a better world is not promising." This talk, by Art Hobson of the University of Arkansas, presented tips about writing for non-scientists, based on his physics textbook for non-science college students, *Physics: Concepts and Connections*, now in its fourth edition and in use on 130 campuses, and also on his bi-weekly hometown newspaper column. Lessons learned include the process of organizing and writing a textbook, tips for writing effective prose, dos and don'ts when writing for non-scientists, choice of subject matter, being relevant to the needs of non-scientists, and unifying one's book through the use of such general themes as "the scientific process," or "energy."

Session D7: Physics Demonstrations and Strategies for Teaching and Public Outreach

Jack Wiegers, Washington University

Youth Exploring Science

Diane Miller, St. Louis Science Center
http://www.aps.org/meetings/multimedia/april2008/upload/April2008-D7-1-Miller.pdf

Diane Miller's presentation Youth Exploring Science described engaging underserved students to think about what they would like to learn and be able to do. She told a great story about groups of students who participated in the Youth Exploring Science (YES) program becoming engaged and doing interesting projects that the students selected. She described clearly how she set behavioral and intellectual expectations for these students and how the students grew and came to meet these expectations. She also described how participation in the program enhanced their learning in the classroom.

Searching for Truth: The Modeling Method of Instruction

James Cibulka, St. Louis Area Physics Teachers
http://www.aps.org/meetings/multimedia/april2008/upload/April2008-D7-2-Cibulka.pdf

Jim Cibulka's presentation Searching for Truth: The Modeling Method of Instruction described an important facet of making school science mirror professional science. He described his own journey in learning how to construct simple but refineable models that build upon one another. Further he gave examples drawn from his classroom that showed how his students gain skills in developing verbal, graphical, and analytic models.

Active Learning in a Large General Physics Classroom

Rebecca Trousil, Washington University

Rebecca Trousil's presentation Active Learning in a large General Physics Classroom described her teaching strategies in a calculus-based physics course that uses the text Six Ideas that Shaped Physics and teaching methods of Thomas A. Moore (Pomona College). She divides each class period in parts that address two-minute problems, examples, mini-lectures, and interactive demonstrations. Each of these parts requires student to be active learners both inside and outside of classes. Strategies were discussed for accomplishing this. Each part, within the class, is characterized by class participation through discussing and answering questions by holding up numbered cards.

Session H4: Undergraduate Education in Nuclear Physics

(co-sponsored by the Division of Nuclear Physics and the Forum on Education)

Con Beausang, University of Richmond

Conference Experience for Undergraduates in the Division of Nuclear Physics-10 Years Running

Warren Rogers, Westmount College
http://www.aps.org/meetings/multimedia/april2008/upload/April2008-H4-1-Rogers.pdf

For ten years, undergraduate students have participated in the fall meetings of the Division of Nuclear Physics. Each year approximately 75 students attend the meeting and present their research in a very well attended poster session. As well they participate in other activities specifically designed for them: nuclear physics seminars, reception, graduate school information session, etc. The "Conference Experience for Undergraduates" (CEU), supported by the National Science Foundation, the Department of Energy (through the national labs), and the Division of Nuclear Physics, awards travel and lodging grants based on the merit of the student's research. The CEU program has received broad enthusiasm and support from the nuclear physics community. For the 10th anniversary CEU, a special mini-symposium was organized at which former CEU students (now professors, post-docs, and graduate students) presented their current research and spoke briefly on the impact that undergraduate research and conference participation had on their career paths. Tracking of CEU students has begun in an effort to assess the impact of the program on retention in nuclear science and physics in general.

Research in an Undergraduate Physics Department

John Shriner, Tennessee Technological University
http://www.aps.org/meetings/multimedia/april2008/upload/April2008-H4-2-Shriner.pdf

The Physics Department at Tennessee Technological University has been emphasizing nuclear physics for over 30 years and at one point had a faculty of nine, all of whom were nuclear physicists. Support from the Department of Energy has led to an emphasis on undergraduate research since 1979. Although the department graduates an average of only two students per year, over 70% of the graduates in the past 20 years have gone on to graduate school in some area, and nearly 25% of those graduates have received or are pursuing a Ph.D. in nuclear physics. In recent years, the number choosing nuclear physics has increased, perhaps due to the students' experience with the CEU program.

U.S. Workforce and Educational Facilities' Readiness to Meet the Future Challenges of Nuclear Energy

Sekazi Mtingwa, Massachusetts Institute of Technology
http://www.aps.org/meetings/multimedia/april2008/upload/April2008-H4-3-Mtignwa.pdf

Due to the recent U.S. interest in expanding nuclear power, the American Physical Society's Panel on Public Affairs sponsored a study of the U.S. workforce and educational facilities' readiness for three scenarios out to the year 2050. They are maintaining the current number of nuclear reactors, significantly increasing the number, and significantly increasing the number while recycling spent fuel. This talk reports on the progress of that study.

Session J5: US Particle Accelerator School (USPAS) Session

(co-sponsored by the Division of Physics of Beams (DPB) and the Forum on Education)

Ernest Malamud, University of Nevada, Reno

This session, jointly sponsored with DPB and chaired by Linda Spentzouris (Illinois Institute of Technology) reviewed the role and experiences with the US Particle Accelerator School.

Overview of USPAS and its role in educating the next generation of accelerator scientists and engineers

William Barletta, Director of the USPAS, MIT, Fermilab
http://www.aps.org/meetings/multimedia/april2008/upload/April2008-J5-1-Barletta.pdf

William Barletta began the session with a nice overview of the functioning of the USPAS. Accelerators are essential engines of discovery in fundamental physics, biology, and chemistry. Particle beam based instruments in medicine, industry and national security constitute a multi-billion dollar per year industry. Yet only a handful of universities offer any formal training in accelerator science. The reasons are several and detailed in Barletta's talk. The USPAS fills this gap. It is a highly successful educational paradigm that, over the past twenty-years, has granted more university credit in accelerator/beam science and technology than any university in the world. Barletta then outlined the way the USPAS functions. Students come from all corners of the world, from universities, laboratories, private companies, government and the military. Some students have been in the field for many years and are interested in a "refresher" course, while others are full-time students looking for additional classes to add to their education. Qualified teachers are chosen from national laboratories, universities and private industry.

USPAS from a student's perspective: learning about accelerator physics.

Evgenya Smirnova, Los Alamos
http://www.aps.org/meetings/multimedia/april2008/upload/April2008-J5-2-Smirnova.pdf

Barletta's talk was followed by Evgenya Smirnova (Los Alamos) who gave the audience the perspective of the student. Overall, graduate education in the US is widely considered to be of the highest quality with students from around the world entering our Universities. Smirnova discussed the difference between the US and European (in particularly, Russian) graduate programs and pointed out how the USPAS became an essential part of her graduate education in accelerator physics and compensated for the lack of coursework at MIT. Dr. Smirnova, in her talk, pointed out places where she felt the school could be improved.

The USPAS from the perspective of the instructor

Michael Syphers, Fermilab
http://www.aps.org/meetings/multimedia/april2008/upload/April2008-J5-3-Syphers.pdf

The final talk in the session was presented by Michael Syphers (Fermilab) who has taught in several schools and presented his perspective as an instructor. He examined the evolution of the U.S. Particle Accelerator School from the perspective of one instructor teaching graduate students, undergraduate students, accelerator professionals and other "interested parties," throughout the history of the school's university credit program.

Session L4: Why We Should Double the Number of Undergraduate Degrees in Physics

Ted Hodapp, APS

Statistics and Rationale for the Doubling Initiative

Ted Hodapp, American Physical Society
http://www.aps.org/meetings/multimedia/april2008/upload/April2008-L4-1-Hodapp.pdf

Leading off, Ted Hodapp, Director of Education and Diversity for the American Physical Society presented data on the significant needs in the community including workforce needs in high school teachers, nuclear industry and medical physics. In addition, demographics of women and minorities in physics show that to bring these groups on par with the majority will require increasing their participation by at least a factor of two. Ted also briefly described current efforts toward addressing this situation including participating in the Physics Teacher Education Coalition (www.PTEC.org), adopting recommendations from the SPIN-UP report (www.aapt.org/Projects/ntfup.cfm), and considering issues of "climate" in departments that impact participation of under-represented groups.

SPIN-UP and the Recent Increase in the Number of Undergraduate Physics Majors

Robert Hilborn, University of Texas, Dallas
http://www.aps.org/meetings/multimedia/april2008/upload/April2008-L4-2-Hilborn.pdf

Bob Hilborn spoke next with a review of SPIN-UP (Strategic Programs in Undergraduate Physics). This report, a result of a national task force that studied decreasing enrollments in physics, compiled case studies from direct site visits with institutions that were bucking the trend. Bob also provided a more informal follow up with institutions like the University of Washington that have significantly increased their production of undergraduate physics majors and found that typically these institutions have implemented many of the SPIN-UP recommendations.

Undergraduate Program at the University of Washington

David Boulware, University of Washington

David Boulware, chair of the University of Washington's physics department, completed the set of talks by relating how his department has managed to rise to near the top of the list of departments that produce physics majors. Although he downplayed an active transformation, it was clear that the department pays particular attention to the introductory courses through the advances of their physics education group led by Lillian McDermott, and espouses good connections with their undergraduates in a wide variety of ways from alternative degree tracks to social connections.

Session T7: Excellence in Physics Education Award Session

Larry Woolf, General Atomics

Excellence in Physics Education Award Talk: Development of research-based and research-validated curriculum by the Physics Education Group at the University of Washington

Peter Shaffer, University of Washington
http://www.aps.org/meetings/multimedia/april2008/upload/April2008-T7-1-Shaffer.pdf

Peter Shaffer, representing the award winner, started the session by discussing the history of the Physics Education Group at the University of Washington. They have been conducting research on the learning and teaching of physics, developing research-based and research-validated curricula, and have been deeply involved in preparing K-12 teachers to teach physics and physical science by inquiry. More recently, the group's work has expanded to include topics beyond the introductory level such as thermal physics, special relativity, and quantum mechanics.

Physics by Inquiry: Deepening Understanding from Elementary Teachers to University Faculty

Jill Marshall, University of Texas, Austin
http://www.aps.org/meetings/multimedia/april2008/upload/April2008-T7-2-Marshall.pdf

Next Jill Marshall discussed the impact of the University of Washington's Physics by Inquiry program on the depth and detail in which it allows students to develop their understanding of topics in basic physics and reflect on that understanding. Physics by Inquiry has provided a platform for learners at all levels, from students taking their first college science course, to those with graduate degrees and teaching experience at the college level, including physics education researchers, to enhance their understanding of physics and how it is learned. In addition, by requiring students to expose their thinking, this curriculum has enabled further research into student understanding.

The Impact of the Washington Physics Education Group on the Teaching and Learning of Introductory Physics

Gary Gladding, University of Illinois
http://research.physics.uiuc.edu/PER/details.asp?paperid=127

Gary Gladding then described the significant impact that the University of Washington Physics Education Group has had on physics instruction through their development of research-based instructional materials. He focused on the use of their Tutorials in Introductory Physics in introductory college-level physics classes, which were designed to target the very real conceptual difficulties that these students have with classical physics topics. He then described the implementation of these materials at a variety of institutions and their impact on student performance.

Session X4: Programs to Prepare Teaching Assistants to Teach

(co-sponsored by the Forum on Graduate Student Affairs and the Forum on Education)

Peter Shaffer, University of Washington

The invited session "Programs to prepare teaching assistants to teach" at the 2008 April APS Meeting illustrated three systematic and ongoing programs for the professional development of graduate and undergraduate teaching assistants (TAs). Each invited speaker described a program designed to leverage the standard departmental teaching assignments to help prepare TAs–not only for their current teaching responsibilities–but more broadly for their future roles as instructors of physics.

Preparing Undergrads to Teach (Well)

Steve Pollock, University of Colorado
http://www.aps.org/meetings/multimedia/april2008/upload/April2008-X4-1-Pollock.pdf

Steve Pollock described a comprehensive and wide-ranging program for 'learning assistants' (LAs) that encompasses not only several science departments at Colorado but also the College of Education. The LA program provides an opportunity for undergraduates who are interested in teaching at the K-12 levels to learn about physics education and obtain first-hand teaching experience in the small group tutorial sections offered by the department. Faculty in the College of Education augment this experience by connecting the teaching experience of the students to research on how students learn and what is currently regarded as 'best practice' in K-12 classrooms. This program, which has proved popular among undergraduates, encourages them to think seriously about careers as precollege teachers.

Professional development of graduate TAs: The role of physics education research

MacKenzie Stetzer, University of Washington
http://www.aps.org/meetings/multimedia/april2008/upload/April2008-X4-2-Stetzer.pdf

MacKenzie Stetzer discussed the extensive TA preparation program associated with the introductory calculus-based course at the University of Washington. This program, which is based on *Tutorials in Introductory Physics*, is required of all graduate students in the Physics Department during their first year of teaching. The TAs are provided with a structured teaching experience that helps them understand some of the specific problems that introductory students encounter in learning physics and illustrates ways of teaching that have proved effective in promoting student learning. The effect of this program has been extensively documented and has formed the basis for similar programs at other institutions.

Preparing and Sustaining Teaching Assistants

Ken Heller, University of Minnesota
http://www.aps.org/meetings/multimedia/april2008/upload/April2008-X4-3-Heller.pdf

Ken Heller presented an overview of the long-term, systemic approach that the Department of Physics at the University of Minnesota has taken to the preparation of teaching assistants. A primary goal is to make the experience valuable for not only the teaching assistants, but everyone involved in the course. The teaching assignments are designed to emphasize the role of the TAs as coaches for the students. The TAs are supported by a five day orientation, a weekly seminar program, a system of mentor TAs, and ongoing meetings with the course instructor to help ensure that their actions as TAs are an integrated part of the course.

Physics Teacher Education Coalition

Section on Teacher Preparation

From the Editor of the Teacher Preparation Section

John Stewart

The annual Physics Teacher Education Coalition (PTEC) conference was held February 29th and March 1st in Austin, Texas. Gabe Popkin provides an overview of the conference. This article is reprinted from the first annual Physics Teacher Education Coalition (PhysTEC) newsletter released this spring. The full article is available at phystec.org. The next PTEC conference will be held in Pittsburgh immediately preceding the APS March Meeting. The conference theme is "Institutional Change" and conference information will be posted at ptec.org as it becomes available.

Four new PhysTEC sites were added last summer: Cornell University, Florida International University, the University of Minnesota, and the University of North Carolina at Chapel Hill. Laurie McNeil, chair of the University of North Carolina Physics &

Astronomy Department, discusses starting a teacher preparation program at an R1 university. Laird Kramer of Florida International University (FIU), an urban university that educates more Hispanic students than any other institution in the country, reports on the FIU program and its connections with CHEPREO, the interregional grid-enabled Center for High Energy Physics Research and Education Outreach. Laird reports not only an increase in the number of teachers produced by FIU, but also a dramatic increase in the number of physics majors since the inception of the program. Teacher preparation is not only an important activity valued by the community and the state, it can also support the research mission. Monica Plisch discusses the use of teacher preparation activities as part of the "broader impacts" requirements of NSF grants.

Finally, I am happy to announce that the newly redesigned PTEC website, ptec.org, is available. The site contains PTEC news and events, conference proceedings, and a growing collection of materials on teacher preparation.

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

2008 PTEC Conference: "Master Teachers: Change Agents for Teacher Preparation"

Gabe Popkin, American Physical Society.

Reprinted from PhysTEC News*, Volume 1, Spring 2008.*

The 2008 Conference on the Preparation of Physics and Physical Science Teachers was held in Austin, Texas on February 29th and March 1st. For the second straight year, the conference attracted a capacity crowd of around 120 physics and education faculty, administrators, K-12 teachers, and students, who soaked up two packed days of 90-minute workshops given by national experts on master teachers, assessment and evaluation, curriculum and teaching methods, and institutional partnerships.

Helen Quinn (Stanford Linear Accelerator Center, APS Past President), Stamatis Vokos (Seattle Pacific University), and Valerie Otero (University of Colorado at Boulder) have an animated discussion between conference sessions. Photo by Ted Hodapp.

Among the best-attended sessions were Ed Prather's workshop on interactive pedagogy, "Are you really teaching if no one is learning?" and Bob Beichner's workshop on his "Student Centered Activities for Large Enrollment Undergraduate Program (SCALE-UP)." Also very popular was a full-day workshop at the University of Texas at Austin on UTeach, one of the best-known and most successful math and science teacher preparation programs, which is now being replicated at twelve universities around the country through grants from the National Math and Science Initiative (NMSI).

Along with the workshops and plenary sessions, the conference provided an opportunity for members of the physics education community to connect with colleagues in other disciplines and with university administrators. Representatives from NASULGC (the National Association of State Universities and Land-Grant Colleges) the American Chemical Society, and Math for America led workshops and organized planning sessions for future multidisciplinary initiatives in science and math teacher education.

Attendees provided overwhelmingly positive feedback on the program, and many told us that the Conference's compact size and intense focus created a particularly rich environment for teaching, learning, and networking. Valerie Otero, a University of Colorado Education Professor, remarked on the collegial atmosphere—"there were no 'knowers,' only learners. The problem of preparing qualified physics teachers is so hard that everyone is looking for someone who knows the answer."

To build on the conference's success, project leadership plans to continue seeking out ways to engage physics departments and institutions in teacher education. The 2009 PTEC Conference, with the theme "Institutional Change," will take place in Pittsburgh on March 13th and 14th, preceding the APS March Meeting. Project leader Ted Hodapp says, "At a time when policy makers are requiring more students to take physics in our nation's already understaffed classrooms, it is critical that we turn the excitement and momentum from the PTEC Conference into action, and results."

Gabriel Popkin (popkin@aps.org) works on education projects for the American Physical Society. He graduated in 2003 with a B.A. in physics from Wesleyan University.

Doing the Right Thing (and in the Right Place): Starting a Teacher Preparation Program at a Research University

Laurie E. McNeil

An institution classified by the Carnegie Foundation as "RU/VH" (research university, very high research activity) rarely considers the preparation of high school teachers to be a central part of its mission. Its faculty members tend to concentrate instead on producing new knowledge and preparing the future professoriate. My own institution's mission statement highlights undergraduate and doctoral education and discovering knowledge, but only at the very end (almost as an afterthought) are we charged to "address, as appropriate, regional, national and international needs." At such institutions the reward system is clear: professors with high-profile research programs resulting in significant and highly-cited publications, abundant grant funds, and doctoral students who become outstanding faculty members are rewarded with endowed chairs, salary increases, and great respect both inside and outside the institution. Outstanding classroom teachers are rewarded with the high regard of their students and perhaps a university teaching award. But producing high school teachers is not something for which a reward mechanism typically exists for faculty at a RU/VH institution.

However, especially at a state institution, this often-overlooked part of the mission statement may be among the most visible and valued parts of what external constituencies expect the institution to do in exchange for the public financial support it receives. Even relatively modest efforts toward solving a serious and widely-recognized problem can have significant benefits in public good will, a fact not lost on Provosts, Chancellors, and Presidents of universities. A department that is willing to establish a teacher-training program "because it is the right thing to do" may well be able to obtain the resources necessary to do so without significantly compromising its pursuit of excellence in research. That has certainly been the case at my institution.

The School of Education (SOE) at the University of North Carolina–Chapel Hill (UNC-CH) sees its role within this research institution as providing strong research and graduate education (not just teacher preparation) in which new knowledge is generated and teachers and administrators are educated to become leaders. It has not had a bachelor's-level program for high school teacher preparation for at least a decade, though it does have a small Master of Arts in Teaching (MAT) program. Until recently, the Physics & Astronomy department had essentially no involvement in teacher preparation beyond teaching a few SOE students in our introductory classes.

In spring 2006, the Chairs of the science departments in the College of Arts & Sciences (CAS) responded to an overture from the Dean of the SOE to form a partnership to produce high school science teachers. All of us were concerned about the quality of the teaching of our subjects in North Carolina high schools and the resulting preparation of the students who matriculate at UNC-CH, as well as the level of science literacy of our state's high school graduates and its implications for an informed citizenry. Geology was well aware that a new North Carolina requirement that all high school students take a course in "Earth/Environmental Science," together with the small number of teachers with geology backgrounds, meant that large numbers of students were being taught geology by people who know very little about it. Physics and geology were both eager to increase the number of majors in our departments, and biology and chemistry wanted to offer alternative career paths to the many "post-pre-med" students who come to realize that medical school is not in their future. We were all aware that there could be political advantages if our institution were to be seen by external constituencies as helping to alleviate the shortage of highly-qualified science teachers.

The program we conceived, called UNC-BEST (UNC Baccalaureate Education in Science and Teaching), was built on the existing alternative licensure ("lateral entry") program that the SOE operates for professionals in other fields who wish to become licensed as teachers. In it, physics, biology, chemistry or geology majors can meet all (or almost all) of the requirements for licensure by the time they complete the BS or BA degree in their science field. They take a focused and intensive set of three Education courses, plus one course in the pedagogy of their science that is taught within their major department and counts toward the requirements for their major. By very careful construction of the syllabi of the four required courses we were able to meet all of the standards for licensure (including required fieldwork) set by the North Carolina Department of Public Instruction (NCDPI) within this extremely compact program. Further, the courses in the program fulfill general education requirements (in social science and experiential education) in the CAS. The students need to use only one free elective to meet the licensure requirements—a critical factor in attracting students pursuing our rigorous BS curricula.

The final requirement for licensure is 10 weeks of full-time student teaching, which our students manage in one of two ways. If through a combination of AP/IB credit and summer school attendance they are able to fulfill all their degree requirements by the end of the fall semester of their senior year, they can do their student teaching in the spring semester and graduate after four years with a science degree and eligibility for licensure as teachers. Otherwise they can complete their science degrees and the teacher preparation course requirements in four years and then be hired as a full-time teacher with a provisional license the following school year under the alternative licensure program. They receive coaching and supervision from members of the SOE faculty (registering as licensure-only students for this purpose), and upon successful completion of a year of teaching are eligible for full licensure.

The next step was to implement the program we designed, which required appropriate personnel. In order to develop and teach the new pedagogy courses within the science departments, we needed instructors who were well-versed in the relevant science, the theoretical and practical aspects of effective pedagogy, and the North Carolina Standard Course of Study that public school teachers must teach. Further, NCDPI requires that the instructors for the pedagogy courses be licensed as teachers. No such faculty existed on our campus, so we needed to hire new people in order to launch the program. We decided to pilot the program in biology, the discipline with by far the largest number of majors (~1700, more than twice as many as the other three disciplines combined), and add the other disciplines later. We pitched the program to our Provost, who is certainly well aware of the severe shortage of qualified science teachers in the state and the small number produced by the UNC system schools each year. If she had not known about it before, the fact that the President of the 16-campus system mentioned it in his inaugural speech would have brought it to her attention. Recognizing the large benefit that could be obtained at modest cost, she provided funding for a Lecturer in the Biology Department to implement the program. We were able to hire a very talented person with BS and MS degrees in biology and BS and PhD degrees in science education (the PhD awarded by our own SOE) as well as an NC teaching license. Shortly thereafter, the Physics & Astronomy Department was selected as a PhysTEC site, and on the strength of that grant we were able to persuade the Provost to provide an additional Lecturer position to establish the program in physics. We hired another very talented person with a PhD in physics education research. She lacks a teaching license, but because the PhysTEC grant provides funding for a Teacher-in-Residence, we are able to fulfill the NCDPI requirement and bring real-world experience to bear by having the two of them co-teach the physics pedagogy course.

Our program is still in its infancy, but we have accomplished much in a short time. We now have approval for all aspects of the program from the CAS, the SOE and the NCDPI; we have taught the biology and physics pedagogy courses for the first time; and have admitted the first cohort of students into the program. We expect to graduate our first teachers in May 2009. We are currently working to implement the program in geology, and that department has made a request to the Dean of CAS for a faculty line to support the program. This last is particularly significant, because this request was made *instead of* a request for a tenure-track faculty line that would also contribute to the research activities of the department.

We have all learned much in this process. The CAS faculty members, having no experience with professional accreditation of their programs by government agencies, were entirely unaware of the degree of detail and specificity required. For example, the syllabus for our new physics pedagogy course is 10 pages long rather than the usual 1-2 pages and shows in detail how a long list of state standards are met. Many of our science colleagues were also unaware of the substantial scholarship of teaching and learning well known to our SOE colleagues. We were also quite ignorant of the many things besides knowing science content that go into becoming an effective high school science teacher, including things that happen outside the classroom. Our SOE colleagues, on the other hand, had not realized that CAS faculty members could display such strong interest in preparing teachers, and that we would be willing to form a full partnership based on mutual respect without assuming that we had all the answers. They also gained from our discussions a much clearer picture of how scientists think about science and what it means to understand science (what educators refer to as an "epistemological stance"), and what kinds of knowledge we consider important for students.

A few lessons arising from our experience may be of use to physics faculty in other RU/VH institutions. First, your School of Education is more likely to be your friend than otherwise. A well-regarded, high-quality program to address a critical need will bring them as much political capital (internal and external) as it brings you. In many institutions, the School of Education is looked down upon by other academic units, so SOE faculty members and administrators are likely to be very eager to engage with you if you treat them with respect as the knowledgeable and dedicated professionals they are. If you approach them to form a partnership to find new and creative ways to train students who would not otherwise have become teachers, they are likely to be receptive. Wise leaders in Education schools are acutely aware of the national problem in science teaching and are interested in thinking about new approaches to science pedagogy. They recognize that the formation of partnerships can lead to new ideas and methods for solving the problem.

Second, two (or more) disciplines are better than one. By including other departments in our program, we were able to divide the labor of dealing with the bureaucracy in CAS as well as have more sources of creative ideas for the program. By partnering with biology we had access to a large pool of potential students that made it much easier to argue for resources to support the program than if we had relied on the few physics students we are likely to enroll each year. By partnering with geology we gained an ally even more eager to increase its numbers of majors and qualified teachers than physics.

A third lesson has to do with departmental support. The shortage of good high school science teachers is a problem all science faculty members (especially those with children in school) are well aware of, and everyone thinks it would be great if *someone* were to solve the problem. They don't necessarily want to do it themselves (and are usually not really equipped to do so), and they certainly don't want the solution to come at the expense of their research and upper-division teaching, but they are happy to reap the benefits. It is possible to convince them that students learning how to teach physics actually learn a lot of physics as they do so, and so a rigorous and carefully-constructed pedagogy course is an appropriate physics major elective. Faculty members at a research university also believe that engaging in original research fosters a deeper understanding of physics, and so tend to be in favor of the idea that future teachers should have such an experience. This makes a research university a logical place for teacher preparation if we want teachers to know physics well. And once your faculty members

realize that having an education specialist in the department can be very useful when it comes to creating programs that fulfill the NSF "broader impact" criterion [ed. note: see the accompanying article by Monica Plisch], they will warm to the idea even further. It also raises the profile of pedagogy in the department and fosters conversations about it among faculty and graduate teaching assistants that would not otherwise take place, and thereby helps to enhance the quality of the teaching that takes place in the department (especially if the specialist assists with the TA training program). Finally, our specialists also teach some introductory physics or biology courses, for which we have a perpetual need for additional sections to meet enrollment demand.

Another operational lesson is the importance of close cooperation with the public schools. Our PhysTEC grant and the Teacher-in-Residence it supports has enabled us to develop a network of local physics teachers who advise us on how to improve our program, supervise our students in their field experiences, help recruit students to the program, and give us a needed reality check when we get too far out of our area of expertise. They are endlessly enthusiastic about teaching, excellent role models and mentors, and feel truly honored to be asked to be part of a university science program.

Finally, it is important not to underestimate the public relations value of doing the right thing. Our program has yet to graduate a teacher, and yet it has already brought praise for the physics (and biology) department from the Dean, the Provost, and the Chancellor. It has been cited as an excellent example of "public engagement" in a major report on that subject prepared by our campus in response to a directive from the President of the UNC system. There is much to be said for having something other than publications on the theory of big-bang cosmology to cite when asked for examples of the contributions being made by my department to the state of North Carolina. But the real benefits will be in the longer term, when more students who come to our campus have been taught physics by teachers who truly know and love their subject. I'm looking forward to that.

Laurie McNeil (mcneil@physics.unc.edu) is chair of the Physics & Astronomy Department at the University of North Carolina at Chapel Hill and P.I. on its PhysTEC grant.

Improving Physics Education through a Diverse Research and Learning Community at Florida International University

Laird Kramer, Eric Brewe, and George O'Brien

Florida International University (FIU) is changing the face of physics education in South Florida, with the goal of increasing the quality and quantity of physics teachers, including traditionally underrepresented minorities and woman, through an integrated research and learning community. Leading the effort is the FIU PhysTEC Project, one of four new PhysTEC (Physics Teacher Education Coalition) Primary Program Institutions that began operation in summer 2007. PhysTEC is a joint effort to improve teacher preparation facilitated by three national physics societies: the American Association of Physics Teachers (AAPT), American Institute of Physics (AIP), and American Physical Society (APS). The member institutions are deeply engaged in the enterprise of producing more and better-prepared elementary, middle, and high school teachers.

The FIU PhysTEC Project is embedded within a physics research and learning community centered in sustained educational reform, adoption and adaption of successful national programs, and community development via partnership. To gain an understanding of how the project will realize its goals, we start by building an appreciation for this physics research and learning community. Then we move on to see how the PhysTEC Project and the FIU community merge to create a successful model. The physics community emerged from a multi-disciplinary team representing both the Department of Physics in the College of Arts & Sciences and the College of Education, and was seeded by several collaborative research grants. The CHEPREO project provided the foundational impetus for the community.

CHEPREO: Foundation of the Physics Learning Community

CHEPREO, the inter-regional grid-enabled Center for High Energy Physics Research and Education Outreach, is an NSF-funded multidisciplinary, multi-institution project based at FIU that supports research in particle physics, grid computing, and advanced networking at CERN. Significant CHEPREO resources are devoted to excite, entice, and retain science and math students using the project's cutting-edge science as a foundation. CHEPREO targets high school and university students as well as the stakeholders that support them: teachers, faculty, parents, etc. Students and stakeholders have come together to form a vibrant research and learning community that provides students with inquiry-based pedagogy and high energy physics, physics education, and cyber research experiences to ensure deep physics understanding that spans fundamental through bleeding-edge physics research. Through these efforts, CHEPREO has redefined the education outreach model for physics, providing pathways and support for students, especially those from traditionally underrepresented groups, to pursue science careers. Before delving into the model, we need to describe FIU and the South Florida region.

Florida International University is a minority serving urban public research institution located in Miami, Florida. Over 38,000 students were enrolled at FIU in the fall of 2007, a population that included 59% Hispanic, 12% African American, and 56% female students (2007 data). Most FIU students come from the South Florida region, a region where the fourth (Miami-Dade County)

and sixth (Broward County) largest public school districts in the country are located. Enrollment in introductory physics courses at FIU reflects a diversity similar to that of FIU as a whole and includes 62% Hispanic, 13% African American, and 40% female students (2004 data). The research design of our model supports all student populations; however, we find that it supports our diverse population very well.

The physics department at FIU includes 82 intended and declared undergraduate majors, 33 graduate students (mostly PhD candidates), and 22 faculty. Our physics department also reflects the diversity of FIU. The 82 majors listed in Fall 2006 include 67% Hispanic, 6% African American, and 20% female students. Similar representation is reflected in our bachelor's degrees granted since 2001: 71% Hispanic, 6% African American, and 29% female students.

Our treatment includes both high school and undergraduate students, so we begin with the high school component. The high school community is centered on working with educational partners (students, teachers, administrators, and schools) to bring excellent content-pedagogy to the classroom and high-energy physics outreach to the high school community. This combination provides teachers with techniques for everyday classroom instruction as well as added activities that build excitement for the future. The physics modeling approach developed by Wells, Hestenes, and Swackhamer has been used as the content-pedagogic standard [Wel95]. Modeling was chosen due to its well-documented success in high school classrooms, its student-as-scientist structure, its active-studio format, its adoptability to introductory physics courses at the university, and its community-building nature both for teachers and students. Our research has shown that modeling was an excellent choice, as evidenced by student performance, community building, and recruitment. High-energy physics outreach is centered in QuarkNet, a well-developed national model of outreach and community building. FIU became one of the 60 QuarkNet centers in 2004. Modeling and QuarkNet form the synergistic foundation of our high school community. The community has evolved substantially, meeting on a year-round basis with multiple activities planned for students and teachers throughout the year.

Typically, a teacher's induction into the community begins with a summer workshop. Two three-week long summer modeling workshops are offered every year (starting in 2003). The high school community now extends to over 80 teachers in over 45 different schools in the South Florida region as well as many teachers in other states and regions in Florida impacting well over 10,000 students a year. High-school activities include intensive summer workshops for teachers, regular meetings of our teacher community named FizMo (Physics Modelers), and a series of high school student activities that entice students to pursue science degrees and careers.

CHEPREO has also transformed the undergraduate experience by creating a physics research and learning community. The undergraduate community starts with the modeling approach-based, guided-inquiry introductory physics classes and high-energy physics experiences and extends the experiences to include a research and learning fellowship program, physics education research (PER), and the establishment of the Physics Learning Center. The undergraduate community impacts all physics majors and many other science and science/math education majors in addition to the fellows and modeling class students who are the direct recipients of the support.

The first studio classes at FIU were our introductory, modeling-based studio physics classes pioneered to support our undergraduate community members. We offer three, 30-student sections of modeling-based physics classes each semester. Cooperative learning is thought to better support under-represented minorities and women than traditional classrooms; hence, our studio classrooms support all students including minorities and women, in alignment with our goals and research focus. These courses have been extremely successful, in terms of student learning outcomes, faculty assessments, and recruiting. The average student performance on the Force Concept Inventory (FCI) [Hes92] in the modeling-based courses is roughly a factor of 2.5 better than in our traditional courses. Also, the DWF rate (drop, withdraw, fail) in modeling-based classes is 1/4th the DWF rate in traditional classes. Faculty evaluations and student feedback have been overwhelmingly positive, and the courses are drawing roughly four times the room capacity in requests to enter the class. We also find 10-20% of the students pursue physics minors and majors after taking the course, either adding a second major/minor or switching majors.

Components that extend the community are the CHEPREO fellowship program and the Physics Learning Center. CHEPREO fellowships give students a unique opportunity to experience both teaching and research. Fellows participate in our summer modeling workshops (working with the teachers) and then go on to assist in the modeling-based courses, lead study sessions, and/or work in the open labs during the first half of their program. As their physics knowledge builds, they concentrate on research. The dual nature of the fellowships allows students to experience both teaching and research so they can confidently make career decisions. The Physics Learning Center includes the modeling classroom, conference room, and lounge. The center is open to fellows and physics majors around the clock, and has become a crucial component of the students' lives.

The impact of combining the undergraduate and high school communities can be seen through many factors. High school teachers using modeling have high student achievement (the average student performance on the FCI is more than twice that of traditional courses). The modeling classes have high student achievement and low DFW rates, as noted above. Department enrollment is up: in our Modern Physics I course (a gateway to upper level courses) enrollment has increased from 9 students in Fall 1997 to over 30 students in Fall 2007, and graduation rates of physics majors increased from 2 or 3 a year in the decade prior to the implementation of the program to 8 in the 2005-2006 academic year and 12

in 2006-2007. It is especially exciting that these improvements are embedded in our diverse community with the DFW results improved strongly across all minority and gender categories.

Our preliminary research into the causes of this transformation is also showing fascinating results. Fellows are seeding the rest of the physics majors with their experiences, thus impacting the larger physics community. A case study of undergraduate teaching assistants hired by the department, comparing ones with modeling experiences to those without modeling experiences, showed that not only the modeling students brought very advanced teaching attitudes (student-centric, Socratic dialogue, group work) to their TA work, but so did several of the non-modeling students. Therefore, students interact about teaching methods throughout their time in the physics learning community. Pathways between high schools and FIU are well established, having broken down barriers through the community approach, resulting in teachers sending students directly to the department.

Our success has been leveraged in many ways, including extending the reform movement deeper into the physics and curriculum and instruction departments, serving as a model for reform in other units in the university, and as a model for many complementary funding proposals. The Department of Education Students' Equity and Achievement in Mathematics and Science project (SEAMS) and the FIU PhysTEC Project are all examples of projects leveraged off of the core CHEPREO project. FIU's PhysTEC Project illustrates that synergy as it builds a model for improving the quality and quantity of physics teachers.

The FIU PhysTEC Project

The FIU PhysTEC project utilizes a multilevel approach that incorporates several successful PhysTEC components into the FIU physics community foundation, yielding a model that supports pre-service teachers all the way from recruitment though successful induction. Top students in our introductory physics sequence will be recruited and offered the opportunity to "test drive" teaching immediately upon joining the program. These learning assistants (LAs) will develop their skills in inquiry-based classrooms where they will learn and lead with the best pedagogical methods. To ensure a smooth transition to the classroom after graduation, we will immerse the LA in our learning and research community and provide induction and mentoring into the initial phase of high school teaching. Our implementation includes a teacher in residence (TIR) who will lead much of the program, contribute to curricular development, provide sage advice and mentoring to both LAs and faculty, help document the site's assessment, and provide support for beginning teachers while experiencing professional development at FIU.

The heart of our PhysTEC program is the recruitment, preparation, support, and long-term commitment to our pre-service physics teachers. The top 20% of freshman and sophomores will be recruited and given an early field experience immediately upon joining the program. This experience gives LAs the opportunity to assist in an active learning classroom, learn about the teaching profession, and experience the intellectual challenges of teaching. They will also enroll in our new *Seminar in Teaching* course that will help prepare them for their field experience and begin learning about teaching methods. The LA experience mimics much of the CHEPREO fellow initial experience: both experience inquiry-based learning immediately upon joining the program, thus seeding both programs.

LAs that elect to continue in the program receive more training and assume greater teaching responsibility, participate in our mentoring support system, and recruit the next cadre of LAs while they prepare for full teacher credentialing. Upon graduation, an LA will have had multiple, inquiry-based teaching experiences and be fully ready to successfully enter the classroom. To further ensure their success, LAs will continue to receive support from teacher mentors and our South Florida learning community.

The teacher in residence (TIR) is a master teacher who spends one year on a rotating appointment at FIU. For the project, they provide much of the leadership and support for daily operations: mentoring LAs, helping document the site's assessment and evaluation, providing support for curricular reform, and aiding LAs when they enter the classroom. TIRs also provide crucial feedback and support for the department: building bridges with faculty, providing input on students and curricula, and sharing their professional experience. For the teacher, the TIR position offers the opportunity for professional development so they may take their skills to another level and experience the university community. They take their experiences back to the classroom, further impacting the community.

The PhysTEC project is also a vehicle for education reform within the physics department, leveraging off of the training opportunities for LAs and the experience of the TIR and the team. At FIU, this has translated into reforming the traditional introductory laboratory sequence for those students not in the modeling courses. Tutorial-style labs were introduced in six of fourteen Introductory Physics I Laboratory sections in Spring 2008, providing the opportunity for LAs and the TIR to experience first-hand both how to implement change and how to measure the effect of that change through the FCI and an attitudinal study. This also offers the opportunity for a feedback loop for further reform, providing the department with the notion of "If reforming the labs does this, what would happen if both lectures and labs were reformed?"

Conclusion

In this short article, we have provided an overview of our vibrant physics research and learning community, an emergent model specifically designed to engage all members of our diverse community, treating the whole community as scientists to achieve our goal of increasing the quantity and quality of scientists and science educators. In our five-year history, we have redefined the education and outreach model for our physics department, a model that has transformed the department. Our model is one of collaborative,

coherent, synergistic project building, using grants to kick start our efforts from which we leverage and expand to suit the needs of our students: the future scientific community.

These efforts mark the beginning. FIU has designated a goal of becoming one of the top ten urban-serving public research institutions in the country within a decade. Our efforts will help serve that goal by producing models that support high quality students, expanding the research mission both in education research and through support of broader impact criteria, and creating teachers that will engage the next generation of students.

Work supported by the CHEPREO project (NSF #0312038) and the FIU PhysTEC Project (AIP, AAPT, APS).

References

1. [Hes92] Hestenes, D., Wells, M. & Swackhamer, G., "Force Concept Inventory," *The Physics Teacher*, 30, 141-158 (1992).

2. [Wel95] Wells, M., Hestenes, D., & Swackhamer, G. "A modeling method for high school physics instruction," *Am. J. Phys*., 63 (7), 606-619 (1995). Also see http://modeling.asu.edu.

Laird Kramer (Physics faculty, kramerl@fiu.edu), Eric Brewe, and George O'Brien (both College of Education faculty) form the nucleus of the Physics Education Research Group at Florida International University. They lead the FIU PhysTEC and CHEPREO projects.

Contributing to Teacher Preparation through "Broader Impacts" Activities

Monica Plisch

The national shortage of highly qualified math and science teachers points to a need to focus more attention and resources on teacher preparation. However, physics faculty often have little time to spare for activities outside of traditional research and teaching. The National Science Foundation (NSF) has strongly supported teacher preparation efforts, primarily through the Directorate of Education and Human Resources. What may be lesser known is that the NSF "broader impacts" criterion opens the door for more conventional research proposals to include teacher preparation activities as well.

Proposals submitted to the NSF are evaluated based on two criteria, *intellectual merit* and *broader impacts*. The broader impacts criterion is intended to promote education, outreach and benefits to society. According to an NSF memo, one way to satisfy this criterion is to "participate in the recruitment, training and/or professional development of K-12 math and science teachers" [1]. While most proposals that mention teachers in broader impacts focus on in-service teachers, a review of abstracts turned up a number of current awards that include pre-service teachers.

At Louisiana State University, physicist Mette Gaarde has an NSF CAREER award to support theoretical work on attosecond pulse generation. For the education component, Gaarde is developing "a concept and inquiry based course on atomic and optical physics specifically directed toward physics majors with a secondary education concentration, which will meet objectives correlated with the National Science Education Standards" [2]. The course addresses a need at LSU for more content-based courses that help prepare and certify physics teachers, and satisfies the NSF broader impacts criterion.

The University of Texas at Austin is a research-intensive institution and home of UTEACH, a nationally recognized math and science teacher preparation program. Physicist Michael Marder, co-Director of UTEACH, has developed a course on research methods for UTEACH students. Marder has an NSF award that supports research on nonlinear dynamics, and to meet the broader impacts criterion "material encountered in this research is employed in creating materials for teacher preparation" [3]. A Nanoscale Interdisciplinary Research Team (NIRT) award to another group at UT Austin also includes a collaboration with UTEACH [4].

"Teacher preparation is a very viable broader impact," according to Kathy McCloud, Program Director for Education and Interdisciplinary Research in Physics at the NSF. The broader impacts component can vary depending on what an individual investigator is willing, interested and has an opportunity to do, according to McCloud. She emphasized that it is important to develop a plan with specifics. Evidence of contacts, for example with existing programs, school districts, and experts in teacher preparation, is viewed positively.

In general, broader impacts activities "should be based on good scholarship, and be designed to achieve clearly stated goals and metrics, while possessing the appropriate expertise and resources available for implementation" [5]. Building partnerships with established teacher preparation programs can be a good way to address these requirements, as long as the role of the investigator is specified. McCloud was supportive of the overall idea and said, "if we could get more people involved in this, it would definitely be a good thing."

References

[1] "Merit Review Broader Impacts Criterion: Representative Activities," July 2007, accessed at http://www.nsf.gov/pubs/gpg/broaderimpacts.pdf.

[2]"CAREER: Theory of attosecond pulse generation," Award Abstract #044923, accessed at http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0449235.

[3] "Nonlinear Dynamics of Solids and Networks," Award Abstract #0701373, accessed at http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0701373.

[4] "NIRT: Functionalization of alloy metal nanoparticles for enhanced transport and catalysis in membranes," Award Abstract #0708779, accessed at http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0708779.

[5] "Dear Colleague Letter on Broader Impacts Proposal Requirements," April 7, 2008, accessed at http://www.nsf.gov/pubs/2008/nsf08044/nsf08044.jsp?govDel=USNSF_25.

Monica Plisch (plisch@aps.org) is the Assistant Director of Education at the American Physical Society (APS). She manages several initiatives within the Physics Teacher Education Coalition (PhysTEC) project including PTEC, a coalition of more than 100 institutions committed to improving the education of future physics and physics science teachers.

Executive Committee of the Forum on Education

Chair: Ernest Malamud
(04/08-03/09)
University of Nevada-Reno

Chair-Elect: Peter Collings
(04/08-03/09)
Swarthmore College

Vice Chair: Lawrence Woolf
(04/08-03/09)
General Atomics

Past Chair: David Haase
(04/08-03/09)
North Carolina State University

Secretary/Treasurer: Bruce Mason
(04/08-03/11)
University of Oklahoma

Councillor: Peter Zimmerman
(01/05-12/08)
Kings College

Member-at-Large: John Thompson
(04/08-03/11)
University of Maine

Member-at-Large: Noah Finkelstein
(04/06-03/09)
University of Colorado-Boulder

Member-at-Large: Olivia Castellini
(04/07-03/10)
Museum of Science and Industry, Chicago

APS/AAPT Member: G. Samuel Lightner
(04/07-03/10)
Westminster College

APS/AAPT Member: Stamatis Vokos
(04/08-03/11)
Seattle Pacific University

APS/AAPT Member: Mel Sabella
(04/08-03/09)
Chicago State University

Non-voting Members

Chair, Committee on Education: Michael Marder
University of Texas, Austin

APS Liaison: Ted Hodapp
APS Director of Education & Diversity

AAPT Representative: Harvey Leff
AAPT Past President
California Polytechnic State University-Pomona

AIP Representative: Jack Hehn
AIP Director of Education

Newsletter Editor (Fall): Thomas Rossing
Stanford University