APS Forum on Education
American Physical Society

Fall 2005 Newsletter

Karen Cummings-Editor

IN THIS ISSUE

Articles

Foundations and Frontiers in Physics Education Research Conference Report

Working Group Reports (Edited by Rachel Scherr)

Teacher Preparation Section

Greetings from the Chair!

Ramon Lopez

2005 is drawing to a close, and the 100th anniversary of Einstein's "Miracle Year" of 1905 is almost over. This anniversary was celebrated by declaring 2005 the World Year of Physics (www.physics2005.org). In addition to numerous public talks about Einstein, the celebration has also included plays, museum exhibits, and musical performances inspired by Einstein and his successors. The December issue of Physics Today features the song that won the July issue's lyrics-writing contest. In October, November, and December of 2005 there are 241 events listed in the American Physical Society's World Year of Physics events database.

Continued on page 2

Continued from page 1

Many of these events have involved Fed members doing what they do best – sharing their love of physics by getting involved in education at all levels. And as an APS unit, the FEd celebrated the World Year of Physics with special sessions at the 2005 APS meetings. We hope that this enthusiasm for sharing physics among FEd members will continue well beyond 2005!

Another thing to celebrate is the progress we have made this year in raising funds to endow the Excellence in Physics Education Award. An endowed award through the APS must raise $100,000 in order to be established. Due to the outstanding work of the Wolfgang Christian and the fundraising committee, as of December 2, 2005, $79,055 has been raised.

The Forum has been matching contributions from FEd members up to $30,000 total, and there is $4218 in matching funds left. So if you contribute soon, your gift will be matched by the FEd. If you contribute $100 or more, you can choose to honor a teacher with your gift, and a letter will be sent by the APS to the honoree or the honoree's family informing them of your gift. We have every expectation that the award will be fully endowed by next year, at which point the FEd will annually select a team or group of individuals (such as a collaboration), or exceptionally a single individual, to honor.

In the coming year, the FEd will be sponsoring a number of outstanding sessions at the APS meetings. The topics range from Teaching Evolution to Nuclear Science Education. At the March meeting we are also sponsoring a pre-conference workshop (Quantum Mechanics With Interactive Computer-based Tutorials) that we hope many of our members will attend. And at the April meeting we will have two invited sessions on results from physics education research that we hope will prove useful to our university faculty members, as well as of

Whichever meeting you attend, you will find a session sure to pique your interest.

Another important thing to consider at the APS meetings is to write your congressman. The APS public affairs office sets up a station where you can send a template letter to your representatives and urge support for physics. I strongly urge you to do this, and to edit the letter to support physics education along with physics research. Communicating your views to your representatives on this matter is very important, and they do listen, especially if several people from their district write. So urge your colleagues from your department who are attending a meeting to do the same thing. You could have a big impact on how your representative views funding for physics-related items.

Two of our session topics, Teacher Education (March and April) and Graduate Education (April), are very timely. The APS and AAPT established a joint task force to review Graduate Physics education, and the report from this group was published in October 2005 (http://www.aapt.org/Resources/GradEdReport.cfm). The report makes a number of excellent recommendations, ranging from the nature of the core curriculum to the need to share best practices between departments and among faculty. The report also discusses items such as the role of professional development in public speaking, ethics training, and the need to establish transparent guidelines for graduate student rights. I recommend that every FEd member who has any concern with graduate education download and read this report.

The topic of Teacher Education is also very timely. The National Research Council has just released "Rising Above The Gathering Storm: Energizing and Employing America for a Brighter Economic Future", a major report that focuses on something that APS members

Continued on page 3

Continued from page 2

know well: knowledge is wealth. The report calls for a huge effort to raise the level of science education and science research in America through the creation of an additional 10,000 new science teachers each year. Bright students would be recruited to science teaching, especially in inner cities and rural areas, with generous educational incentives and salary supplements. The report call for an equally large investment in research, with 10% increases in funding each year for the next seven years, along with other actions to reward creativity. There is also a call to increase the number of US citizens who earn degrees in science, math, and engineering by offering 25,000 new 4-year competitive undergraduate scholarships.

Who will educate these students? It is certain that all of them will pass through our departments, taking one or more physics courses. Therefore the APS is positioned to play a significant role in making this report's recommendations a reality. Right now, legislation is being drafted and will be discussed in the spring. As a registered lobbying organization, the APS can play a constructive role in that process and provide input from the physics community, input that can help make sure that physics departments and individual physicists are able to participate fully in any national effort to improve science education. Together with the Committee on Education, the FEd is working to make sure that the concerns of the physics education community are addressed. And you can help by writing your representative at the APS meeting, as I discussed above. This spring will be a crucial time when you can make a real difference by supporting physics education.

Soon we will have elections for FEd officers for the coming year. I hope all of you will participate and keep the FEd healthy and active. And I hope that all of you will continue working to improve education at all levels, that you urge your colleagues and congressional representative to do the same, and best of all, that you share your love of physics with anyone who is willing to listen.

Ramon Lopez is Professor in the Department of Physics and Space Sciences at the Florida Institute of Technology in Melbourne, Florida and Chair of the Forum on Education.

Letter to the Editor: Why Distinguish Work from Heat?

Carl E. Mungan

Gislason and Craig[1] discuss thermodynamic definitions of work (W) and heat (Q) in the Spring 2005 Newsletter. They clearly have been thinking and writing about this topic for some time, judging by the references they furnish. Their examples deal with the irreversible compression of an ideal gas, a situation I also have analyzed.[2]

As a physics educator, my point of view differs from that of Gislason and Craig who are chemistry educators. I see only two fundamental reasons to invest class time in defining work and heat. The first stems from the way these concepts are typically developed in the first physics course. Work evolves out of the basic mechanics definition of force times displacement into thermodynamics applications such as pressure times volume change or electromagnetic field times change in total dipole moment, while heat is introduced in terms of conduction, convection, and radiation between materials at different temperatures. That is, work and heat represent particular categories of *energy-transferring interactions* between two systems.

Continued on page 4

Continued from page 3

The interaction of applying pressure to a piston enclosing a gas is different from that of directing a bunsen burner flame onto the gas, even if the effects on the gas (in terms of changes in P, V, T, etc) are the same. In this view, W and Q are only distinguished insofar as they help a student to properly *count* and calculate all relevant external effects acting on a system of interest. This is analogous to the way that friction and normal force are separately marked on a free-body diagram, even though a single "surface interaction" force would theoretically have sufficed. But Gislason and Craig define W and Q in terms of concepts such as internal energy (U) and entropy (S), so that an explicit connection to the physical processes is lost. Defining W and Q via abstract equations rather than by two lists categorizing specific interactions is not helpful for introductory students.

A second reason for defining and determining W and Q is to subsequently use them to calculate changes in thermodynamic potentials such as S and U. However, if ΔU and ΔS can *first* be computed in some other way, as they are in the examples Gislason and Craig discuss such as Bauman's problem,[3] then what possible reason is there to *next* deduce W and Q? This seems a case of closing the barn door after the horse has already escaped!

Based on the preceding considerations, as I have remarked elsewhere,[4] it is my opinion that distinguishing W from Q is not useful in general for irreversible processes. An exception is an irreversible process (such as a free expansion or the problem discussed in Ref. 2) in which W and/or Q (for each external agent) is *a priori* known to be zero, whereby each sum $W+Q$ in the first law of thermodynamics happens to reduce to a single term. In contrast, for example, if a block slides over a rough table, one cannot cleanly distinguish a portion of the energy transferred between the block and table due to W because of the contact forces between protrusions on their surfaces, and a portion due to Q as their surfaces warm up. In both this and Bauman's example, mechanical and thermal effects are intimately convolved with each other.

References

1) E.A. Gislason and N.C. Craig, "The proper definition of pressure-volume work: A continuing challenge," APS Forum on Education Spring 2005 Newsletter, pp. 9-11.
2) C.E. Mungan, "Irreversible adiabatic compression of an ideal gas," Phys. Teach. **41**, 450-453 (Nov. 2003).
3) R.P. Bauman, "Work of compressing an ideal gas," J. Chem. Educ. **41**, 102-104 (Feb. 1964). My question upon reading this problem is: Would it not have been better to have asked for ΔU and ΔS rather than for W?
4) C.E. Mungan, "A primer on work-energy relationships in introductory physics," Phys. Teach. **43**, 10-16 (Jan. 2005); C.E. Mungan, "Radiation thermodynamics with applications to lasing and fluorescent cooling," Am. J. Phys. **73**, 315-322 (Apr. 2005).

Carl E. Mungan is Assistant Professor of Physics at the U.S. Naval Academy in Annapolis, Maryland. He can be reached via email at mungan@usna.edu

Activity Based Physics Faculty Institutes

Are you interested in increasing your students' understanding of the physical world? 2-year college, 4-year college and university faculty are invited to attend one of the NSF-sponsored Activity Based Physics Faculty Institutes to be held at Dickinson College, summer 2006 and at the University of Oregon, summer 2007. These one week institutes will encourage faculty to use active learning strategies and computer-based tools and curricula--based on physics education research--in their introductory physics courses by 1) giving them hands-on experience with the materials in the Activity Based Physics Suite, 2) assisting them with modifying those materials for use in their own courses, and 3) providing continued follow-up support for the five years of this project. The institutes will be taught by Priscilla Laws (Dickinson College), David Sokoloff (University of Oregon), Ronald Thornton (Tufts University) and Patrick Cooney (Millersville University). Faculty from doctoral/research universities and from institutions that serve under-prepared and under-represented populations, are especially encouraged to apply. Expenses on campus will be paid, and travel grants are available for those who demonstrate need. For more information and an application, please visit our web site: http://darkwing.uoregon.edu/~sokoloff/abpi.htm

World Year of Physics Fun Day in Kahului, Maui

Peggy McMahan

As part of the worldwide celebration of the World Year of Physics (WYP), the Division of Nuclear Physics (DNP) organized a 'Physics Fun Day' in Kahului, Maui on Saturday, Sept 17th, the day before their annual meeting. The celebration consisted of three parts:

- A Physics Open House at the Queen Ka'ahumahu Shopping Center in Kahului,
- Physics Olympics, a competition for teams from high school physics and middle school physical science classes throughout the island of Maui and a neighboring island, which also took place at the shopping center,
- a WYP public lecture by Lawrence Krauss, Professor of Astronomy, Case Western University, *Einstein's Biggest Blunder: A Cosmic Mystery Story*.

Continued on Page 6

Continued from page 5

The event was a big success, in large part due to the help of the staff of the Women in Technology project of the Maui Economic Development Board. Their team, led by Jennilynne Gaskin, coordinated with the schools and handled publicity, which consisted of both newspaper advertisements and articles. The Queen Ka'ahumahu Shopping Center was a perfect venue. Not only is it the center of island life on weekends; the large open air atrium in the center of the shopping center was an ideal location.

At the Open House, nuclear scientists from universities and national laboratories manned tables with hands-on activities and give-aways covering a range of age groups and physics topics. Participants included Argonne, Brookhaven, Florida State, the Joint Institute for Nuclear Astrophysics, Lawrence Berkeley Laboratory, Los Alamos, Michigan State, Rutgers and TUNL. In addition, there was a resource area for teachers.

The Physics Olympics was organized by Professor Con Beausang of University of Richmond based on similar events he has organized in Richmond and previously at Yale.

Volunteers included students attending the meeting and physics students and faculty from Maui Community College. Teams of four competed in five events. For example in *Dive, dive, dive* they were to construct a boat out of aluminum foil, straws and rubber bands. The winning team had the boat that could hold the most cargo (marbles) without sinking. Thanks in part to a Forum on Education mini-grant, all participants received lunch, World Year of Physics t-shirts, and the winning teams at both high school and middle school levels received WYP watches, presented by Lawrence Krauss. The second place teams received Einstein action figures.

Physics Fun Day culminated with a free public lecture by Lawrence Krauss, which took place at the nearby Maui Cultural Arts Center. The crowd of about 150 people was enthusiastic and full of questions.

The Physics Fun Day was organized by the DNP Education and Outreach Committee. The Steering Committee consisted of Con Beausang (U. of Richmond), Jolie Cizewski (Rutgers), Jennilynne Gaskin (Maui Economic Development Board), Peggy McMahan (LBNL, Chair) and Andrea Palounek (LANL).

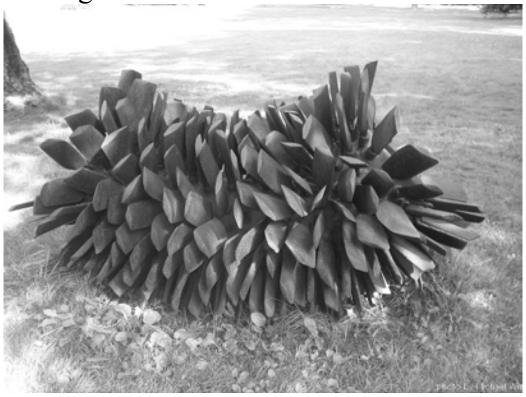
Overview of the Foundations and Frontiers in Physics Education Research Conference

Michael Wittmann, Paula Heron, and Rachel Scherr

The conference *Foundations and Frontiers in Physics Education Research* was held August 15–19, 2005, in Bar Harbor, Maine. This week-long residential meeting was attended by 60 active researchers in the field of physics education. The conference provided a unique forum for examining and articulating the current state of the field, exploring future directions, and discussing ways to pursue the most promising avenues for future research.

The conference featured a series of plenary lectures given by established and emerging leaders in PER: Lillian C. McDermott (University of Washington). E.F. (Joe) Redish (University of Maryland), Ron Thornton (Tufts University), Karen Cummings (Southern Connecticut State University), David Meltzer (Iowa State University), David Hammer (University of Maryland), Steve Kanim (New Mexico State University) and Valerie Otero (University of Colorado). Each addressed the theme of "Foundations and Frontiers" by synthesizing major accomplishments in the field and/or speculating on the directions they consider especially important and promising. Afternoons were unscheduled, and were variously spent exploring issues raised by the plenaries, developing collaborations, or enjoying the superb weather and natural beauty of Bar Harbor. Evening sessions included topical groups for specific research issues, a contributed poster session, and working groups on subjects of community-wide interest. Reports of the working groups appear on the pages that follow.

Feedback from post-conference surveys indicated tremendous satisfaction with the format, setting, and content of the meeting. Several participants described collaborations, papers, or projects that were created or revitalized at the meeting. Nearly half of all respondents felt it was among the best conferences they had ever attended. There was very strong support for holding a similar conference in 2007.



Infamous "Attacking Pinecone" sculpture on the College of the Atlantic campus.

The conference organizers would like to thank the staff of the College of the Atlantic in Bar Harbor and the Center for Science and Mathematics Education Research at the University of Maine for their assistance. We are especially grateful for a grant from the Forum on Education of the APS that allowed graduate students to attend at a greatly reduced registration cost. The endorsement of the conference by the APS and the AAPT is appreciated.

Michael Wittmann, Paula Heron and Rachel Scherr are co-organizers of the Foundations and Frontiers in Physics Education Research Conference. Michael Wittmann is Assistant Professor of Physics, Cooperating Assistant Professor of Education and Co-director of the Physics Education Research Laboratory at the University of Maine. Paula Heron is Associate Professor of Physics at the University of Washington and a Forum on Education APS/AAPT Member-At-Large. Rachel Scherr is Research Assistant Professor of Physics at the University of Maryland and Editor of the Conference Report that follows.

Querying other Fields

Andy Elby and Michael Loverude

Our working group was asked to articulate queries that the PER community may wish to direct to other research communities. In the course of our discussion, we had to make a choice as to the nature of these questions—should they be queries about settled questions in other fields, or questions of active research interest? The former category would lead to a bibliography of published research, a useful but essentially static result. We instead focused on actively pursued research questions, in the hopes that our work could lead to partnerships across research communities. So, although prior research partially addresses many of these queries, new collaborations are needed to answer them more completely.

Subfields of PER

After compiling an initial list of queries, we reflected about what subfields of PER would benefit from the answers to those queries. During this discussion, little controversy arose as to the boundaries of PER. However, it became clear that the same query may inform different PER subfields for different reasons. For instance, in studying students' learning in other fields, some researchers may focus on implications for cognitive models of learning, while others may focus on insights for effective curriculum development. Other questions, such as those dealing with research methods, might cut across subfields.

We articulated nine subfields of PER. This is not necessarily a comprehensive list of what PER *is*; rather, it clarifies for us where the particular queries we generated fit into the field of PER. To that end, our list is as follows:

- cognitive mechanism
- curriculum and instruction
- epistemology, attitudes, and etcetera
- institutional change
- problem solving and reasoning
- research methods
- sociocultural mechanisms
- student conceptions
- teacher education

Fields Queried

Over four hours of discussion, we considered queries addressed to more than twenty different fields. The queried fields included some that would be expected: educational psychology, chemistry education, cognitive neuroscience, mathematics education. Others were more surprising. For example, group members brought up clearly relevant examples of research on how people learn and solve problems from fields that seem quite different from physics, including art education and economics. We discussed at length subfields of business including marketing and organizational change.

Rather than listing all the fields and queries here, we have decided to describe a few examples in detail in order to give readers a sense of the nature of our discussions. (See http://perlnet.umaine.edu/ffper/querying/ for the complete lists, hyperlinked to references and other resources.) The examples below illustrate how the process went in two directions. In some cases, we started by considering a field, and came up with queries. Our examples of this field-based query generation focus on one expected field (math education research) and one unexpected field (business). In other cases, we began with a specific query and discussed what other fields might be able to help answer it. We discuss two examples of this type of query: one arising from phenomena observed in classroom instruction, the other arising from a desire to optimize our research methods.

Continued on page 9

Continued from page 8

An Example of a Queried Field: Math Education Research

For many in the PER community, the most natural adjacent fields to query include discipline-based education research (DBER) in other sciences and in mathematics. We generated a number of queries for these fields and could easily have discussed more. Here, we discuss the queries we posed to math education research, as illustrative of the type of partnerships that this work might promote. (For those interested in DBER in other disciplines, the Physics Education Research Conference in Syracuse, held immediately after the AAPT national meeting, will examine this topic.)

The first and perhaps most obvious type of query involved the content of mathematics, particularly as it relates to physics. What pre-instruction ideas do students have about concepts including graphs, slopes, functions, differential equations, and proportional reasoning? What instructional interventions help students to master these topics? These queries connect to PER work on student conceptions as well as curriculum and instruction. A related set of questions involves problem solving and reasoning: how do students go about the construction of mathematical proofs, and how do they self-evaluate their work for correctness and completeness?

For physicists involved with teacher preparation, we might collaborate with math education researchers on the nature of pedagogical content knowledge (the knowledge an expert teacher needs about pedagogy in his or her field *and* about students' conceptions, difficulties, reasoning, and learning in that field). For example, to what extent is pedagogical content knowledge in math or physics separable from the corresponding content knowledge? The answer has implications for the standard practice in which future math/science teachers take *separate*, disconnected courses about math/science and about teaching methods.

The mathematics community has long confronted the issue of 'math phobia' or anxiety. Physics teachers have certainly observed similar affective issues, in which even bright students claim they can't (or don't) 'do physics.' Do these phenomena share sociological or cultural roots? What do they reflect about students' beliefs about the nature of math/science knowledge and learning?

Math education research and other DBER face many similar concerns. These include methodological issues: what methods have other disciplines developed to study these questions that may be of interest to PER? These fields also share deeper sociological and political issues: the growing fields of DBER face a difficult funding climate, uneven levels of acceptance among traditionally-oriented departments, and the need for means of scholarly communication and criticism.

Another Example of a Queried Field: Business

While mathematics education is a field that we expect to inform PER, business is perhaps not. However, some of the questions that PER is beginning to address closely resemble issues studied in schools of business. In particular, the adoption of PER-based curricula in traditional departments is a process similar to those studied in fields described as decision theory or organizational studies. What can these fields tell us about how institutions decide to change and about the trade-offs between large dramatic changes versus incremental improvements?

The fields of physics in general and PER in particular are confronted with challenges that are, in part, marketing issues. How does a physics department sell itself to potential students? How does a department contemplating curricular reform justify the expense to its own faculty and to higher administrators?

Finally, the group discussed focus group techniques as used by market researchers. PER typically gathers data from

Continued on page 10

Continued from page 9

whole classes or individual students. Could we also use established techniques to elicit information on student understanding from a small focus group?

Example of Research Questions Arising from Our Own Work: Cognitive Conflict

Many PER curricula use cognitive conflict, in which students make predictions and then are confronted with evidence that their predictions are incorrect. One of the working group members observed that, in some cases, her students seem to 'shut down' when presented with the conflict. This process appeared to be related to a cognitive mechanism of suppression and/or a related emotional response. Another member of the group referred to current research in cognitive neuroscience using brain scans. When students made observations of a particular counter-intuitive phenomenon, scans indicated the activation of a portion of the brain associated with suppression.

These results lead to a number of intriguing questions. During cognitive conflict in instruction, what cognitive suppression mechanisms are activated? Do these results suggest that incorrect intuitions do not go away, but are merely suppressed? What affective or emotional responses are associated with these processes? Do men and women experience different responses? Although the initial query was posed to the field of neuroscience, the questions we just listed also touch upon cognitive and social psychology, sociology, and perhaps even identity theory. The answers to these questions might influence curriculum developers as well as researchers interested in a more fundamental understanding of cognitive mechanisms in physics learning.

Another Example of Research Questions Arising from Our Own Work: Non-verbal Communication

Another member of the group brought up a series of questions that have arisen in her ongoing examination of research methods and their underlying assumptions. Many PER studies rely upon the analysis of video data from clinical interviews or classroom interactions. Typically a researcher transcribes utterances, what students and interviewers say. However, emerging evidence suggests that something can be learned from events that aren't typically recorded in a transcript. When students pause mid-statement or between statements, or make non-verbal utterances and false starts, what can we learn about student thinking? Can a researcher gain meaningful information from the tone or rapidity of student statements? These non-linguistic elements of speech, called 'paralinguistic' elements, are studied in many fields including linguistics, psychology and sociology.

Conclusion

Our group's consensus was that PER could benefit greatly from interacting more with other fields -- not only from reading their papers, but also from collaborating on specific research projects. We acknowledge that there are significant barriers to such collaborations, including lack of knowledge about other fields, lack of contacts in other fields, and institutional pressures to collaborate and publish within one's discipline. We nevertheless hope that researchers will take advantage of appropriate opportunities to expand and deepen physics education research with interdisciplinary collaborations.

Acknowledgements

The working group co-chairs would like to thank the other members of our group for their input: Leslie Atkins, Tom Bing, David Brookes, Eugenia Etkina, Gary Gladding, David Hammer, Andrew Heckler, Beth Lindsey, Ellie Sayre, Rachel Scherr, and Laura Walsh.

Andy Elby is Assistant Research Scientist in Physics at the University of Maryland. He is currently co-authoring an introductory calculus-based physics textbook for John Wiley and Sons. Michael Loverude is Associate Professor of Physics at California State University at Fullerton. His research primarily focuses on student understanding of fundamental concepts.

Maximizing the Benefits of Physics Education Research: Building Productive Relationships and Promoting Institutional Change

Charles Henderson, Tim Stelzer, Leon Hsu, and Dawn Meredith

Our group had the task of identifying how those of us in Physics Education Research (PER) might best cultivate productive relationships with other physics faculty members. Prior to the conference, the group leaders identified two objectives related to this topic: (1) Gaining respect for PER as a serious research area that belongs in physics departments; (2) Getting results of PER known and used by physics faculty. To help with this task members of the PER community were invited to complete a web survey prior to the conference. The full results of this survey are described elsewhere.[1] Based on the web survey and discussion within the working group, there appears to be agreement within the PER community that both of the above objectives are important goals for the PER community. The working group saw these areas as strongly connected, with one reinforcing the other.

Roles of PER faculty

In physics departments, PER is sometimes mistaken for a service enterprise whose purpose is to improve instruction in the department, rather than a scholarly pursuit similar to other subfields of physics research. Where this misperception exists, departments may miss opportunities to hire PER candidates; after hiring, this misperception can result in higher service and teaching responsibilities for PER faculty and difficulty in using PER work as a basis for tenure and promotion. This issue was addressed recently by Heron and Meltzer who argue that the success of PER depends on having a critical mass of PER faculty with appointments in physics departments.[2] Suggestions for improving the status of PER made by the working group and web survey largely mirror those made by Heron and Meltzer. These include improving the marketing of PER as well as improving the quality and rigor of PER. The working group also discussed the advantages and disadvantages of making analogies between PER and traditional physics research and of portraying PER as interdisciplinary.

Adoption of PER tools and methods

In recent decades, researchers in PER have documented significant and reproducible results related to the teaching and learning of physics, and have demonstrated the effectiveness of instructional strategies and materials based on these results. PER is also a leader in discipline-based science education research, with other fields often turning to PER as a model. A challenge currently facing the PER community is dissemination. While increasing numbers of faculty use PER knowledge and products in their teaching, others are unaware of PER or question its relevance to their own teaching. Working group discussions revolved around both individual and institutional factors that might be related to an instructor's use of PER.

Emerging research [3,4] and the experiences of group members suggest that potentially important barriers to change are existing frameworks that presuppose an unequal relationship between PER faculty and other faculty; e.g. an expert/novice or provider/client relationship. In such frameworks, PER faculty supply curricular products to other faculty who are then responsible for adopting the new products and techniques. These frameworks, unfortunately, fail to recognize faculty members' knowledge, skill, and unique teaching circumstances, and fail to acknowledge the independent scholarly pursuits of PER faculty. We suggest that a more effective framework might be one of mutually beneficial collaboration.

Continued on page 12

Under this framework physics education researchers might work with instructors to customize PER products and knowledge to their individual teaching situations, personal preferences, skills, and goals, and physics education researchers might, for example, gain access to data supporting their research or gain valuable perspective on teaching. Both participants would be valuable to the process with learning occurring on both sides. Possible means of collaboration range from informal one-on-one interaction[5,6] to more formally organized groups including both faculty interested in improving their instruction and physics education researchers conducting investigations relevant to that instruction.[7] Other possibilities include instructional materials developed to facilitate local customization.[8]

Promoting institutional change

Even faculty strongly committed to PER-based instructional reforms may be inhibited by factors such as student expectations, questions on course evaluation forms that focus on presentation of material, room arrangement, content coverage expectations, faculty reward structures, and so forth.[9] Such factors tend to support traditional instructional practices and may not become visible until change is attempted. For example, one of the major impediments to the success of the Technology Enhanced Active Learning (TEAL) program at MIT was student resistance to the new instructional style.[10] At MIT, students were eventually persuaded to accept the reforms, thanks to expertise and perseverance among the TEAL faculty along with a significant commitment of institutional resources. However, student resistance to new instructional methods can derail instructional changes, especially for instructors working alone and with little institutional support.[11]

Our working group identified institutional change as a major factor in successful PER-based instructional reform and therefore in productive relationships with non-PER faculty members.[12] For example, at the University of Illinois, Urbana-Champaign, organizers relied on three key changes in departmental structure to support reform of the introductory calculus-based physics sequence.[13] First, a team of ten faculty members substantively worked on the project, rather than one or two PER-immersed individuals. The team approach – common for research projects, but rare for teaching innovations – provided a critical mass not only for implementing the changes, but also for sustaining the changes and gaining acceptance of the reforms throughout the faculty. Second, the department provided resources (including release time) for the team to effectively plan and implement its instructional vision. Third, the department created a position with the authority to allocate the resources necessary to maintain the quality of the courses, including appropriate staffing for the courses. As a result of these institutional changes, over 50 faculty members have successfully taught in the reformed courses. Many of these faculty members have incorporated reforms into their upper division courses.

PER is only beginning to look at change from the perspective of PER-supportive institutional reforms. As Sheila Tobias recently noted, "physics education reform has been focusing largely on classroom-based innovation rather than on the more political and institutional conditions required for long-lasting change,"[14] Our working group acknowledged the need for tools to help us better understand these institutional factors and their often political origins.

Summary

PER has made significant progress in understanding the teaching and learning of college level physics in recent years. Building on this foundation we suggest that new work is required in the frontier areas of 1) understanding physics faculty and their teaching situations; 2) developing ways to support faculty in changing long-standing instructional practices; and 3) identifying and changing political and institutional conditions to make them more hospitable to PER-based instructional reforms.

Continued on page 13

Continued from page 12

Acknowledgements

We would like to thank the 11 members of this working group for many fruitful discussions. The working group consisted of: John Belcher, Bruce Birkett, Jaehyeok Choi, Peter Fletcher, Charles Henderson, Leon Hsu, Tim McCaskey, Dawn Meredith, David Pritchard, David Schuster, and Tim Stelzer.

References

1) Henderson, C. and Stelzer, T. (2005) The gap between PER and mainstream faculty: The PER perspective. Poster presented at the Foundations and Frontiers in Physics Education Research Conference, Bar Harbor, Maine, August 16, 2005. Available online:http://homepages.wmich.edu/~chenders/Publications/FFPER05Poster.pdf

2) Heron, P. R. L. and Meltzer, D. E. (2005) The future of physics education research: Intellectual challenges and practical concerns. *American Journal of Physics* 73 (5), 390-394. Available online: http://link.aip.org/link/?AJP/73/390/1

3) Henderson, C. and Dancy, M. (2005) Teaching, learning and physics education research: Views of mainstream physics professors. In *Proceedings (peer reviewed) of the 2004 AAPT Physics Education Research Conference* (Franklin, S. Marx, J. and Heron, P., eds.), American Institute of Physics. Available online: http://homepages.wmich.edu/~chenders/Publications/PERC2004Henderson.pdf

4) Henderson, C. and Dancy, M. (2006) Physics faculty and educational researchers: Divergent expectations as barriers to the diffusion of innovations. In *Proceedings (peer reviewed) of the 2005 AAPT Physics Education Research Conference* (Franklin, S. Marx, J. and McCullough, L., eds.), American Institute of Physics. Available online: http://homepages.wmich.edu/~chenders/Publications/Henderson%20PERC%202005.pdf

5) Briscoe, C. and Prayaga, C. S. (2004) Teaching future k-8 teachers the language of newton: A case study of collaboration and change in university physics teaching. *Science Education* 88 (6), 947-969. Available online:http://dx.doi.org/10.1002/sce.20005

6) Van Sickle, M. and Kubinec, W. (2002) Transforming teaching: A physics professor's thoughts. *Journal of College Science Teaching* 32 (4), 258-263.

7) Cox, M. D. (2004) Introduction to faculty learning communities. *New Directions for Teaching and Learning* 2004 (97), 5-23. Available online: http://dx.doi.org/10.1002/tl.129

8) A project recently undertaken by A. Elby and the University of Maryland PERG encourages such customization through easily edited materials and support tools that include explanations about the instructional design and annotated video snippets of the materials and techniques in actual classroom use. See McCaskey, T., Hodges, R. and Elby, A. (2005) Integrating adaptable tutorials with professional development materials. Paper presented at the American Association of Physics Teachers Winter Meeting, Albuquerque, NM.

9) Dancy, M. and Henderson, C. (2005) Beyond the individual instructor: Systemic constraints in the implementation of research-informed practices. In *Proceedings (peer reviewed) of the 2004 AAPT Physics Education Research Conference* (Franklin, S. Marx, J. and Heron, P., eds.), American Institute of Physics. Available online:http://homepages.wmich.edu/~chenders/Publications/PERC2004Dancy.pdf

10) Belcher, J. W. (2003) Improving student understanding with TEAL. *The MIT Faculty Newsletter* 16 (2), 1,8-11. Available online: http://web.mit.edu/jbelcher/www/802TEAL.pdf

11) Felder, R. M. and Brent, R. (1996) Navigating the bumpy road to student-centered instruction. *College Teaching* 44, 43-47. Available online: http://www.ncsu.edu/felder-public/Papers/Resist.html

12) For an approachable introduction to a view of institutions as complex systems and the implications for change, see Senge, P. M. (1990) *The fifth discipline: The art and practice of the learning organization*, Bantam Doubleday Dell Publishing.

13) Campbell, D. K., Elliot, C. M. and Gladding, G. E. (1997) Parallel parking an aircraft carrier: Revising the calculus-based introductory physics sequence at Illinois. *Forum on Education Newsletter of the American Physical Society* (Summer), 9-11. Available online: http://www.aps.org/units/fed/newsletters/aug97/index.cfm#campbell

14) Tobias, S. (2000) From innovation to change: Forging a physics education reform agenda for the 21st century. *American Journal of Physics* 68 (2), 103-104. Available online:http://link.aip.org/link/?AJP/68/103/1

Continued on page 14

Continued from page 13

Charles Henderson is an assistant professor at Western Michigan University with a joint appointment between the Physics Department and the Mallinson Institute for Science Education. Tim Stelzer is Research Associate Professor of Physics at the University of Illinois at Urbana-Champaign, Leon Hsu is Assistant Professor in the General College at the University of Minnesota-Twin Cities Campus, and Dawn Meredith is Professor and Chair in the Physics Department at the University of New Hampshire.

Lobbying for Discipline-based Education Research

Paula Heron and David Meltzer

This working group began its discussions with an assessment of the current state of funding for physics education research (PER). Most PER work is funded directly or indirectly by the National Science Foundation (NSF), primarily through the Directorate for Education and Human Resources (EHR). Within this Directorate three separate divisions fund physics education work, although the funding programs—and therefore the projects that are funded—rarely designate research explicitly as a primary objective. The Division of Elementary, Secondary, and Informal Education (ESIE) funds teacher preparation and curriculum development projects targeted at grades K-12, while the Division of Undergraduate Education (DUE) funds course, curriculum, and laboratory development projects for college and university-level instruction. Research in the teaching and learning of physics is sometimes a component of these projects, and many PER groups are able to partially support their research endeavors by linking them to the development projects funded by ESIE and DUE. A similar situation exists for education researchers in chemistry, geoscience, and other science disciplines.

Projects with a primary focus on research are funded by the Division of Research, Evaluation, and Communication (REC). Although individual projects funded by REC generally receive substantial amounts of support, only a very small percentage of REC-funded projects have a focus on physics education (approximately one in 20), or for that matter any specific science discipline. Most funding goes to researchers with backgrounds and interests in K-12 math and science education, cognitive science, educational psychology, school systems administration, etc. PER and other discipline-based research groups have found it very difficult to persuade review panels and program directors in REC to designate significant amounts of funding for discipline-based education research. Moreover, the new federal budget proposed this year for NSF incorporates very substantial budget cuts for REC, and this leaves the future of NSF-funded science education research very much in doubt.

Very recently, the Division of Undergraduate Education has established new funding programs within its broader Course, Curriculum, and Laboratory Improvement (CCLI) program specifically targeted at discipline-based education research. Although this new program has yet to make its first set of awards, it represents a promising development in the establishment of ongoing funding mechanisms for research in physics education and similar fields.

Finally, it should also be mentioned that the NSF Directorate for Physical and Mathematical Sciences (MPS)—the home of funding in traditional research fields in physics, chemistry, astronomy, and mathematics—has taken a few tentative steps to participate in funding discipline-based education research. Several modest projects in PER have been funded by MPS over the past few years and, although these projects represent a potentially important first step, the future of such MPS funding remains very uncertain.

Continued on page 15

Continued from page 14

The assessment of the Working Group was that the overall funding situation for discipline-based education research, and specifically for PER, remains poor with an equally dismal prognosis. In terms of the funding levels that are actually required to establish, maintain, and develop a new subfield of physics research on a national basis, there is currently no mechanism in place nor is there any projected for the future that could meet the need.

Ironically, coexisting with the dismal funding situation for discipline-based education research, there are vast amounts of funding being provided to education and outreach projects. For example, the GK-12 program and the Math and Science Partnerships (MSP's) together represent many millions of dollars in current funding. PER workers have often found it very difficult to persuade program directors and project leaders in these programs that expertise in discipline-based education research may be crucial to achieving and documenting success in science education. Similarly, very large funded projects (for example, Science and Technology Centers) are mandated to devote 20% of their total budgets to education and outreach, once again with little contribution by specialists in discipline-based education research.

The Working Group concluded that our funding objectives can be characterized by two distinct themes: (1) the need to increase total federal expenditures on science and science education (a "bigger pie"), and (2) the need for a larger proportion of such funding (relative to present levels) being devoted to discipline-based education research (a "bigger slice"). The Group felt that such increased funding for this research was well justified based on the unusually large educational impact that such targeted funding may achieve for relatively small amounts of funding dollars. Past experience has shown that PER projects have been able to achieve significant learning gains for very modest amounts of funding, and this point merits heavy emphasis in discussions with political leaders and representatives of the science and science education communities.

The Group recognized that the objective of obtaining a bigger pie would require dissemination and constant re-emphasis within the political community of the message that good science—widely recognized as essential to the security and development of the nation— requires good science education; this theme has already been taken up to some extent by the NSF and the National Science Board, among others. This political effort can include lobbying of federal Representatives and Senators through a coherent effort of individuals. Members of the APS Forum on Education are drafting talking points and brief information sheets for members to use when talking to their congresspersons. Additional measures might include a blitz of congress (following the model of high energy physics) with preparation by APS lobbyists. Lobbying of federal powers-that-be by APS itself is a long-term objective; getting science education included in APS lobbying efforts will be a lengthy and (possibly) contentious effort due to perceptions of "turf-infringement," etc.

The Group proposed that the objective of achieving a larger slice might be addressed by lobbying of NSF powers-that-be by a delegation of PER luminaries, and physics luminaries who are sympathetic to PER, in close collaboration with representatives of the education research communities in astronomy, chemistry, mathematics, geoscience, and engineering. This lobbying effort would need to make the case that support for discipline-based education research is well merited based on vast and long-standing evidence that it is actually effective.

Finally, the Group discussed a number of concrete steps that individual APS members might initiate on their own: These include nominating members of the PER community for leadership positions within APS and other professional scientific organizations, voting in favor of PER

Continued on page 16

Continued from page 15

candidates in AAPT and APS elections, and participating in meetings of APS, NARST, and other organizations.

Acknowledgments
The authors of this report would like to thank the other members of the working group: Constance Barsky, Joseph Beuckman, Karen Cummings, Melissa Dancy, Noah Finkelstein, Steve Kanim, Don Mountcastle, Ronald Thornton and Esther Zirbel. We appreciate your time and thoughtful input.

Paula Heron and David Meltzer are co-chairs of the working group on lobbying for support of PER. Paula Heron is a Forum on Education APS/AAPT Member-At-Large and David Meltzer is a Forum General Member-At-Large.

A Literary Canon in Physics Education Research

John Thompson and Bradley Ambrose

In recent years the field of physics education research (PER) has experienced tremendous growth in not only the number of professionals within the field but also the depth and diversity of research questions being explored. Experts in PER have themselves emerged from a variety of academic backgrounds, including physics, science education, and cognitive science. In August 2005, the conference "Foundations and Frontiers in Physics Education Research" provided an opportunity for PER specialists to compile a list of publications describing research on the teaching and learning of physics that are considered primary and necessary by everyone in the field. A group of conferees volunteered to accomplish this task.

In light of the successes achieved in PER and the accelerating expansion of the frontiers of the field, the prospect of assembling a literary canon in PER was viewed as simultaneously necessary and daunting. In contrast to the existing resource letters in PER and problem solving research,[A] the desired outcome was a concise list of readings that articulate the fundamental interests and issues of PER, thus providing a common language and point of reference in the field. The canon could be used, though perhaps with minor modifications, as a resource by new graduate students and faculty members entering the field or by other physics educators who wish to familiarize themselves with seminal and exemplary research and curriculum development in PER.

The PER canon working group divided into teams. Each team was assigned to compile a list of exemplary readings fitting one of the following general categories: (a) empirical investigations of student understanding, (b) modeling student learning, (c) PER-based curricular materials, (d) PER-based diagnostic instruments and assessments. Sources to be included in the former two categories were limited to those that best illustrated particular research methods utilized in PER as well as the types of research questions on which those methods are brought to bear. For the latter two categories the focus was instead on published PER-based curricula and validated assessment methods that have gained acceptance both within the PER community and in the larger physics education community.

When the entire working group reconvened to discuss and debate which sources should be included in the canon, it became clear that a single list of 25 or fewer sources would be too restrictive.

Continued on page 17

Continued from page 16

However, group members agreed upon a two-tiered structure for the canon and, after extensive discussion, selected which readings belonged in the primary tier. This primary list of PER readings, and the rationale described above for selecting them, was presented to the entire body of conferees by the co-facilitators of the working group. Those readings are listed below in chronological order of publication, from earliest to most recent. A few entries list two articles; these articles were originally written as complements to one another, as indicated explicitly in their titles.

The supplementary readings assigned to a secondary tier included research articles or conceptual surveys that are regarded as essential in PER, but were not the first of their kind, or describe research conducted outside the realm of PER. (Due to limited space, these readings—which would have more than tripled the size of the list shown here—will instead be cited on the *Foundations and Frontiers in Physics Education Research* conference website: http://perlnet.umephy.maine.edu/ffper/WG.htm.)

Literary canon in PER: Primary list

1. "Investigation of student understanding of the concept of velocity in one dimension," D.E. Trowbridge and L.C. McDermott, *Am. J. Phys.* **48**, 1020-1028 (1980); "Investigation of student understanding of the concept of acceleration in one dimension," D.E. Trowbridge and L.C. McDermott, *Am. J. Phys.* **49**, 242-253 (1981).
2. "Accommodation of a scientific conception: Toward a theory of conceptual change," G.J. Posner, K.A. Strike, P. W. Hewson, W.A.Gertzog, *Sci. Educ.* **66**, 211-227 (1982).
3. "Student understanding of the work-energy and impulse-momentum theorems," R.A. Lawson and L.C. McDermott, *Am. J. Phys.* **55**, 811 (1987).
4. "A view from physics," L.C. McDermott, in *Toward a Scientific Practice of Science Education,* edited by M. Gardner, J.G. Greeno, F. Reif, A.H. Schoenfeld, A. diSessa, and E. Stage (Lawrence Erlbaum Associates, Hillsdale, NJ, 1990), pp. 3-30.
5. "Learning to think like a physicist: A review of research-based instructional strategies," A. van Heuvelen, *Am. J. Phys.* **59**, 891-897 (1991).
6. "Modeling games in the Newtonian world," D. Hestenes, *Am. J. Phys.* **60,** 732-748 (1992).
7. "Force Concept Inventory," D. Hestenes, M. Wells, and G. Swackhamer, *Phys. Teach.* **30**, 141-158 (1992).
8. "Teaching problem solving through cooperative grouping. Part 1: Group versus individual problem solving," P. Heller, R. Keith, and S. Anderson, *Am. J. Phys.* **60**, 637-644 (1992); "Teaching problem solving through cooperative grouping. Part 2: Designing problems and structuring groups," P. Heller, M. Hollabaugh, *Am. J. Phys.* **60**, 627-636 (1992).
9. "Research as a guide for curriculum development: An example from introductory electricity. Part I: Investigation of student understanding," L.C. McDermott and P.S. Shaffer, *Am. J. Phys.* **60**, 994 (1992); Printer's erratum: *Am. J. Phys.* **61**, 81 (1993); "Research as a guide for curriculum development: An example from introductory electricity. Part II: Design of instructional strategies," P.S. Shaffer and L.C. McDermott, *Am. J. Phys.* **60**, 1003 (1992).

Continued on page 18

Continued from page 17

10. "Millikan Lecture 1994: Understanding and teaching important scientific thought processes," F. Reif, *Am. J. Phys.* **63**, 17-32 (1995).
11. "Using qualitative problem-solving strategies to highlight the role of conceptual knowledge in solving problems," W.J. Leonard, R.J. Dufresne, and J.P. Mestre, *Am J. Phys.* **64**, 1495-1503 (1996).
12. "More than misconceptions: Multiple perspectives on student knowledge and reasoning, and an appropriate role for education research," D. Hammer, *Am. J. Phys.* **64**, 1316-1325 (1996).
13. "Student expectations in introductory physics," E.F. Redish, J.M. Saul, and R.N. Steinberg, *Am. J. Phys.* **66,** 212-224 (1998).
14. "Do they stay fixed?", G.E. Francis, J.P. Adams, and E.J. Noonan, *Phys. Teach.* **36**, 488-490 (1998).
15. "Assessing student learning of Newton's laws: The Force and Motion Concept Evaluation and the Evaluation of Active Learning Laboratory and Lecture Curricula," R.K. Thornton and D.R. Sokoloff, *Am. J. Phys.* **66**, 338-352 (1998).
16. "Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses," R.R. Hake, *Am. J. Phys.* **66**, 64-74 (1998).
17. "First-year physics students' perceptions of the quality of experimental measurements," S. Allie, A. Buffler, L. Kaunda, B. Campbell, and F. Lubben, *Int. J. Sci. Educ.* **20**, 447-459 (1998).
18. "Millikan Lecture 1998: Building a science of teaching physics," E.F. Redish, *Am. J. Phys.* **67** (7), 562-573 (1999).
19. "Computers in teaching science: To simulate or not to simulate?" R.N. Steinberg, *Am. J. Phys. Suppl.* **68**, S37-S41 (2000).
20. "Oersted Medal Lecture 2001: Physics education research—The key to student learning," L.C. McDermott, *Am. J. Phys.* **69** (11), 1127-1137 (2001).
21. "Tapping epistemological resources for learning physics," D. Hammer and A. Elby, *J. of Learning Sciences* **12**, 53-90 (2003).
22. *Teaching Physics with the Physics Suite,* E.F. Redish (Wiley, 2003), Chapters 2, 7, 8, and 9.[B]
23. "A theoretical framework for physics education research: Modeling student thinking," E.F. Redish, from *Proceedings of the Varenna Summer School, "Enrico Fermi" Course CLVI,* edited by M. Vicentinni and E.F. Redish (IOS Press, Amsterdam), July 2003, pp. 1-63.
24. "Cognitive processes and the learning of physics, Part I: The evolution of knowledge from a Vygotskian perspective," V. Otero, and "Cognitive processes and the learning of physics, Part II: Mediated action," V. Otero, from *Proceedings of the Varenna Summer School, "Enrico Fermi" Course CLVI,* edited by M. Vicentinni and E.F. Redish (IOS Press, Amsterdam), July 2003, pp. 409-445 and pp. 447-471, respectively.

Acknowledgements

In closing, the authors of this letter, who served as co-facilitators of the group, wish to thank those who participated by sharing their expertise, experience, and insights (and completing homework assigned during unscheduled conference time): Saalih Allie (Univ. of Cape Town, South Africa), Eric Brewe (Hawai'i Pacific Univ.), Warren Christensen (Iowa State Univ.),

Continued on page 19

Continued from page 18

Ray Hodges (Univ. of Maryland), Rebecca Lindell (Southern Illinois Univ. Edwardsville), Rosemary Russ (Univ. of Maryland), MacKenzie Stetzer (Univ. of Washington), Michael Wittmann (Univ. of Maine), and Karen Wosilait (Univ. of Washington).

It is expected that, as the field of PER flourishes and evolves, the canon will be revisited and revised appropriately.

Footnotes

A) "Resource Letter: PER-1: Physics Education Research," L.C. McDermott and E.F. Redish, Am. J. Phys. **67**, 755-767 (1999) and "Resource Letter: RPS-1: Research in problem solving," L. Hsu, E. Brewe, T.M. Foster, and K.A. Harper, Am. J. Phys. **72** (9), 1147-1156 (2004).

B) Chapter 2 provides a succinct review of research results that motivate empirical and theoretical investigations in PER. Chapters 7 through 9 give sketches of various PER-based curricular materials that have been published for use in lecture, recitation, and lab/workshop environments.

John Thompson is Assistant Professor of Physics, Cooperating Assistant Professor of Education and Co-director of the Physics Education Research Laboratory at the University of Maine. Bradley Ambrose is Associate Professor of Physics at Grand Valley State University in Allendale, MI.

Trying to organize the conference photo………..

Conference Photo

Names are from left to right. The large group standing at the back is named en masse.

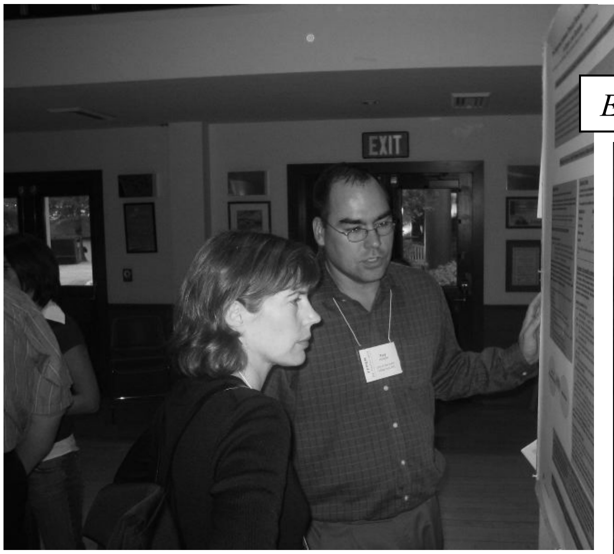
Standing: Gary Gladding, Joe Beuckman, Paul Camp, David Pritchard, Beth Lindsey, Mackenzie Stetzer, Warren Christensen, Saalih Allie, Andrew Crouse, Leon Hsu, Charles Henderson, Alan van Heuvelen, David Schuster, David Brookes, Andrew Elby, Roger Feeley, Tim McCaskey, Rebecca Lindell, Paul Hutchinson, Jeff Morgan, Ray Hodges, Constance Barsky, Leslie Atkins, Peter Shaffer, Andrew Boudreaux, Karen Wosilait, Bruce Birkett, Tim Steltzer, Tom Bing, Brad Ambrose, John Thompson, Jae-hyeok Choi, Eric Brewe, Michael Loverude, Dewey Dykstra, Don Mountcastle, Esther Zirbel

Seated: Luanna Ortiz, Andrew Heckler, David Meltzer, Valerie Otero, Karen Cummings, "Joe" Redish, Lillian McDermott, Steve Kanim, David Hammer, John Belcher, Eugenia Etkina

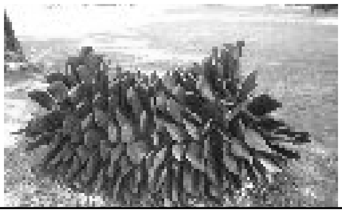
Kneeling: Eleanor Sayre, Nicole Gillespie, Jennifer Neakrase, Michael Wittmann, Paula Heron, Rachel Scherr, Dawn Meredith, Rosemary Russ, Laura Walsh, Melissa Dancy, Noah Finkelstein

Afternoon discussion breaks on a terrace overlooking the Atlantic

Evening poster sessions



Discussions in the dorms



Michael Wittmann attacked this pinecone sculpture one night. The pinecone won.

Physics Teacher Education Coalition

Section on Teacher Preparation

A Note from the Teacher Preparation Section Editor

Chance Hoellwarth

Future physics teachers have different needs than the typical physics major. In addition to a solid understanding of physics, teachers need to understand the difficulties students have with physics and they must know how to address these difficulties with effective instructional strategies. At most institutions, these skills are treated separately. The education department teaches about teaching and the physics department teaches physics. In the last issue of this newsletter, McDermott, Heron, and Shaffer made the case that K-12 teachers needed special courses, in addition to their content courses, that address all of these needs. It is not enough to have physics knowledge and a generic teaching course. Teachers need courses geared especially for teaching science.

In this issue we will hear from four institutions that have taken this message to heart and designed programs especially for high school physics teachers. These programs vary in style; there are integrated degrees, fifth year certification, and/or concentrations. But they all have designed programs (courses, teaching experiences, etc) that meet the needs of future physics teachers, explicitly addressing ways to facilitate the teaching and learning of science.

These stories are motivating and encouraging on their own, but I think they can also give ideas for improving the teacher preparation programs at our institutions. It is easy to read these stories and say, “That is a great program, but I could never do that at my institution.” And it may be true that you can not make wholesale changes in the way teachers are educated at you institution. But each of these programs has aspects that might just work at your institution and make your program better. For example, last spring I visited the University of Arizona. They have an amazing integrated physics-teaching program. That is not something I can implement at my institution. However, I left marveling at the involvement of their local teachers in the program and wondering how I can do the same thing here.

With that in mind, let’s hear about the programs at UTeach (University of Texas-Austin), University of Arizona, Illinois State University, and Rutgers.

Chance Hoellwarth is Associate Professor of Physics at California Polytechnic State University (Cal Poly), SanLuis Obispo.

UTeach

Michael Marder

History

UTeach, at the University of Texas at Austin, has become one of the largest and most successful programs preparing secondary science and mathematics teachers at a research university in the US. It came in part from the long delayed action of a law that had almost been forgotten by the time it had an effect.

The law was Texas Senate Bill 994 of 1987. Arguing that "greater numbers of bright students should be encouraged to enter the teaching profession" the law required that "undergraduate requirements for professional teacher education not extend beyond the quantitative equivalent of a typical minor." Secondary teachers were required to major in their discipline. Secondary education majors were abolished. Education coursework was capped at 18 hours. Responsibility for preparing teachers had been removed from education faculty, but without clearly being turned over to anyone else. The number of students obtaining secondary certification began to drop, particularly in the sciences. In 1997-1998, only 10 science majors obtained secondary certification in science at UT Austin, down from around 20 per year a decade before. Over 30 states now have such laws, and given today's insistence on basing educational decisions upon research, it would be interesting to see what their effect has been.

In 1997, the Dean of the College of Natural Sciences at UT Austin, Mary Ann Rankin, began searching for an alternative to outreach in the hopes of improving public school science and mathematics education. The greatest impact, she reasoned, would come not from after-school activities or summer camps, but by helping some of the College's best students to embark on careers as teachers. With encouragement and seed funding from Jeff Kodosky, physicist and co-founder of National Instruments, she convened a group of four award-winning secondary teachers, who spent the summer preparing a report on how they thought secondary teachers should ideally be prepared. One of these Master Teachers, former Texas Teacher of the Year Mary Long, took a permanent position with the college, and a first group 28 students enrolled in the fall of 1997. I joined the effort in the spring of 1998, rather unsure how all the courses needed to certify these students could be created or what they would be, but hopeful that since a measure of responsibility for teacher preparation had in principle been turned over to the college of science some solution should be possible. Apart from a tenured position in the physics department, and a high level of enthusiasm for the task at hand, my qualifications to lead a large new effort in teacher preparation were not obvious.

The Program

The development of UTeach involved many choices. It is hard to check the necessity and effectiveness of the primary components of UTeach in a systematic way, because we are reluctant to remove one by one the very elements that have made UTeach successful. Nonetheless, here are a few of what we believe to be the most important elements of our program:

Master Teachers

The instructional staff for UTeach within the College of Natural Sciences largely consists of former secondary teachers, employed full time to teach courses, organize field experiences for the future teachers including student teaching, and assist with many facets of education and outreach. We now employ seven.

Field Experience

UTeach begins with two one-hour courses that get students out into public schools as quickly as possible to begin teaching carefully supervised lessons. Field experience continues throughout the program and is woven into most of the courses.

Continued on page 24

Continued from page 23

The logic behind early field experience is that prospective teachers should find out as soon as possible whether they actually enjoy teaching children, and should make a graceful exit if they do not. Typically around 60% of those who begin the first one-hour courses continue on to the 3-hours courses.

Collaboration

UTeach involved from the start a very close collaboration with the College of Education. Jere Confrey, a Professor of Mathematics Education, was a co-founder of the program and greatly influenced all the UTeach courses. Three three-hour courses at the heart of UTeach have been developed and taught by the College of Education faculty. These courses are specific to the challenges of teaching secondary mathematics and science, and have little overlap with courses taught to elementary teachers. Traditional classes such as Observation, Educational Psychology, and Science Methods were eliminated in favor of a course sequence that focuses on how students learn, how teachers and students interact in classrooms, and how projects can be used to develop units of instruction. UTeach is administered by a joint committee from Education and Natural Sciences, and has co-directors in Education and Natural Sciences.

Degree Plans

We insist that all degree plans within UTeach be possible to finish within four years, and therefore UTeach poses no financial burden for a student who was going to obtain a degree anyway. Some UTeach students graduate under regular degree plans, adding teaching courses as a concentration. In addition we have worked out with every department in the College a Teaching Option that shaves off a small number of upper-division classes to make room for teaching coursework.

Student Support

We work aggressively to support students within UTeach. We reimburse them for the cost of the two introductory one-hour courses. All students are eligible to take internships, which are paid jobs with educational nonprofit organizations that range from opportunities to tutor children to preparation of educational software. We constantly search for scholarship support, and are able to give almost every student thousands of dollars to support their education. We have an excellent advising staff, and all instructors try to get to know the students, and to make UTeach a supportive community.

Funding

Rather than relying upon a succession of grants, the bulk of UTeach funding comes from permanent funds of the College of Natural Sciences. The Master Teachers, advisers, and additional support staff essentially constitute a new department, one that is devoted to preparing teachers. We have also raised a substantial endowment that enables us to support students, and to pay stipends to hundreds of teachers in the local school district who host our students and observe them during the field experiences.

Recruitment

We send letters about UTeach to all students entering the College of Natural Sciences as freshmen or as transfers. We mention UTeach during all College orientation sessions. We mail a letter to all continuing students once a year, and make public announcements about scholarship opportunities or other notable events so that the university community remains aware of our existence.

Other Elements

All UTeach students prepare a portfolio that documents their progress toward teaching proficiency. We have a required course on the history and philosophy of science and mathematics, a required course on performing scientific research, and a course on reading strategies. Students learn early on to prepare 5-E lesson plans[1], and employ this format through much of the program. We find that prospective teachers tend to want a carefully structured education,

Continued on page 25

Continued from page 24

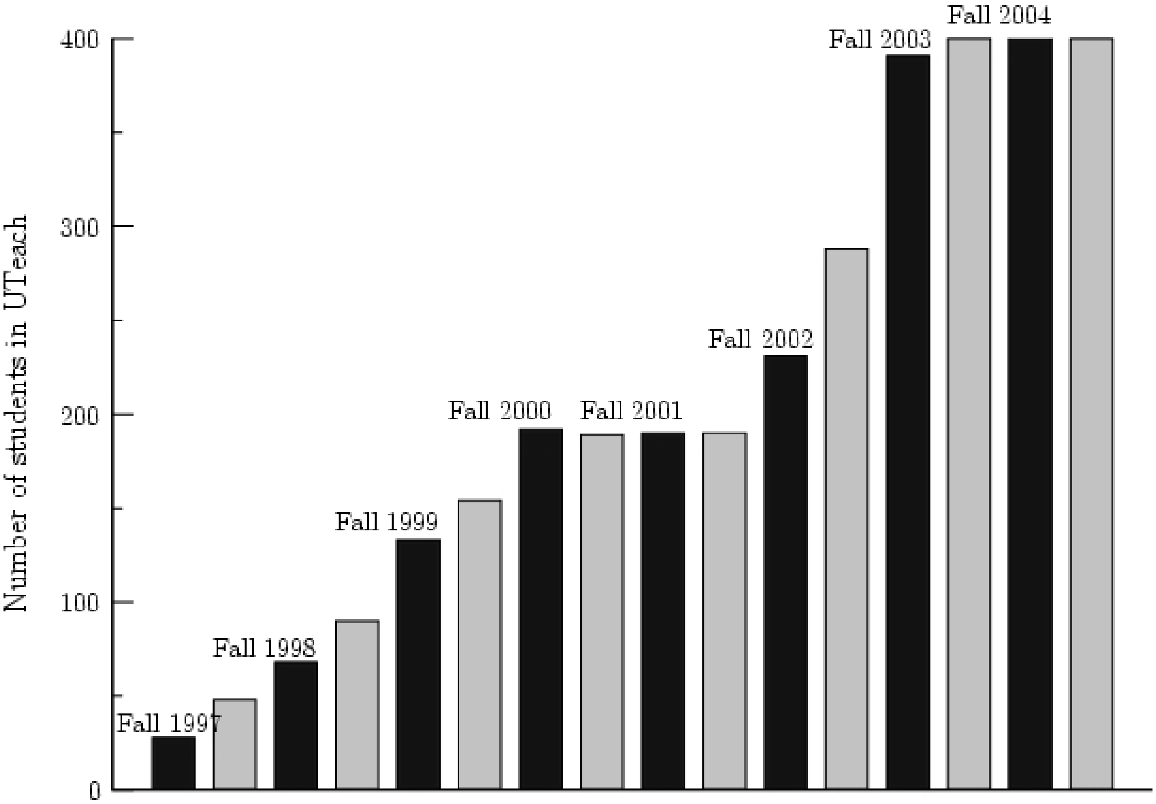


Figure 1: Growth of UTeach from 1997 to the present.

Outcomes

UTeach has grown to over 400 students, as shown in Figure 1. The number of graduates is shown in Figure 2 on the following page. Almost half the students are math majors, with the majority of science students majoring in biology. The number of UTeach physics majors is around 10, with 2-3 students obtaining physics certification per year. Sadly, this is a substantial percentage of the state total. The students overall are strong, with SAT scores and grade point averages a bit above the college as a whole. In addition to typical undergraduates, we also welcome applicants with college degrees who wish to obtain teaching certification. Our earliest graduates have been out now for four and five years, and over 75% of them are still teaching. We try to remain in touch with them and provide services ranging from extra support during the first critical years to a new Master's degree program.

Several other universities have already implemented programs that are loosely or closely based upon UTeach. The largest initiative to be influenced heavily by UTeach is the Science and Mathematics initiative in California[2]. UTeach required effort and planning to create, but its ingredients are not unique to Texas. Each UTeach graduate has a much more profound impact on public school students than the university could obtain in any other way. The frightening gap in mathematical and scientific competence between students in the US and other countries will not easily close, but we believe that helping strong students become great teachers is the best way to make progress.

Continued on page 26

Continued from page 25

References

1)http://www.bscs.org/page.asp?pageid=0|31|95|96&id=0|bscs_5es
2)http://www.universityofcalifornia.edu/academics/1000teachers/

Michael Marder is Professor of Physics and Co-Director of UTeach at The University of Texas at Austin. More information about UTeach is available at http://uteach.utexas.edu

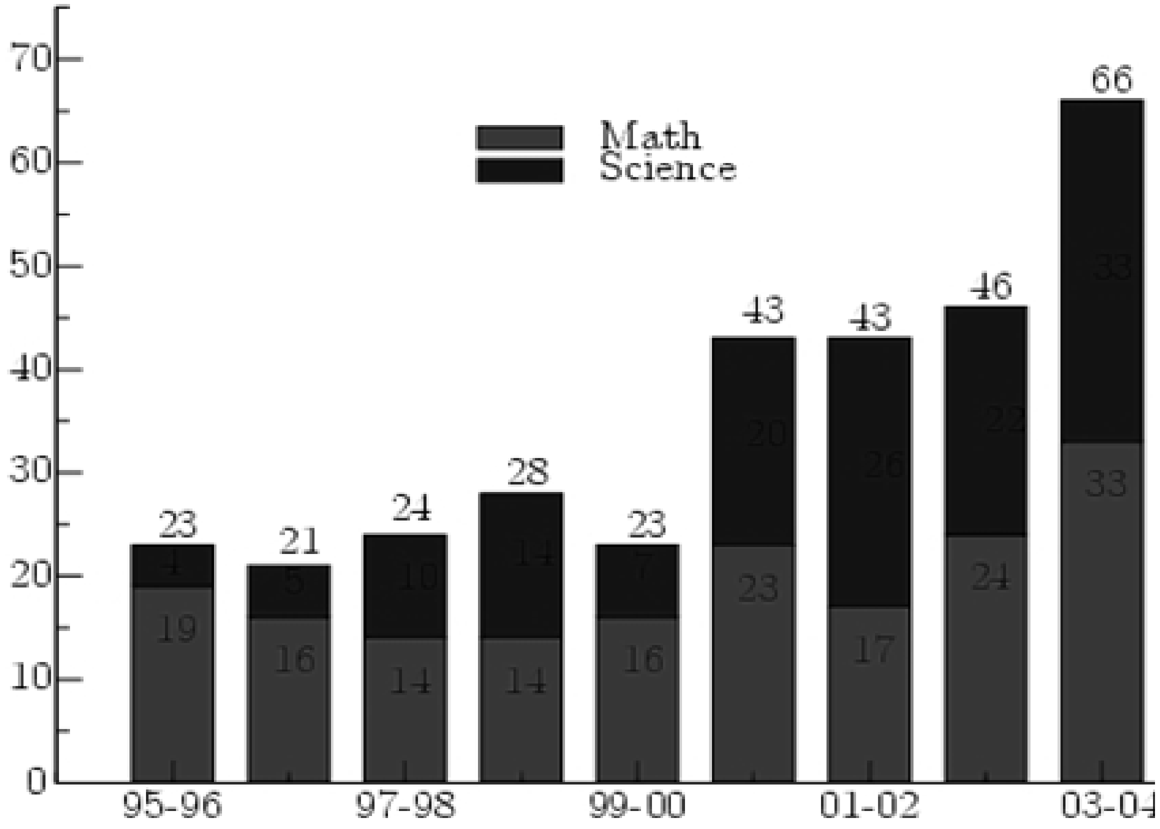


Figure 2: The numbers of science and mathematics majors obtaining secondary certification by year at UT Austin.

Development of the Physics Teacher Education Program at Illinois State University

Carl J. Wenning & Richard F. Martin, Jr.

Like many former state teacher's colleges, Illinois State University used to offer only degrees in teaching. In a statewide university growth spurt in the 1960's, the former physical science department split into separate physics and chemistry departments. The new physics department gained a second degree program titled "Arts and Sciences Physics" - essentially a traditional physics degree. As the university moved toward its current status as a comprehensive university, this "arts and sciences" degree, rechristened simply "physics", overshadowed the physics teacher education (PTE) degree to such an extent that by the 1990's the number of majors enrolled in the PTE program had dwindled to only a handful - five *total* in 1994, for example. It was at this point that the department decided that this situation was unacceptable and that the high school science students of the State of Illinois deserved better. There are many other contributing factors that led to this decision, including the desire to better prepare our PTE majors and the realization that science teaching was a growth field. Another motivation was partially self-serving – we reasoned that producing more and better secondary-level physics teachers would improve the quality, and potentially even the number of incoming freshmen in our own department.

While the number of physics majors was down across the nation in the mid-to-late 1990's, the Illinois State physics program held its own, even growing somewhat, to the extent that we were mentioned as one of the more successful departments in Ehrlich's 1998 article "Where are the physics majors?" (Ehrlich, 1998). We were invited, as an example of a successful program, to present at the conference on *Revitalizing the Undergraduate Physics Curriculum* in 1997, sponsored by the APS and AAPT. A significant contributor to this success was growth in the PTE program. Under new leadership, the program mushroomed such that by the fall 2005 semester it enrolled 40 physics teaching majors. The revised PTE program, briefly described in an earlier *Forum on Education* article (Wenning, 2001), was predicated on a number of "big ideas" that have guided the program through its development. Some of these ideas are presented here.

The re-emergence of the PTE program at ISU began with the hiring of a part-time PTE coordinator in 1994. The coordinator, a certified secondary high school physics teacher, was originally assigned the responsibility of running the PTE program as an adjunct to other existing duties. Being fully aware of the lack of physics teaching majors and the growing demand, a long-term effort was begun to develop a program that would attract more teacher candidates.

Beginning in 1994 four additional physics teaching methods courses were added to the PTE major. By 2001 the part-time coordinator had become full time, and PTE majors were taking six required physics teaching methods courses spanning 2.5 years and consisting of 12 semester hours. All six methods courses were described earlier in a *Forum on Education Newsletter* (Wenning, 2001). Up-to-date syllabi for each of these courses can be accessed online at http://www.phy.ilstu.edu/pte/. This sequence of courses is logically related and strongly coordinated. All have in some way been influenced by the *NSTA Standards for Science Teacher Preparation* and the *National Science Education Standards.* Each has as its focus some aspect of inquiry-oriented physics teaching. The sequence provides a systematic and comprehensive treatment of secondary-level pedagogical practices and scientific inquiry processes (Wenning, 2005a).

Continued on page 28

Continued from page 27

Our seven-step sequence for teacher preparation includes the following foci (Wenning, 2005b): 1) introducing inquiry, 2) modeling inquiry, 3) promoting inquiry, 4) developing inquiry, 5) practicing inquiry, 6) deploying inquiry, and 7) supporting inquiry. Courses, including student teaching and first-year induction activities, continue as novice teachers advance to become more seasoned professionals.

Much of the development of the PTE program was based on an assessment of teacher needs. A detailed teacher knowledge base was established following a literature review, after conversations with in-service teachers, and employing the coordinator's experiences with science teaching. This periodically reviewed and updated teacher knowledge base provides impetus for ongoing development within the PTE program. The knowledge base, consisting of 18 discrete elements, spans a range from content, pedagogical, and pedagogical content knowledge, through active learning, classroom management, and the nature of science.

Additional attention has been paid to candidate recruitment and retention. Special concern is shown for the physics teacher "pipeline" that conducts graduating high school students back to the high school classroom as teachers following university graduation. The Illinois Section of the American Association of Physics Teachers has been very active in this area (Wenning, 2004), and has made a number of recommendations to help improve the process that the ISU PTE program is attempting to more fully implement. The ISU program is now working cooperatively with a number of professional societies within Illinois in an effort to increase the number of teacher candidates in all areas of science and mathematics.

The ISU Physics Department directly recruits students not only for the PTE sequence, but all four sequences within the major – physics, computational physics, engineering physics, and physics teaching. Efforts include personal letters to high school science teachers, personal contacts with prospective students such as phone calls by female majors to female applicants, a departmental scholarship program, and a growing outreach program consisting of Saturday fun physics presentations and hands-on programs, an annual "Expanding Your Horizons through Math and Science" program for middle school girls, participation with the local children's science museum and Challenger Learning Center, and a student-centered traveling outreach show instigated by a "Physics on the Road" grant. However, underlying all these efforts is an underlying long-term effort to create better relationships with high school physics teachers.

Much of the recruitment for the Illinois State University PTE program is of this latter indirect variety. Goodwill generated through summer physics teacher workshops appears to be having a positive impact on enrollment. For instance, from 2001-2005 ISU was an AAPT/PTRA Rural Center offering summer professional development activities for teachers within about 100 miles of Normal, IL. During 2001, 2003, and 2005 grants were obtained to host two- and three-week-long Modeling Method of Physics workshops. Participating teachers, as well as ISU PTE program graduates, have been channeling PTE majors and other physics majors to ISU. Combined with our other recruitment activities, we have seen strong growth in the teacher education program. Today it is not uncommon to see a dozen or more PTE majors enrolled in a single physics teaching methods course as a result of these and similar efforts. It is expected that some 18 PTE majors will graduate over the course of the next two spring semesters.

A fortunate set of circumstances appears to have allowed these improvements in the Illinois State PTE program, including:

1) The PTE coordinator who took over the program in 1994 was: (a) passionately committed to improving the teacher preparation process,

Continued on page 29

Continued from page 28

(b) an certified secondary school teacher with knowledge of the teacher preparation process, (c) a dedicated teacher capable of modeling effective teaching for others, and (d) willing to learn the best practices and deal with the administrative details involved in the certification process.

2) The coordinator was given the resources and release time necessary for properly educating teacher candidates, for incorporating external standards, and for participating in and providing professional development activities.

3) Department chairpersons who, over more than ten years, recognized the importance of the PTE program and a physics faculty open to being educated in the ways and worth of physics teacher education and who frequently lent support to the coordinator's efforts.

These circumstances have been generalized into set of five change principles (Wenning 2003) applicable to building up similar programs at other institutions.

The success of our program is a synergistic effect of many contributors coordinated by a teacher education leader. There are no magic bullets here. We believe that the process can be replicated in any department ready to support such a project. The growth of our program has indeed aided our recruitment of physics majors in all degree sequences. It is not uncommon now to hear from new freshmen that they had one of our graduates as their high school physics teacher - and we would not be surprised if a recent increase in our incoming freshman ACT scores could be partially attributed to better physics education at the secondary level.

As a result of program improvement and both indirect and direct recruitment procedures, the this past year, the department remains one of the top ten producers of physics degrees from undergraduate-only departments, a distinction held since the late 1990's. Although we know of no national statistics, we suspect our average number of physics teacher graduates per year since 2000 would also rank us highly - perhaps an unfortunate comment on the current national shortage of physics teachers.

References:

Ehrlich, R. (1998). Where are the physics majors? American Journal of Physics, 66(1), 79-86.

Wenning, C.J. (2002). Physics Teacher Education at Illinois State University, *Forum on Education,* American Institute of Physics, Summer Issue, June 2001. Available: http://www.aps.org/units/fed/newsletters/summer2001/wenning.cfm

Wenning, C.J. (2003). Change principles for departmentally-based physics teacher education programs. *Journal of Physics Teacher Education Online, 2*(1), 7-12. Available: http://www.phy.ilstu.edu/jpteo/

Wenning, C.J. (2004). Repairing the Illinois high school physics teacher pipeline: Recruitment, preparation and retention of high school physics teachers ~ The Illinois model. *Journal of Physics Teacher Education Online, 2*(2), 24-32. Available: http://www.phy.ilstu.edu/jpteo/

Wenning, C.J. (2005a). Levels of inquiry: Hierarchies of pedagogical practices and inquiry processes. *Journal of Physics Teacher Education Online, 2*(3), 3-11. Available: http://www.phy.ilstu.edu/jpteo/

Wenning, C.J. (2005b). Implementing inquiry-based instruction in the science classroom: A new model for solving the improvement-of-practice problem. *Journal of Physics Teacher Education Online, 2*(4), 9-15. Available http://www.phy.ilstu.edu/jpteo/

Carl J. Wenning is Lecturer in Physics and Coordinator of the Physics Teacher Education Program at Illinois State University. Richard F. Martin, Jr. is Professor of Physics and Chair of the ISU Physics Department. Both can be reached at Campus Box 4560, Normal, IL 61790-4560 or 309-438-8756.

Preparing Tomorrow's Physics Teachers

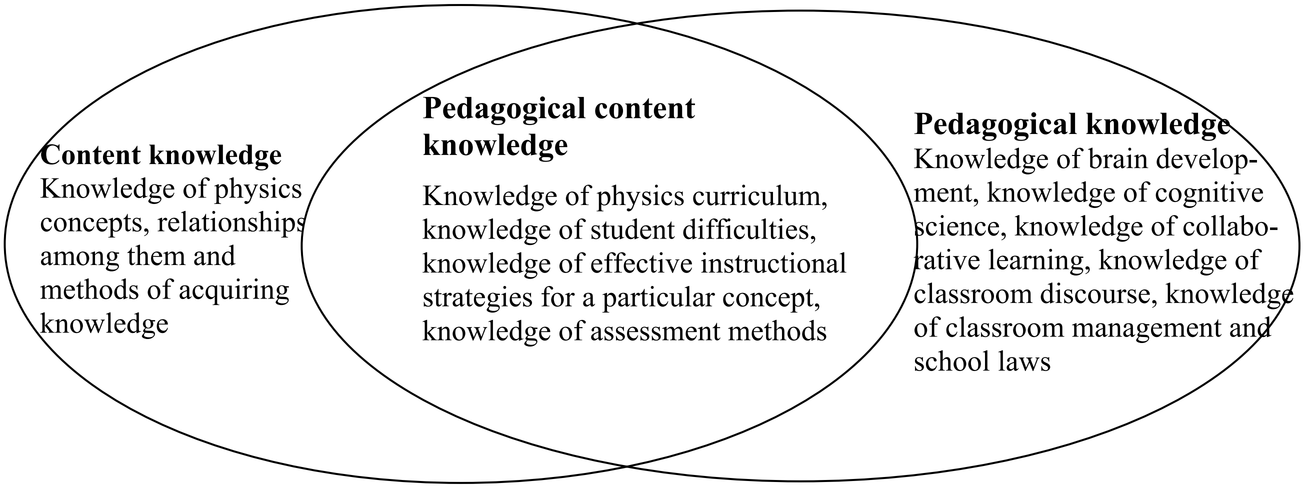
Eugenia Etkina

What does a physics teacher need to know and be able to do?

American students studying science are expected not only to master the fundamental concepts of the discipline but more importantly to understand the methods of inquiry in science. The workplace now expects graduates to be able to use scientific knowledge to design experimental investigations, devise and test models of natural phenomena, work collaboratively, and communicate effectively. Research in education demonstrates that the success of the current reform goals in K-12 science education depends on the preparation of teachers[1,2]. In addition to knowing the content and the methods of scientific inquiry teachers should be able to create learning environments in which students can master the concepts and processes of science while working with their peers. Students will not learn if content knowledge is simply transmitted to them.

Teachers should know how people learn, how the human brain functions, how memory operates and how a brain develops with age. However, content knowledge and knowledge of learning and learners cannot be considered separate domains. Teachers should possess "special understandings and abilities that integrate their knowledge of science content, curriculum, learning, teaching, and students. This special knowledge called pedagogical content knowledge (PCK), distinguishes the science knowledge of teachers from that of scientists"[1]. Pedagogical content knowledge, defined by L. Shulman as "the special amalgam of content and pedagogy that is uniquely the providence of teachers, their own special form of professional understanding…"[3], has become a key word in teacher preparation and assessment. Another important idea is that teaching science based on the methods advocated by current reforms is fundamentally different from how teachers learned science themselves[4]. Yet research indicates that teachers tend to teach the way they have been taught.

Fig. 1. The structure of teacher knowledge



Content knowledge
Knowledge of physics concepts, relationships among them and methods of acquiring knowledge

Pedagogical content knowledge
Knowledge of physics curriculum, knowledge of student difficulties, knowledge of effective instructional strategies for a particular concept, knowledge of assessment methods

Pedagogical knowledge
Knowledge of brain development, knowledge of cognitive science, knowledge of collaborative learning, knowledge of classroom discourse, knowledge of classroom management and school laws

Continued on page 31

Continued from page 30

Building a physics teacher preparation program

The considerations above suggest that in a successful physics teacher preparation program future teachers should learn the content and the methods of the discipline in environments similar to the ones that they will need to create for their students. They also need to acquire pedagogical content knowledge (PCK). See Figure 1 above. However, if one cannot learn physics by just listening and reading but rather one needs to be engaged in the active process of knowledge construction, the same should apply to acquiring PCK. That is, one can only acquire PCK by actively constructing it in the process of teaching. Thus clinical practice, an opportunity to engage in interactions with learners, that model good teaching becomes very important for teacher preparation. Hence, we can now define the characteristics of a potentially successful physics teacher preparation program:

1. Future teachers learn physics through the same methods that they should use when teaching.
2. They acquire knowledge of how people learn in general and how they learn physics in particular.
3. They engage in teaching in environments that mirror the environments that we want them to create later.

Two more considerations are important. Teachers prepared today will be teaching for the next 25-30 years. Thus we need to include elements in the teacher preparation program that will give teachers ways of keeping abreast of new technological developments. We also want the teachers to be able to bring the spirit of authentic science into the classroom.

So, we need now expand the characteristics of an exemplary teacher preparation program:

4. Future physics teachers master technology that they can use in the classroom and acquire methods of updating their knowledge and skills.
5. Teachers to be learn ways to engage their students in authentic scientific practices.

These five characteristics are the features of the physical science teacher preparation program at Rutgers.

Rutgers has two teacher preparation programs that both result in the same master's degree and a certificate to teach physics and/or physical science. (In the state of New Jersey all certification programs require a major in the subject being taught.) One is a post baccalaureate program and the other is a 5 year program. In the 5 year program students begin taking courses in the school of education in their 4th year of undergraduate studies and then continue in the 5th year. Both are 45-credit programs that can be completed in a minimum of two full academic years. The majority of the students are post baccalaureate.

The distribution of the course work in these programs is as follows:

Physical science methods courses where students acquire physics PCK, the knowledge of using technology and how to bring authentic science experiences into learning physics – 18 credits

General education courses where students acquire knowledge of learning and learners – 12 credits

Clinical practice where students observe teaching and teach physics - 9 credits

Graduate level (300-400) physics courses - 6 credits.

Fine-tuning the preparation of physics teachers

The main threads running through physics-related methods courses and clinical practice are the epistemology of physics, physics reasoning, formative assessment (assessment of student work in the process of learning), and reflection on learning. Although students have (or are finishing) an undergraduate degree in the discipline, they usually learned the subject through traditional lecture-based instruction and not through the methods that they will need to use when they themselves teach.

Continued on page 32

Continued from page 31

Thus in all courses pre-service teachers re-learn (or re-examine) physics ideas via the methods that they can later use with their students. For example, future teachers learn how to select phenomena for their students to first observe and later explain. They learn how to perform experiments to test predictions and to see whether the explanation survived empirical testing[5]. In other words, they engage in scientific investigations and by doing this learn how to engage their future students in similar activities. They participate in a learning process that we want them to model for their students in the future. There is a significant focus on formative assessment and feedback; when a student completes any assignment, she/he receives feedback suggesting improvements and subsequently revises the assignment. In all courses students teach a lesson in class – after the lesson plan has received multiple levels of feedback and undergone multiple revisions. In each class meeting, students reflect on the teaching methods that helped them learn.

The Physics Methods Courses

Below we briefly describe each physics methods course.

Development of Ideas in Physical Science (1st year, fall semester) – students learn the processes that scientists used to construct concepts and relationships that make up the content of physics courses in a high school. Students learn to distinguish between experimental work, theoretical explanations and modeling, and testing. They read and discuss original works, replicate classical experiments and learn to adapt them for a high school setting. Students learn about the personalities and lives of famous scientists. They design and teach a 2-hour lesson that engages high school students in the construction of a particular concept following a historical sequence of events (for example that light can be modeled as a wave). Again, the students design the lesson, receive feedback, revise it, and only then teach it in class. They enact a story telling piece (as a mini-play) about the life of one of the physicists involved in the development of that idea.

Teaching Physical Science (1st year, spring semester) -- students re-learn and re-examine the physics curriculum through the lens of inquiry-based interactive teaching methods. They participate as students in physics lessons that model high quality instruction and then reflect on their experiences. They investigate different physics curricula and resources - tutorials, interactive demonstrations, workshop physics[6], *ISLE*[7] ,etc., master different methods of assessing their students and discuss the difficulties that high school students might have with various concepts[8]. At home, students write reflective journals reconstructing class experiences[9]. They design a curriculum unit (for example: Electrostatics) and a lesson that is a part of that unit. They design a unit, attempt it on their own (working in groups), receive feedback from the instructor, revise the unit, rehearse the lesson further and then teach it in class.

Demonstration and Technology in Science Education (1st year, spring semester) – students learn how to use computer interfaces to collect and analyze data, videotape physics experiments, design webpages and use them in the classroom. They learn about available technology-based physics learning software such as ActivPhysics, Webtop, etc. As a final project they make a movie of a physics experiment and embed it into a lesson.

Research Internship in X-ray Astrophysics (Summer after 1st year) –Our teachers-to-be engage in x-ray astrophysics research. They also observe high school juniors learning physics and astrophysics via the same research methods as well as the methods that the teachers-to-be experienced in the courses described above. (Details of this program, called Rutgers Astrophysics Institute, can be found in reference 10)[10].

Student Teaching Internship Seminar (2nd year, fall semester) – This course accompanies student teaching. Students reflect on their teaching experiences, share problems and discuss solutions together.

Continued on page 33

Continued from page 32

They design a curriculum unit and lessons, receive feedback and use these materials directly in their student teaching experience. They create a teaching portfolio to use when applying for a job, including their teaching philosophy statement.

Multiple Representations in Physical Science (2nd year spring semester) –Here students reexamine physics though the lens of multiple representations. They study research articles examining the role of different representations in learning science; they think of how their future pupils will learn to use them for problem solving, they create multiple representations tasks and rubrics for assessment. They design a representations-based lesson, revise it with the instructor, and then teach the lesson in class.

Clinical practice (teaching) is strongly emphasized in the program. In the fist year students teach recitations and labs in reformed interactive-engagement physics courses. In the summer they work with high school students in the Rutgers Astrophysics Institute. In the second year they do four months of student teaching, often being placed with prior graduates of the program, who can reinforce what the new student teachers have been learning.

Does the program work?

The first indication that the program is succeeding is an increase in the number of graduating students (1 student in 2003, 5 students in 2004 and 7 in 2005). For a small school of education (we graduate only about 60 elementary school teachers per year), these are very impressive numbers. We think that one of the reasons for the increase is the unique structure of the program which focuses on learning how to teach physical science not all sciences together.

The second indication that the program is succeeding is the transformation of students in the program. They come to understanding what good teaching is and what a person should know to be a successful physics teacher. Space does not permit a detailed discussion. However, we can say that students' conception of a successful teacher changes from one who is knowledgeable in the content, has good organization skills, and can make physics fun, to a conception of a teacher who can engage students in an inquiry-based exploration of nature, knows how students learn, knows what will facilitate learning of the most difficult, abstract concepts in physics and who is able to plan lessons with all this in mind. When asked about knowledge gained in the program, students consistently list the knowledge of physics and being able to see physics everywhere, the understanding of how scientists construct their own knowledge, and the understanding of how students learn. When asked about skills, students say that they learned how to write a unit plan, plan a lesson and teach a lesson. They say that they learned how to design a test that probes a students' true understanding of the material and creativity as an experimenter. They often mention that they learned how to engage students in scientific investigations, how to motivate students using challenging problems, how to organize lessons so that new material builds on previously learned knowledge, how to use multiple representations in a classroom, how to organize students in groups, and how to write an exam using non-traditional questions. Although the above might sound impossible to master, the fact that students think they learned these things tells us that they are aware of their importance[11].

The third indication that the program is succeeding is the comments of cooperating teachers during student teaching. In interviews they mention the unique preparation of Rutgers interns: their content knowledge, their ability to bring inquiry to the classroom, their ability to use technology in a productive way, their skill at lesson planning and implementing what was planned and, most importantly, their ability to make students active participants in learning. To date, all graduates of the program found jobs and are teaching. Perhaps the most compelling evidence of the success of the program is the comment

Continued on page 34

Continued from page 33

that one graduate made when meeting with a new cohort: “In my first year of being a high school teacher I had more happy days at work than in all ten years of being an engineer”.

References

1. National Research Council, *National Science Education Standards.* (National Academy Press, Washington, D.C. 1996).
2. National Commission on Mathematics and Science Teaching for the 21st Century. *Before It's Too Late*. (National Academy Press, Washington, D.C. 2000).
3. L. S. Shulman, L. S. "Knowledge and Teaching: Foundations of the New Reform." Harvard Education Review, **57** 1-22 (1987).
4. American Association for the Advancement of Science *Blueprints for Reform; Science, Mathematics and Technology Education: Project 2061*. (Oxford University Press, New York 1998).
5. E. Etkina & A. Van Heuvelen, “Investigative Science Learning Environment: Using the processes of science and cognitive strategies to learn physics,” *Proceedings of the 2001 Physics Education Research Conference*. (Rochester, NY, 17-21, 2001).
6. *The Physics Suite*. A series of curriculum materials including *Interactive Tutorials* (M. Wittmann, R. Steinberg, and E. Redish), *Interactive Lecture Demonstrations* (Sokoloff, D., and Thornton, D.), *Real Time Physics* (D. Sokoloff, R. Thornton, and P. Laws) and *Workshop Physics* (P. Laws). (Wiley, Hoboken: NJ. 2004)
7. A. Van Heuvelen and E. Etkina. *Active Learning Guide*. (Addison Wesley, San Francisco, CA 2006).
8. R. Knight. *Five easy lessons*. (Addison Wesley, San Francisco, CA 2003).
9. E. Etkina. “Weekly Reports: A two-way feedback tool.” Science Education, **84**, 594-605 (2000).
10. E. Etkina, T. Matilsky, and M. Lawrence “What can we learn from pushing to the edge?” Journal of Research in Science Teaching, **40**, 958-985 (2003).
11. E. Etkina “Making a dream teacher”. Invited presentation at the AAPT National Meeting, Sacramento, California, August 2004.

Eugenia Etkina is Associate Professor in the Graduate School of Education, Rutgers, The State University of New Jersey.

Secondary Science Teacher Preparation at the University of Arizona

Ingrid Novodvorsky

Undergraduate students at the University of Arizona who wish to become middle or high school science teachers have a unique opportunity to pursue their goal in the company of other science majors under the guidance of science educators and experienced mentor teachers. In this article, I present some of the central ideas that guide this teacher preparation program, and how those ideas are implemented. I conclude with information about program enrollment and teacher retention.

As described in an article in the Spring 2005 issue of this newsletter, the Teacher Preparation Program (TPP) was established at the University of Arizona in 1999 to provide preparation for prospective middle and high-school science teachers within the College of Science. Faculty members in the program are affiliated with various content departments, including physics, chemistry, molecular and cellular biology, astronomy, and biochemistry, and function as members of an interdisciplinary program in managing the program, teaching its courses, and advising students.

Continued on page 35

Continued from page 34

Early in the program, we developed a set of Core Understandings, which form the underpinnings of all of our science education courses and guide assessment of both students and the program. (See Appendix for a list of these Core Understandings.) The science-education courses in the program are all linked to one or more of these Core Understandings, and they form the basis of our regular internal program reviews. We have found that these Core Understandings enable us to talk about our courses and student performance in ways that faculty members in content departments often do not. We all know the content of each other's courses very well, we collaborate in planning and teaching the courses, and we regularly discuss our students' progress toward attaining the Core Understandings.

Another central idea that guides our program is the key role of middle and high school science teachers. In the Spring 2005 issue of this newsletter, I described the work of our Teacher Advisory Group in shaping the direction of the program and in hosting preservice teachers in their classrooms. We collaborate closely with science teachers in two other ways. First of all, we have hired two retired high-school science teachers who work with our program on a continuing basis. These two adjunct instructor positions are funded through a University Workforce Development Initiative, which resulted from a voter-approved state sales tax increase; this funding is secure through 2010. Secondly, we have secured grant funding to support two Teachers in Residence each year. These teachers work with us on campus for a year as adjunct instructors, while we pay their districts the cost of replacement teachers. Currently, one Teacher in Residence is funded by the PhysTEC project, and the Howard Hughes Medical Institute funds the other. As both of these grants are ending soon, we are working with the Dean of the College of Science to secure other funding, possibly by asking the departments that participate in the TPP to share the cost of these two Teachers in Residence.

These four adjunct instructors co-teach science pedagogy and subject methods courses with TPP faculty members, arrange for and supervise the field placements of our students in area schools, mentor the preservice teachers in our program, and participate fully in all program activities. In addition to their work with the program, they are especially valuable due to their recent experience in secondary schools. While most of the TPP faculty members also have secondary school teaching experience, the Teachers in Residence have much more current experience and our students find this particularly valuable.

A third central idea that guides our program is closely related to our partnership with area science teachers. When our students are placed in these teachers' classrooms they have clearly defined tasks to accomplish, instead of being sent to passively observe. The field experiences in our program are divided into three general categories, guided observation, internship, and student teaching. In all three of these categories, our partner teachers have played a critical role in shaping the field experiences. At the guided observation level, partner teachers wrote most of the tasks that preservice teachers are asked to complete, and we consult with them regarding major modifications to these tasks. At the internship level, which is an 8-week experience working with one class, partner teachers have provided input on both structure and expectations. And for the student-teaching experience, which encompasses an entire secondary-school semester, partner teachers work closely with our adjunct instructors in supervising the student teachers.

Continued on page 36

Continued from page 35

The table below indicates enrollments over the lifetime of the program. We anticipate a steady state of about 20 program completers each year.

	2000-01	**2001-02**	**2002-03**	**2003-04**	**2004-05**	**2005-06 (proj.)**
CoS TPP Course Enrollment	26	35	67	100	114	135
CoS TPP Completers	5	1	5	14	8	11
Physics teachers prepared#	0	0	2	1	1	3*

#Prior to TPP, ~ 6 science teachers graduated each year from College of Education; 2 physics teachers graduated in 4 years

*2 of these 3 are women

It is also important to note that of the 33 program completers by the spring of 2005, every completer who sought a teaching position secured one, and is still teaching. This is in contrast to national statistics which indicate that only about 2/3 of new science teachers stay in teaching past their third year, and only about half remain past their fifth year. (Five of our completers have chosen to pursue other avenues, including medical school, nursing school, research, and at-home parenting.)

These data and our own experiences lead us to believe that over the past five years we have built a vibrant science teacher preparation program, grounded in Core Understandings, closely connected with the local science-teaching community, and visible within the College of Science.

Appendix
CoS TPP Core Understandings

Prospective teachers will:

1. *Demonstrate understanding of their science disciplines and the nature of science. They understand science deeply enough to build alternative representations of the scientific knowledge that are pedagogically sound and meaningful for diverse learners.*

a) Articulate and connect the central ideas in their scientific discipline.

b) Demonstrate solid and coherent conceptual understanding of the central ideas and tools of inquiry of school-based scientific disciplines, particularly in their area of expertise.

c) Critically reflect on the philosophical and social facets of the scientific work.

d) Build multiple meaningful and appropriate pedagogical representations of the science content to be taught.

2. *Demonstrate understanding of how adolescents learn and develop. They display a philosophy of teaching that focuses on students' understanding.*

a) Analyze and evaluate the central tenets of relevant theories of learning and adolescent development.

b) Demonstrate knowledge and understanding of students' common alternative conceptual frameworks in science and the role that they play in learning.

c) Use their scientific and pedagogical knowledge to conceive meaningful learning opportunities that recognize learners' diversity and focus on students' understanding.

Continued on page 37

Continued from page 36

3. *Make coherent curriculum decisions that promote students' engagement in learning and understanding of science; plan, implement, and assess lessons with the learning goals guiding their choices and actions.*
a) Identify and describe the curriculum/teaching decisions that influence learning outcomes.
b) Identify and select coherent sets of long-term and short-term learning goals.
c) Select and create meaningful activities that build upon students' interests and prior knowledge and promote understanding.
d) Implement and evaluate diverse teaching strategies and materials to achieve instructional goals and meet student needs.
e) Select and implement assessment strategies that support understanding.
f) Analyze assessment data to guide teaching.
g) Assess the coherence of curriculum/teaching decisions that influence learning outcomes.

4. *Create and manage a productive learning environment that fosters the development of student understanding.*
a) Demonstrate and use knowledge about human development, motivation and behavior to create an engaging, safe and supportive learning environment.
b) Recognize, describe, and implement effective classroom management practices that are fair to students and support individual and group work.
c) Recognize, describe and analyze the connection between effective classroom management and opportunities for student learning.

5. *Establish clear communications and positive interactions with learners, colleagues, administrators, and parents. They are comfortable interacting with members of these groups and actively work to become a part of the school culture.*
a) Present ideas and information, outline expectations and desired behaviors, ask questions and facilitate discussions in clear and unambiguous ways.
b) Interact with individual learners and groups of learners in ways that develop a climate of respect and rapport in the classroom.
c) Collaborate with colleagues, administrators, parents and other members of the community to support student learning.

6. *Acknowledge the complex and often unpredictable contexts in which teachers work. They manage the complexity in ways that support and sustain student learning.*
a) Identify the professional demands that compete for a teacher's attention.
b) Identify and evaluate teaching and curriculum dilemmas and suggest possible actions.
c) Assess teaching decisions in light of the competing demands and dilemmas that teachers face.

7. *Reflect on classroom teaching to identify evidence of student understanding; thoughtful consideration of this evidence results in well-grounded decisions to improve practice. They are comfortable in continually questioning their own practice and beliefs, are open to constructive criticism, and actively seek out opportunities to grow professionally.*
a) Pose reflective questions about the teaching/learning process related to their own teaching and the teaching of others.
b) Gather evidence to answer their own questions about the teaching/learning process.
c) Use their knowledge of practical evidence to plan and implement changes in the classroom.
d) Evaluate the learning outcomes of their actions and be open to the constructive criticism and suggestions of supervisors and colleagues.
e) Reflect critically on their personal beliefs about science, and science teaching and learning.
f) Self-assess their weaknesses and strengths and utilize human and institutional resources to develop professionally.

Ingrid Novodvorsky is Senior Scientist in the Department of Physics and Director of the College of Science Teacher Preparation Program at the University of Arizona.

Browsing the Journals

Thomas Rossing

- "Do US high schools dedicated to science generate future academics or burnt-out whiz kids?" is a question addressed in a news feature in the 16 June issue of *Nature*. There are now some 86 science magnet schools nationwide, which select gifted children with an aptitude for science. Australia, Jordan, Israel, Korea, Thailand, Japan and the United Kingdom have set up similar science-focused schools. The two high schools focused on are Thomas Jefferson High School for Science and Technology in Alexandria, Virginia and the Illinois Mathematics and Science Academy (IMSA) in Aurora. Competition inevitably arises when over-achieving students are placed under one roof, but most teachers promote group, rather than individual, efforts. Neither high school calculates class ranks, and there are no valedictorians. Most students interviewed were positive about their experiences. About 40% of alumni earn a graduate degree, with healthcare and computer professions as the top career fields.

- "There is a myth in academia that people in universities work the hardest. There is also a myth that good students become professors and everyone else goes off to work in the real world. Also not true," according to Steve Koonin, physicist, as quoted in the September issue of *Physics World*. Koonin took leave of his position as provost at Caltech to become chief scientist for BP. However, business people are sometimes astounded at the way he is able, as a physicist, to come to conclusions with the minimum of reasoning.

- "Will today's students learn important science lessons and acquire the necessary job skills by playing video games, or will the role information technology plays in 21st-century science education evolve in ways that we cannot yet envision?" is a question raised in a front-page story in the July/August issue of *NSTA Reports.* Susan Patrick, director of educational technology for the Department of Education is quoted as saying, "The paper-based system does not make any sense to kids who are coming up in school. Is our educational system geared toward innovation? Do we want an 18th-century model or a 21st-century model for our schools? The 18th-century model is the one we have now."

- The first of three editorials on the state of engineering education appears in the May issue of *Sound & Vibration.* The author, a professor of mechanical engineering, extols the virtue of "hands-on" experience, which means designing and constructing one's own apparatus, sometimes individually, sometimes in small groups. In a typical project, students use CAD and other tools to design a mechanical system, complete with engineering drawings, which they then fabricate in the machine shop.

- "Manna from Heaven or 'Clickers' from Hell" is the title of an article in the July/August issue of *Journal of College Science Teaching.* Clicker technology, which is becoming popular in large lecture classes, refers to a computer-mediated, wireless response system that asks students to respond electronically to questions designed to stimulate discussion. A clicker system typically consists of three parts, small remote control-like devices used by students, receivers, and a program installed on the instructor's computer. Student clickers emit infrared signals that are picked by the receiver. In spite of many frustrations in getting the system up and running smoothly, the authors concluded that the positive outcomes far outweigh the negatives.

Continued on page 39

Continued from page 38

- Having a good mentor can determine the direction and probability of success for a young researcher, according to an article in the 21 July issue of *Nature* entitled "Learning to Mentor." Mentoring takes skill, and institutions are paying attention to mentoring post docs to develop their skills as teachers as well as researchers. Making the transition from having a mentor to being one is harder than one might think. Managing people, rather than experiments, is unfamiliar territory for many early-career scientists.

- Societal issues, such as global warming and stem cell research, now more than ever show why we must take the advice of novelist/physicist C. P. Snow and bridge the two cultures of the sciences and the humanities, according to an article in the September issue of *Journal of College Science Teaching.* George Ellis, the renowned humanitarian and physicist, refined Snow's vision by describing the need for three types of experts, researchers, generalists, and synthesizers, to address contemporary complex issues. Science education should encourage interdisciplinary collaboration among all three types of scholars.

- The October issue of *Journal of Science Teaching* features a set of articles on the use of case studies in science. The case method, which has long persisted in business, medical, and law schools, now promises to do the same in undergraduate science courses. Far and away the most popular tactic for many faculty when teaching a case is the method of "progressive disclosure," where the story is provided piecemeal to students who must act as detectives to solve the mystery. Students who become involved in case analysis and the construction of solutions to the problems raised are likely to remember them and become more confident in their own problem solving ability.

Thomas Rossing is Distinguished Professor Emeritus of Physics at Northern Illinois University. He is a Fellow of ASA, AAAS, and IEEE as well as APS and edits the fall issue of the Forum on Education newsletter.

Executive Committee of the Forum on Education

Chair
Ramon E. Lopez
Florida Inst. of Technology, Melbourne, FL 32901
TEL: (321) 674-7348
relopez@fit.edu

Chair-Elect (and Chair of Program Comm.)
Margaret McMahan
LBNL, One Cyclotron Rd , Berkeley, CA 94720
TEL: (510) 486-5980
p_mcmahan@lbl.gov

Vice-Chair (and Chair of Nomin, Comm.)
David Glen Haase
North Carolina State Univ., Raleigh, NC 27695
TEL: (919) 515-6118
david_haase@ncsu.edu

Past Chair
(and Chair of Fellowship Committee)
Gay B. Stewart
University of Arkansas, Fayetteville, AR 72701
TEL: (479) 575-2408
gstewart@comp.uark.edu

Secretary-Treasurer
Bruce A Mason
Univ of Oklahoma, Norman, OK 73019-0225
TEL: (405) 325-3961
mason@mail.nhn.ou.edu

Forum Councillor
Peter D. Zimmerman
King's College, London WC2R 2LS U.K.
peter.zimmerman@kcl.ac.uk

General Member-At-Large
Lawrence D Woolf
General Atomics, San Diego, CA 92121
TEL: (858) 526-8575
larry.woolf@gat.com

General Member-At-Large
David Elliott Meltzer
Univ. of Washington, Seattle, WA 98195
TEL: (206) 543-2997
dmeltzer@u.washington.edu

General Member-At-Large
Gregory R Snow
Univ of Nebraska, Lincoln, NE 68588-0111
TEL: (402) 472-6279
gsnow@unlhep.unl.edu

APS/AAPT Member-At-Large
Paula R. L. Heron
University of Washington, Seattle, WA 98195
TEL: (206) 543-3894
pheron@phys.washington.edu

APS/AAPT Member -At-Large
(and Newsletter Editor, Spring)
Karen Cummings
Southern Connecticut St Univ,
New Haven, CT 06515
TEL: (203) 392-7043
cummingsk2@southernct.edu

APS/AAPT Member-At-Large (Newsletter Editor Summer, Web Page Administrator)
Ernie Malamud
16914 Pasquale Road, Nevada City, CA 95959
TEL: (530) 470-8303
malamud@foothill.net

Chair, Committee on Education
Edward F Redish (Joe)
Univ of Maryland, College Park, MD 20742
TEL: (301) 405-6120
redish@physics.umd.edu

Newsletter Editor (Fall)
Thomas Rossing
Stanford University, Stanford, CA 94305.
rossing@ccrma.stanford.edu

APS Liaison
Ted Hodapp, APS
One Physics Ellipse, College Park, MD 20740
TEL: (301) 209-3263
hodapp@aps.org

AAPT Representative
Richard Peterson (AAPT President)
Bethel University, St. Paul, MN 55112
TEL: (651) 638-6465
petric@bethel.edu