



Forum on Education

American Physical Society

Spring 2006 Newsletter

Karen Cummings-Editor

IN THIS ISSUE

Articles

Greetings from the Chair! by Ramon Lopez	1
What is the Buoyant Force on a Block at the Bottom of a Beaker of Water? by Carl E Mungan	3

Issues in Graduate Education

A Ph.D. in Any Language: World Year of Physics Country Profiles by Ben Brown	6
Tapping Physics Education Research for a Graduate-Level Curriculum: A Novel Approach for a Ph.D. Qualifying Exam Preparation Course by Warren Christensen and Larry Engelhardt	7
Graduating Educated Graduate Students by Edward Price and Noah Finkelstein	15
A Course on Integrated Approaches in Physics Education by Michael C. Wittmann and John R. Thompson	21
Development of a Comprehensive Physics Program at a Non-traditional Upper-level Undergraduate and Graduate Small University by David Garrison	28

Teacher Preparation Section

A Note from the Teacher Preparation Section Editor by Chance Hoellwarth	32
A Physics Teacher Education Program in the Philippines by Ed van den Berg, Jocelyn Locaylocay and Marilou Gallos	33
A New Model Alternative Certification Program For High School Physics Teachers by Dan Maclsaac, Joe Zawicki, Kathleen Falconer, David Henry, and Dewayne Beery	38

Browsing the Journals by Thomas D. Rossing	46
FEd Executive Committee	49

Greetings from the Chair!

Ramon Lopez

With spring 2006, we have a new Chair taking over – Peggy McMahan Norris from Lawrence Berkeley Lab will take the lead for the coming year. The FEd also announced the results from this year's election. We had a superb slate of

candidates, so the FEd can look forward to continued excellent leadership. My congratulations to the winners, and my thanks to all who stood for election. *Continued on page 2*

Continued from page 1

The FEd depends on committed members to carry forward the education agenda within the APS. And I also would like to thank those members of the FEd Executive Committee whose terms have expired. I will serve one more year as Past-Chair, and I will also serve as Chair of the APS Committee on Education (COE) through 2006.

In general, the COE provides education policy input to the APS, with its members appointed by the APS President, while the FEd is the membership unit of the APS, and so takes the leads in sessions and other “operational” education activities, like sessions at meetings. Of course, there is a lot of overlap between the two bodies, but the close relationship between the FEd and the COE that was institutionalized just a couple of years ago. Now the Past-Chair, Chair, and Chair-Elect automatically serve on the COE. What is more, as of this year the Chair of COE serves on the Physics Policy Committee (PPC), which oversees the efforts of the Washington Office. This arrangement recognizes the need for education issues to be considered when discussing APS efforts to influence policy-makers in Washington. COE, working with FEd and PPC, introduced a resolution to Council at the April meeting calling for enhanced lobbying on behalf of education. The resolution approved by Council states that “High-quality education is essential for the progress of science and for the public understanding of its importance. To help address this need, the American Physical Society, through its Washington Office, will advocate support of appropriately peer-reviewed programs that foster and improve undergraduate and graduate science education or that seek to improve education of K-12 science teachers.” This resolution will support more targeted lobbying on behalf of education, especially discipline-based education research.

Individual FEd members can also play an important role in the education debate. To get involved, just write your congressional representatives. Urge them to support education funding, especially in the NSF. When you go to an APS meeting, look for the booth set up by the Public Affairs office where you can send a template letter to your representatives and urge support for science funding. If you are visiting Washington, stop by your representative’s office and speak up in favor of investment in science and science education. If you visit the APS website you can find information that you can use (look in Public Affairs), and you can always refer to “Rising above the Gathering Storm” (www.nap.edu/catalog/11463.html), the recently released National Academies of Science report that calls for significant increases in funding for both science and science education.

Another way FEd members can get involved is to help organize sessions at the APS meetings. If you are interested, email your idea to the program Chair, David Haase (see the FEd webpage for contact info). We are always looking for people who will do the work to put together good sessions. At the March and April meetings we had a number of excellent sessions. From Physics Education Research, to preparing K-12 teachers, to innovations in Graduate Education, FEd put on a range of session topics. We also shared sessions with the Forum on History in Physics, the Forum on Physics and Society, and the Division of Nuclear Physics, among others. Another pleasant event that took place at the March meeting was the presentation of the new FEd Fellows during our business meeting. In general, we intend to alternate the FEd business meeting and reception between the March and April meeting. We hope that if you are attending you check to see if the FEd reception is at your meeting. We would love to see you there.

Continued on page 3

Continued from page 2

The final thing that I would like to report is that we have reached our goal to endow the Excellence in Physics Education Award. An endowed award must raise \$100,000 in order to be established. We had a great response from FEd members, the FEd itself matched \$30,000 in contributions, and a gift from the Lounsbery Foundation put us over the top. I hope that many of our members will consider nominating outstanding groups that have made national contribution to physics education at any level for this award. Wolfgang Christian, who spearheaded the fund-

raising effort, will Chair the first award committee.

So with the passing of the gavel we have a new Chair. I have enjoyed my role in the FEd leadership for the past few years, and I look forward to the coming year as past-Chair (which has the lightest duties!). I hope that some of you reading this who have never run for office in the FEd will consider doing so, and that you will get as much out of the experience as I have.

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

What is the buoyant force on a block at the bottom of a beaker of water?

Carl E. Mungan

Abstract

I propose that buoyant force be generally defined as the negative of the total weight of the fluids that are displaced, rather than as the net force exerted by fluid pressures on the surface of an object. In the case of a body fully surrounded by fluids, these two definitions are equivalent. However, if the object makes contact with a solid surface (such as the bottom of a beaker of liquid), only the first, volumetric definition is well defined while the second definition ambiguously depends on how much fluid penetrates between the object and the solid surface

Several recent papers [1-3] have revived questions about the nature of the buoyant force on a submerged object that is not fully surrounded by fluid. Suppose it makes contact with a solid surface, such as a rectangular block firmly pressed to the bottom of a beaker of water. An earlier pair of papers [4-5] suggests that in such a case the buoyant force has been *removed*. Others argue that while a buoyant force still exists, its direction is now *downward* [6].

The logic behind both of these viewpoints is evident, but which one is consistent with introductory physics textbooks? Open your favorite text and see if it answers this question. You will probably find that it does not. Conventional books introduce buoyant force by considering an object suspended in a liquid (perhaps by a string of negligible cross-sectional area) so that it is fully surrounded by a single fluid.

Continued on page 4

Continued from page 3

Alternatively the body is floating and is thus surrounded by two fluids. But the question of what happens when an object is only partly surrounded by fluid is passed over in silence.

This silence leads to a nontrivial pedagogical issue for introductory physics [7]. Consider drawing a free-body diagram for a block on a table including the effects of the atmosphere. Should this diagram include a buoyant force and, if so, in what direction [8]?

To resolve this ambiguity, we need to *clarify the definition* of buoyant force [9]. Consider the following model situation. A block of lower density than a fluid is held down at the bottom of a beaker of the fluid as a result of the reduced pressure inside a suction cup [10] (or thin o-ring) spanning the block's bottom face. The block has mass m and top and bottom surfaces of area A , while the plastic of the suction cup has negligible mass and volume. Define P_{top} to be the fluid pressure at the depth of the top surface of the block, and let $P_{\text{bottom,inside}}$ and $P_{\text{bottom,outside}}$ be the fluid pressures at the depth of the bottom surface of the block respectively inside and outside the volume of fluid enclosed by the suction cup. The existence of suction implies that

$$P_{\text{bottom,inside}} < P_{\text{bottom,outside}}.$$

The weight of the block is balanced by the difference in fluid forces on the bottom and top of the block and by a normal force N exerted by the semi-rigid side walls of the suction cup,

$$mg = N + AP_{\text{bottom,inside}} - AP_{\text{top}}. \quad (1)$$

We can express the pressure inside the suction cup as the difference between the pressure in the surrounding fluid at the same depth and the pressure differential across the membrane of the suction cup,

$$P_{\text{bottom,inside}} = P_{\text{bottom,outside}} - \Delta P.$$

This can be substituted into Eq. (1) to obtain

$$mg = N + B - F, \quad (2)$$

where the magnitude of the buoyant force B has here been defined to be equal to the weight of fluid displaced by the block, and $F = A\Delta P$ is the "holding" force due to the suction.

Although Eqs. (1) and (2) are fully equivalent and both contain exactly one upward and one downward fluid force term, there are three advantages of the second equation over the first:

1. We can use Eq. (2) to immediately compute the minimum force F_{min} required to hold the block down, by setting $N = 0$. One finds the intuitively appealing result that it is equal to the negative of the block's apparent weight $mg - B$. In contrast, the hold-down force is not explicit in Eq. (1).

2. We have separated the variation in fluid pressure with depth from the pressure differential ΔP due to the suction. This is a pedagogically instructive distinction to make.

3. Equation (2) consistently *defines* the buoyant force on an immersed object to be upward and equal in magnitude to the weight of fluid displaced, even when the object makes contact with solid surfaces [11]. This definition remains simple and unambiguous if ΔP is non-zero.

Equation (2) also holds for a block (of arbitrary density) on a table, if we broaden F to include not just the force resulting from suction, but also from such effects as surface tension, cold welding, and electrostatic surface charge interactions when appropriate [12]. But usually these effects are negligible. With that understanding, it is reasonable to ask students, "What is the magnitude of the force required to slowly lift the block?" A good first approximation is its weight mg . If the problem asks us to account for the effects of the fluid environment (such as the atmosphere) on an ordinary block, the correct answer would then be its apparent weight $mg - B$ [13].

Continued on page 5

Continued from page 4

It is only when there is a reasonable expectation that the block is somehow coupled or sealed [14] to the table that one needs to include additional forces F . This is entirely analogous to how projectiles are treated in introductory physics: One initially takes them to be in freefall. Subsequently a velocity-dependent drag force can be added to account for air resistance. But additional effects such as lift are only modeled under special circumstances.

References

- [1] J. Bierman and E. Kincanon, "Reconsidering Archimedes' principle," *Phys. Teach.* **41**, 340-344 (2003).
- [2] B.M. Valiyov and V.D. Yegorenkov, "Do fluids always push up objects immersed in them?" *Phys. Educ.* **35**, 284-286 (2000).
- [3] E.H. Graf, "Just what did Archimedes say about buoyancy?" *Phys. Teach.* **42**, 296-299 (2004).
- [4] G.E. Jones and W.P. Gordon, "Removing the buoyant force," *Phys. Teach.* **17**, 59-60 (1979).
- [5] J.R. Ray and E. Johnson, "Removing the buoyant force: A follow-up," *Phys. Teach.* **17**, 392-393 (1979).
- [6] "Downward" and "upward" are relative to the direction of the effective gravitational field \mathbf{g} including the acceleration of the reference frame. On a carousel, for example, "upward" is tilted toward the axis of rotation, as shown in H.J. Haden, "A demonstration of Newtonian and Archimedean forces," *Phys. Teach.* **2**, 176-177 (1964). As another example, on an elevator accelerating downward, the weight of and buoyant force on a submerged object are decreased.
- [7] J. Harper, "Archimedes' principle and the FCI," *Phys. Teach.* **41**, 510 (2003).
- [8] Place a block of mass m on the submerged tray of a spring scale, as described in P.A. Tipler and G. Mosca, *Physics for Scientists and Engineers*, 5th ed. (New York, Freeman, 2003), Sec. 13-3. Tare the scale while the block is submerged but before it contacts the tray. If you now place the block on the tray, the scale reading will be $mg - B$ where B is the weight of fluid displaced by the block. This neither proves nor disproves that there is a buoyant force on the block *alone*. For example, if fluid is squeezed out between the block and tray, the downward fluid force on the block *increases* and that on the tray *decreases* by exactly the same amount. That is, the scale is actually sensitive to the buoyant force on the *combination* of the block and tray, but its reading results from the manner of taring. (For further discussion of methods of weighing a block in contact with the bottom of a fluid, see Ref. 3.)
- [9] The integral of the fluid pressure over the surface of a body could be sideways (e.g., on a submerged block in contact with the wall of an aquarium). Therefore taking that to be the general definition of buoyant force would be misleading: A dictionary defines "buoyant" to mean upward, as the reader is invited to check. In any case such an integral cannot be evaluated if the extent of fluid seepage at the solid interface is unknown.
- [10] Interestingly, the adhesion of many common tapes results from suction, as discussed in R. Kunzig, "The physics of tape," *Discover* **20**, 27-29 (July 1999).
- [11] Archimedes' principle is deduced in R.E. Vermillion, "Derivations of Archimedes' principle," *Am. J. Phys.* **59**, 761-762 (1991) by considering the net change in the gravitational potential energy of *both* the fluid and block during a virtual upward displacement of the block. No fluid need initially be under the block for this derivation to hold.
- [12] For example, if fluid seepage under the block can occur, so that suction cannot be sustained, then some other effect such as a glue must exert force F to hold down a block whose density is less than that of the fluid. This is consistent with my analysis in C.E. Mungan, "Reprise of a 'Dense and tense story'," *Phys. Teach.* **42**, 292-294 (2004).
- [13] The effect of atmospheric buoyancy on scale readings is memorably illustrated in H. Stokes and W.D. Peterson, "Buoyancy of air: An attention-grabbing demonstration," *Announcer* **33**, 94 (Summer 2003), as described on the web at <http://stokes.byu.edu/alkaseltzer.html>.
- [14] A striking demonstration of an object sealing to a surface is the "Atmospheric Pressure Demonstrator" currently sold by PASCO. It consists of a rubber sheet (with a knob attached to its top) that when slapped down onto a stool can be used to lift it.

Continued on page 6

Continued from page 5

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

A Ph.D. in Any Language: World Year of Physics Country Profiles

A FGSA newsletter article

Ben Brown

So what does it take to be called “Doctor” the world over? Is a D.Phil. the same as a Ph.D.? Do students in China receive government support for a terminal degree in physics? How is the traditional path to professorship in Germany being challenged?

These questions (and many others) were recently addressed by an American Physical Society Forum on Graduate Student Affairs (FGSA) project to uncover the often overlooked differences between graduate education systems in the U.S. and other countries.

To honor the World Year of Physics in 2005, FGSA embarked on a year-long project to learn more about physics graduate study in countries around the world. Young scientists in a number of countries gave generously of their time to prepare short articles summarizing their path to a Ph.D. (or equivalent degree), as well as describing some of the notable physics research currently undertaken in their native country. These country profiles can be read in their entirety on the FGSA website at [<http://www.aps.org/units/fgsa/worldyearprofiles.cfm>].

Physics is an inherently international endeavor. Historically, the diversity of physics research programs in the U.S. has attracted students and researchers from numerous countries. When I

first joined my doctoral research group at the University of Rochester, I was one of only two Americans in a group that included citizens from Argentina, Brazil, France, Mexico, the United Kingdom, and Poland. Yet aside from lunch-time conversations, we students were relatively unknowledgeable regarding the variety of graduate research experiences in countries outside our own.

Across Europe, there is significant variety in the path to the Ph.D. In Germany, students seeking a doctorate first must complete a Diploma Thesis---essentially a research thesis masters degree. In the U.K. and France, a Ph.D. (D.Phil. in the U.K.) is nominally three years in length---extremely short compared to the six-to-seven year average length of a Ph.D. obtained in the U.S. This difference is in part a result of the broadly differing philosophies of the American and European undergraduate and school-age educational systems. The European system tends to emphasize academic specialization at an earlier age, while the American system stresses exposure to a wide variety of subjects. For example, British undergraduates typically take courses exclusively in their major subject, permitting a reduced emphasis on formal coursework at the graduate level as compared to the American system.

Continued on page 7

Continued from page 6

In the rising technical powers of India and China, governments are rapidly increasing the resources devoted to science and engineering, with clear benefits to students. In the span of two decades, literally hundreds of new physics and engineering doctoral programs have blossomed, producing graduates eager to contribute to their country's increasingly vital role in international research and development efforts. Recent publications such as Thomas Friedman's *The World Is Flat* have stressed the rising influence of India and China as budding technological powers. Clearly the number of opportunities for physics graduate study in these countries is in the ascendance.

Around the world, the influence of the close cultural and governmental ties persisting after colonialism are manifest in the similarities of various graduate courses to the British and French systems. Canada and South Africa, for instance, allow entry to a Ph.D. course (nominally three years in length) only after completion of an M.Sc. or equivalent degree---

essentially the same academic path required in the U.K. Both of these countries have witnessed impressive recent growth in research opportunities for physics students.

The World Year of Physics has now passed into memory. However, FGSA has an abiding interest in promoting appreciation for the diversity of experiences of physics graduate students. If you notice that your home country is absent from the collection of country profiles thus far, and would like to write a profile for inclusion on the project homepage, please contact the FGSA Secretary. Those interested in addressing the needs of international students and organizing the exchange of ideas between FGSA and international student organizations are encouraged to become involved in the FGSA International Affairs Committee; contact the FGSA Chair or Secretary for more information.

Ben Brown is Member at Large for the APS Forum on Graduate Student Affairs. He can be reached via e-mail at blbrown@optics.rochester.edu

Tapping Physics Education Research for a Graduate-Level Curriculum: A Novel Approach for a Ph.D. Qualifying Exam Preparation Course

Warren Christensen and Larry Engelhardt

Introduction

Every summer a painful ritual is undertaken by many would-be physicists in classrooms across the country. A comprehensive written examination, although it has been modified or even removed at certain institutions, is still a key measure used by many schools to determine who is qualified to continue on a quest for a

Ph.D. in physics. Over the last two years, the authors of this article have created a Ph.D. qualifying exam preparation course that utilizes several research-proven methods.¹ These methods include, but are not limited to, peer-led instruction, training in problem-solving skills, and the use of multiple representations. The teaching of upper-level undergraduate and introductory graduate physics content in this

Continued on page 8

Continued from page 7

manner was not only engaging and interesting, but also gave students an opportunity to improve their understanding and, as is borne out in our data, an improved chance to pass the exam.

Exam Background

At Iowa State University (ISU), the physics Ph.D. qualifying exam is administered in two four-hour-long exams in a large lecture hall, on a Tuesday and Thursday morning during the same week, approximately 2 weeks before the start of fall classes. The first exam, known as the “Classical Exam,” covers questions on Newtonian mechanics, Lagrangian mechanics, electricity and magnetism, relativity, optics, as well as qualitative questions about experiments or scientific ideas. The “Modern Exam” (the Thursday exam) includes problems on quantum mechanics, condensed matter physics, high energy physics, nuclear physics, and astrophysics, as well as other modern topics.

Problems range in difficulty from introductory level concepts to advanced graduate material, with most of the exam being at the advanced undergraduate and first-year graduate school level. Until recently, students were required to pass both exams in the same year in order to continue on with their studies. Now, however, students can pass the two parts in subsequent years and still continue toward their Ph.D. Graduate students who are new to ISU, entering without a Masters degree, are expected to pass the exam within their first two years, and students entering with a Masters degree are expected to pass after one year. Those students who fail to pass the exams in their allotted number of attempts become ineligible to continue working towards a Ph.D. in physics at ISU. In most cases, these students choose to finish a Masters degree from the department and then transfer to another department on

campus or to another university in a similar field of study.

Authors’ Background

We both entered graduate school having received degrees in physics, but discovered that we were unprepared for the breadth and depth of the exam’s topics. Upon the recommendations of a graduate student who had previously failed his two attempts to pass the qualifying exam, we confined ourselves in a classroom and collaboratively worked problems from old qualifying exams for roughly 20-40 hours a week for multiple months. Initially, we had many questions regarding the material, and we discovered that the answers to our questions could not be efficiently found in textbooks. We were provided solutions to these old exam questions, but they were often limited to algebraic solutions with very little written explanation. Thus, determining how or why we were supposed to apply a certain method, and interpreting details about underlying assumptions or approximations, was nearly impossible. We found that discussing ideas between ourselves was an effective method for studying but lacked efficiency. What we really needed was an “expert” to direct our conversations, leading us not only to correct answers but to correct understanding as well.

Not surprisingly, neither of us was successful in passing the exam on our first attempt, although the material that we encountered in future courses became much more accessible and comprehensible. The following summer, we adopted a different approach that we believed would improve the efficiency of our studying. We focused our attention on the key concepts behind each particular problem and strived to look at a larger number of problems. We met weekly with a larger group of people to discuss specific worked problems, but also did a great deal of independent studying.

Continued on page 9

Continued from page 8

With these revisions incorporated into our study tactics, we both passed the exam on our second attempt, much to our own delight.

Course initiative

After an external review of the department and several meetings between the department chair and the graduate student body, it was obvious that the qualifying exam and, in particular, the lack of assistance in passing it, was a significant cause of distress among graduate students. The department chair thus determined that instruction directly focusing on the qualifying exam was desired by the students, and he approached us with the idea of creating such a course. Having painstakingly developed our own successful study techniques, and being familiar with proven pedagogical techniques used in physics education research (PER), we enthusiastically agreed.

Course structure

Our 12-week course covers a different subject each week, alternating between topics in classical and modern physics. In a given week, two class meetings occur. A one-hour introduction to the material takes place early in the week, and later in the week the students spend two hours presenting the solutions to assigned problems. In the first meeting, we introduce the weekly topic in a brief PowerPoint® presentation, lasting no more than 20 minutes. We purposely minimize lecture instruction for the following reasons: 1) Developing lecture instruction at an appropriate level for everyone was impossible due to the diverse background (and content knowledge) of our graduate student population. 2) Although it has not been rigorously tested at the graduate level, the PER community has provided overwhelming evidence that standard lecture instruction is not an effective method of learning physics for the majority of students.²

The remainder of the first meeting has students working in small groups, solving problems from old qualifying exams. These specific problems are chosen because they satisfy two criteria: They are relatively straightforward, and they clearly showcase the key aspects of the weekly topic. At the conclusion of this meeting, the students are assigned five problems which are to be presented during the second class of the week. The second class period, which lasts two hours, involves students taking turns working problems out at the board, spending 20-30 minutes per problem. Each student leads a discussion of the solution, responds to questions, and is asked to elaborate on the concepts of a particular problem in various ways that are discussed in the following section.

Another key feature of our course was the administration of full-scale practice exams to students throughout the summer. One of the underlying challenges of passing the exam is the context in which it is taken: A four-hour time limit, an 8 AM start time, and a formal test-taking environment. This makes for a very different experience when compared with a student's typical problem-solving environment (i.e., casually working problems often with readily available resources). We therefore schedule four different sets of exams that are administered to students in a classroom, at eight o'clock in the morning, on Tuesday and Thursday mornings throughout the summer. As one of our students stated, "They were quite helpful in forcing me to sit through a full exam early in the morning in cramped conditions. The practice exams were also useful in that by the time the real qualifying exam came by, it was old hat and I was quite relaxed, which helps."

Continued on page 10

Continued from page 9

Course Goals and Methods

Our primary goal for the course is quite simple: To enable students to pass the qualifying exam. In order to succeed in this goal, there are a number of strategies that we employ. Some of these strategies are aimed at learning physics, by developing both our students' conceptual understanding and their problem solving abilities. Other methods focus on preparation and test-taking tactics for the *specific* type of exam for which they are studying. In this section, we describe some of the specific methods that we use, as well as our motivation for choosing them.

Efficient and effective use of study time

Since the exam consists of solving written problems, it seems obvious that the most appropriate means of studying is also to solve problems. However, we found that many students relied primarily on reading physics books to prepare for the exam. We therefore placed an enormous emphasis on working problems, both during the class hours and throughout the rest of the week. Solving problems, however, is quite challenging if one does not already have a firm grasp of the different topics and methods that should (and should not) be employed to solve the myriad of problems. Simply being told "work problems" can lead to hours of painfully inefficient studying as we discovered during our first summer of preparation.

The alternative, reading books, has the advantage that one can easily make progress, but it is a highly ineffective means of studying for this type of exam.¹ The central strategies of our

course are therefore to provide the students with summaries of the most relevant physics content (in the form of our 20-minute presentations) and to provide immediate feedback on their progress (in the remaining 160 minutes of weekly class time). If we could focus students' time on working problems in an open group environment that allowed for immediate feedback, we were confident that we would give them the best chance to succeed.

With this in mind, we set out to create an environment in our class that would support students discussing, critiquing, and assisting one another. We had groups of students work problems under the guidance of experienced exam-takers (i.e. us), with rapid feedback regarding both their solutions and their solution methods. While working problems, student questions arise and are often redirected back to the other class members, asking for volunteers to explain certain techniques or ideas. This not only helps answer the inquisitive student's question, but it also allows another student the opportunity to explain his or her ideas, thereby benefiting both students. In addition, other members of the class become involved in the process, commenting and asking further questions. Our role as peer-instructors (*we are* fellow graduate students) further facilitates these discussions in that students do not hesitate to engage us in healthy debate. Unlike the previous alternatives that we described, solving challenging problems in this way is very efficient, since in a class of fifteen graduate students,

Continued on page 11

¹Perhaps an analogy might better explain our idea: You and I are going to have a swimming contest in three-month's time. I am going to spend that time reading all of

the best books and articles about proper swimming techniques. Meanwhile, you will go to a pool and swim everyday for three months. Who do you think will win the race?

Continued from page 10

someone almost always knows the answer or method that should be used to solve the problem.

Pedagogical methods

We strive to build on student understanding primarily via the student-student and student-instructor interactions that occur while students are solving problems. While these interactions are present during the first meeting each week, they truly flourish throughout the second meeting when students are working problems at the board. Instructor-led discussions cover all aspects relevant to the problem, with particular emphasis placed on promoting problem-solving skills. The ability to identify key ideas and plan an efficient solution strategy is imperative for success on the exam. There is a vast research base that supports the notion that use of structured problem-solving strategies is an effective means of developing student conceptual understanding.³ Additionally, we explore alternative contexts, alternative solution methods, and how slight modifications to the question would affect the solution. The goal is to strengthen the understanding of the student working at the board by challenging them to think on their feet, while also eliciting ideas from the class to paint a complete picture of how each problem fits in with other concepts.

Another pedagogical technique that has been shown to improve student conceptual understanding is the use of graphical and diagrammatic representations,⁴ both of which are often required as a part of qualifying exam problems. While initially we felt it was important to practice such skills to be prepared for these types of questions, we subsequently realized that substantial knowledge can be gleaned from a proper sketch, and that improved depth of understanding can result from analyzing it. Once a sketch has been produced, questions concerning limiting cases and points of interest (such

as equilibria) are readily tractable. By using graphical representations, peer-led instruction, and a variety of other methods, we continually refocus students' attention on their method of approach to solving problems.

The scope of the exam

A key feature of our course is the highly focused nature with which we present the material. During our own exam preparation, we spent a great deal of time determining what types of questions are commonly asked in order to improve the efficiency of our studying. To specialize our course, (and to save our students from unnecessarily investing similar time) we meticulously cataloged and analyzed the most common topics and problem-solving methods that have been used in previous years of the exam; we hence determined which topics should be covered, and in which order. We also provided our students with a detailed inventory of all 26 years worth of old exam problems. Sorted primarily by topic, this resource allows students who are looking to practice, for instance, boundary value problems, to instantly locate 19 previously asked qualifying exam questions.

Language

A few weeks into the first summer of teaching the course, we become aware that, at times, students were misinterpreting portions of the questions. This was sometimes as simple as clarifying the distinctions among scientific words (e.g., constant, uniform, invariant). Occasionally confusion also arose when students were trying to interpret the instructions in the question, such as the difference between "Write down ...", "Determine...", and "Derive...". Students, particularly those who received undergraduate educations outside the United States, also had difficulties narrowing the scope of particular problems. When discussing problems,

Continued on page 12

Continued from page 11

we therefore make a pointed effort to address precisely what each question is asking and what is required for the solution. While this may seem trivial to some, considering the timed nature of the exam it is important to focus students on doing the work that will yield the most points. As one student remarked after taking our course, "As a foreign student, language is always a barrier... I need to be familiar with the way they ask questions."

Additional resources

We also highly recommend the series of books titled "Major American Universities Ph. D. Qualifying Questions and Solutions" (1998)⁵ as another resource for problems at the appropriate level. A set of these books was purchased by the department and is on reserve for the students. All other resources are made available to the students onlineⁱⁱ, and recently the school produced CDs that contained all of our course material, including PowerPoint® files, the question inventory, and every qualifying exam with its solutions in electronic format going back to 1979.

Data

This past August, 37 Ph.D. hopefuls took at least some portion of the qualifying exam. Of these students, 17 were new arrivals at ISU and, as such, had limited opportunities to attend our summer preparatory course. Typically, these students have little to no chance of passing the exam anyway, so we have removed them from our data set. Furthermore, due to the recent change in the passing requirements, five students taking the exam only had to pass one portion of the exam (all five did pass). By also removing those five students from our data, we are left with 15 students, eight of whom regularly attended our course. To attempt to assess the effectiveness of our course, we have analyzed the performance of those 15 students.ⁱⁱⁱ

Continued on page 13

ⁱⁱ [URL: http://www.public.iastate.edu/~wmchris/qual.html](http://www.public.iastate.edu/~wmchris/qual.html)

ⁱⁱⁱ) Note that the data presented in this section were only given to the authors in summary form in order to protect the confidentiality of the results for those who took the exams.

Continued from page 12

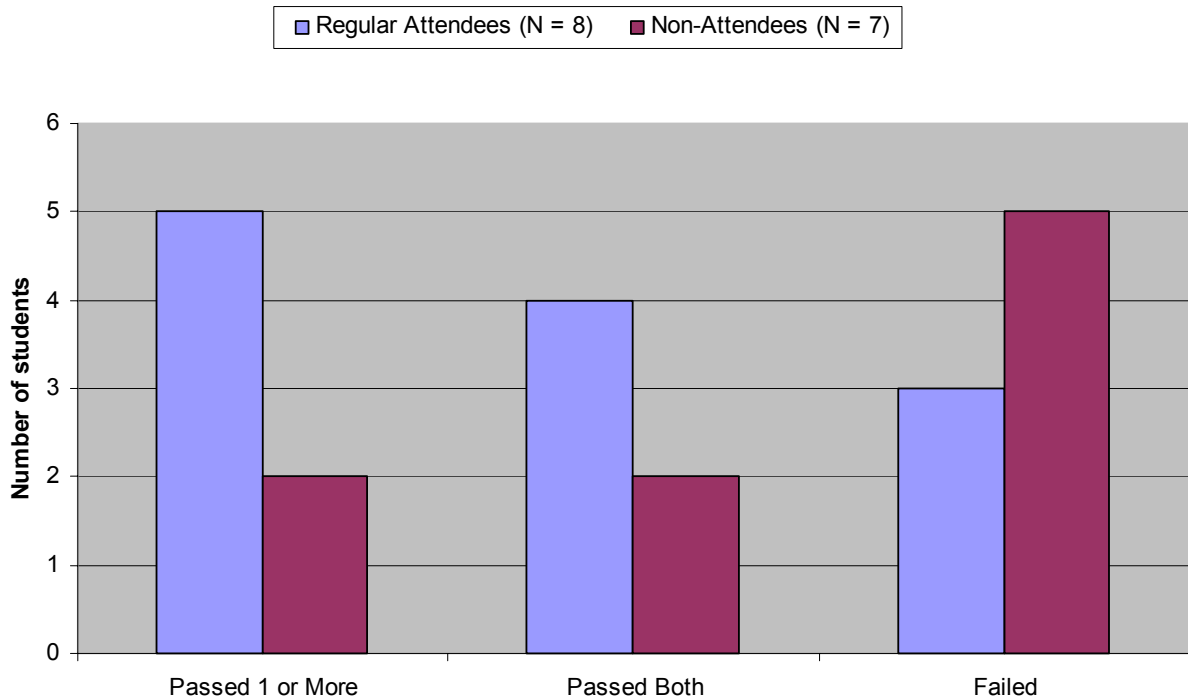


Figure 1. Student Qualifying Exam Performance

As shown in figure 1, five of the eight students who attended class regularly passed at least one of the exams, while only two out of seven non-attendees passed. Although a higher percentage of our attendees passed, it was not obvious whether this was as a result of having attended our course, or if the students who attended our course were already better prepared. In an attempt to shed additional light on this issue, we obtained the average scores that these two groups achieved on the GRE Quantitative

and GRE Physics Exams which they took prior to entering graduate school. These data, shown in figure 2, suggests that our attendees were unlikely to have had any type of pre-instruction advantage. Given this very small sample of students, it is impossible to claim any statistical significance with these findings. However, we believe that these data suggest that our course is successfully fulfilling its goal, that is, to enable students to pass the qualifying exam.

Continued on page 14

Continued from page 13

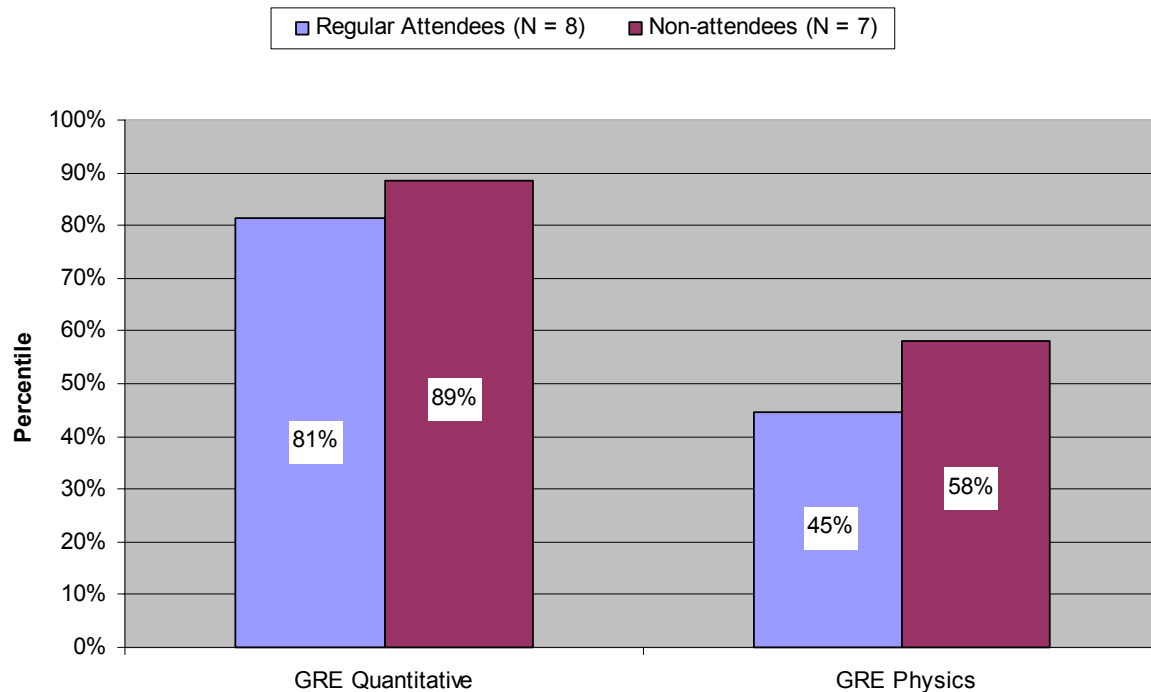


Figure 2. Average GRE Quantitative and Physics Percentiles

Conclusions

We have developed a summer-long course whose goal is to prepare graduate students for the comprehensive written qualifying examination that is administered at Iowa State University. This course is taught using pedagogical methods from Physics Education Research that have been proven to be effective at the introductory level, with a particular emphasis on active learning and peer-led instruction. We also teach efficient studying techniques and stress their importance in order to drastically improve our students’ chances of passing the exam in a matter of mere weeks. Data are presented which suggest that this course is indeed effective. We believe that this course could effectively serve as a model, both for qualifying exam preparation at other universities and for

GRE exam preparation for advanced undergraduates.

Acknowledgments

We would like to acknowledge with gratitude the contributions of the late Ngoc-Loan Nguyen, in particular his insight and interest in assisting fellow graduate students in their exam studying. Thanks to Eli Rosenberg, our department chair, for his drive and financial support in improving the opportunities (and the quality of life in general) for graduate students at ISU. Also, thanks to David Meltzer for his invaluable discussions and suggestions, and to Lori Hockett, the graduate secretary, for compiling the data from student records.

Continued on page15

Continued from page 14

References

1. "Resource Letter: PER-1: Physics Education Research," L.C. McDermott and E.F. Redish, *Am. J. Phys.* **67**, 755-767 (1999). Surveys a wide scope of research on teaching methods for and student learning of physics at nearly all levels.
2. "Guest Commentary, How we teach and how students learn-A mismatch?," L.C. McDermott, *Am. J. Phys.* **61**, 295-298 (1993).
3. "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). Comprehensive review of relevant research on problem solving.
4. "Relation between students' problem-solving performance and representational format," D.E. Meltzer, *Am. J. Phys.* **73**, 463-478 (2005). As part of a discussion of student difficulties with multiple representations, this paper contains a thorough listing of references on research in the use of graphical and other forms of representation in physics instruction.
5. "Major American Universities Ph. D. Qualifying Questions and Solutions," Y.-K. Lim, ed., (World Scientific Publishing Co. Pte. Ltd., 1998). There are a total of seven volumes in this series.

Warren Christensen and Larry Engelhardt are graduate students in the Department of Physics and Astronomy at Iowa State University in Ames, Iowa. Warren can be reached via e-mail at wmchris@iastate.edu and Larry at lengelha@iastate.edu

Graduating Educated Graduate Students

Edward Price and Noah Finkelstein

Academia appears to do a remarkable job at producing the next generation of research faculty. The long-anticipated shortage of well-qualified researchers has not appeared¹. At the same time, while there are calls to reform educational practices in college and university classrooms, we are not broadly preparing our future faculty to develop or implement these now well-understood research-based educational practices.

The relative emphasis of research and teaching in the preparation of future physicists is symptomatic of the asymmetry between research and teaching in the practice of current physicists, in the attitudes and beliefs of physicists, and in the hiring and promotion practices at the most prestigious physics departments. The physics community at-large considers teaching and research to be separate endeavors: the generation of new understanding (research)

Continued on page 16

Continued from page 15

and the transmission of old understanding (teaching). In this view, the practice of teaching and research share little more than physics content and do not inform one another. In contrast, recent efforts in physics education suggest an alternate characterization of teaching (or learning); learning is the generation of understanding that is new to the student. In this view, teaching and research complement, support, and enrich one another. Furthermore, by taking teaching and learning as the focus of scholarly activity, we place teaching and research on equal footing. Extending this point of view, we propose a vision of the profession where education is part of the core conception of being a physicist, and we focus on graduate school as a critical experience in the preparation of future physicists. Graduate education is a key point of leverage as we attempt to integrate teaching and education research into the broader physics culture.

During graduate school, physicists engage in authentic research experiences, but most often there is no corresponding apprenticeship regarding teaching and learning^{2,3}. By definition, graduate preparation occurs in an institutional context of Ph.D. granting universities. This context informs the goals and practices of graduate students and faculty, but our traditional preparation may be a mismatch for graduates bound for institutional settings with other goals and practices. We do not dispute the need for institutions that emphasize research, but wish to emphasize that the minority of graduate students become faculty at institutions similar to those in which they were trained^{2,4-6}. Such a focused emphasis on research to the exclusion of other professional characteristics has consequences for the entire physics community. By extending the focus of physics graduate school to include structured attention to education, we may begin to give education greater prominence and validate education research and reform in physics, by

physicists. In this way, we can begin to shift the culture of physics to include education in the core practice of physicists.

Relatively recent efforts have started to attend to the development of graduate students more broadly – to support their development as educators and professionals in physics – and to support the development of the growing field of physics education research (PER). While there are many excellent model programs which support the development of graduate students, as TAs, as professional actors within physics, and in PER, we examine two programs as University of Colorado and University of California, which are designed to couple and to address each of these graduate roles.

Preparing Future Physics Faculty

In 1998, the American Association of Physics Teachers (AAPT) funded Preparing Future Physics Faculty (PFPF), a graduate program designed to augment traditional training in research. PFPF was a discipline-specific version of Preparing Future Faculty, a program initiated by the Council of Graduate Schools and the Association of American Colleges and Universities⁷. PFPF and PFF were responses to calls for increased emphasis on preparation in the areas of teaching and professional development by the Association of American Universities and the National Academy of Sciences^{8,9}. The University of California, San Diego was one of the sites chosen for a PFPF program. One of the authors [NF] was involved with establishing the program; the other [EP] is a former participant and director. The program ran with external support until 2000, and has since continued with the support of the physics department and UCSD's campus-wide Center for Teaching Development.

Continued on page 17

Continued from page 16

Initially, the PFF/PFPF program was intended to reshape graduate preparation to "produce students who are well prepared to meet the needs of institutions that hire new faculty" by including an emphasis on teaching and professional development⁷. Over the eight years of its existence, the UCSD instantiation of the program has undergone substantial changes and evolved to address four goals:

- Preparing graduate students for their future responsibilities as educators by promoting awareness and understanding of PER;
- Raising awareness of differences in the needs and opportunities at different academic institutions (i.e., community colleges, bachelor's granting institutions, and regional and research universities);
- Providing physics graduate students with professional and career development in areas such as conducting a job search and writing grant proposals;
- Creating an environment where physics graduate students discuss issues in the physics community.

Graduate students participating in PFPF attend weekly (or bi-weekly) seminars on topics relating to the goals discussed above. In addition to weekly seminars, graduate students are encouraged to participate in a range of practice-based activities: researching, developing curricula, and teaching. Research projects include graduate students engaging in PER-based studies of local practice (such as examining instructor beliefs about teaching). Curricular development often takes the form of graduate students appropriating PER-based activities and adopting them for local practice – for example, graduate students have augmented the complement of Interactive Lecture Demonstrations¹⁰ (ILDs) running in the introductory sequence by building an RC circuit ILD (and testing its effectiveness in the algebra-based course). Finally, teaching practice is heavily

a single topic to the rest of the PFPF seminar). Subsequently, students engage in observations and guest lectures in local introductory courses and at partner institutions (community and teaching colleges). Ultimately, several students have become instructors- of- record, taking responsibility for designing and implementing a full term class at these partner institutions. All of these activities are supervised both locally by the PFPF supervisors and at the host institutions by practicing faculty. These activities ground the seminar discussions in practical experience, making both more meaningful. The scope of engagement (ranging from guest lecturing to teaching a course as instructor-of-record) depends on the participant's interests and constraints. Guest lecturing is valuable experience with a small time commitment. On the other hand, teaching a course provides a more comprehensive experience but is a demanding undertaking. Our most successful participant activities combine the best of both approaches by including a group planning component and a modular workload. By involving multiple participants, these programs achieve a significant impact, yet require only modest effort from individual graduate students.

The program's tiered-participation model has been remarkably robust through several changes in program leadership. We attribute this to three essential features: the involvement of a program organizer, sustained graduate student interest in the issues addressed by the program, and a flexible format that allows the program to reflect the participants' and organizer's interests. Except for modest funding, official administrative support has not been essential, and in fact has lagged behind the bottom-up support for the program. (Three years ago, participation in the program was officially recognized as fulfilling the departmental teaching requirement; this year, for the first time, the department officially recognized the organizer's effort by granting teaching relief.)

Continued on page 18

Continued from page 17

Following the initial framework developed at UCSD, NF implemented a PFPF program two years ago at the University of Colorado.³ The model's central framing – voluntary participation of graduate students in tiered levels of participation – has remained the same. More on the UCSD program can be found at <http://www.ctd.ucsd.edu/programs/pfpf/> and the CU program at <http://per.colorado.edu/pfpf>

Teaching and Learning Physics.

Complementing the PFPF program is another model for incorporating educational issues in graduate preparation – a course in teaching and learning physics that provides an intensive focus on physics education and physics education research. Intended for graduate students more focused on the study of education, the course is formalized institutionally through course credit; in contrast, the PFPF program exists as a voluntary activity with little institutional reward for graduate students. Initially developed in 1998 at UCSD and subsequently implemented in 2003 at CU, the physics course Teaching and Learning Physics is structured around three central components: study of pedagogical issues (cognitive, psychological, educational), study of physics content, and practical experience teaching in the community (both in local community and within the University). Each of these course components complements the others by providing a differing perspective on the same area of inquiry. For example, the same week that students read studies documenting individuals' difficulties with the electric field, the students study the concept itself, and teach it to others. This model has been demonstrated to increase stu-

dent mastery of physics, proficiency at teaching, and the likelihood that students engage in future teaching experiences¹¹. This course attracts students to physics from all demographic backgrounds, increases the number of physics majors enrolling in teacher education, and builds strong and sustainable ties between the university and community partners.

Particularly relevant, the course on teaching and learning physics engages students in research activities throughout – applying tools of science to education. Student projects in the course allow them to view the practices of education, teaching and learning as scholarly pursuits. The resultant projects have spanned from developing after-school programs that increase younger students' interest and acuity in physics, to programs that study the role of gender in the classroom. Several of these projects have led to published work^{12, 13}, while others have led to the creation of community partnerships that would not have otherwise existed (such as the CU STOMP program or UCSD's Fleet University). Other student research and teaching efforts have been instrumental in the implementation of educational reforms spurred by faculty at the university. For example, at CU, in order to implement *Tutorials in Introductory Physics*¹⁴ in our undergraduate courses, we required an increased teacher: student ratio. Students from the course on teaching and learning physics provided critical human resources, while the Tutorials provided real world examples of educational reforms that graduate students could study. Each of these activities provides students the opportunity to engage in authentic educational practices, while also sending the message that these activities are part of a physicist's pursuits.

Continued on page 19

³ It is worth noting that of the four original sites, two (University of Arkansas and UCSD) have operated continuously, and a third (University of Colorado) was restarted after a hiatus.

Continued from page 18

Outcomes and Discussion:

In the broadest sense, PFPF and Teaching and Learning Physics represent attempts to address, through graduate preparation, the asymmetry between teaching and research by more fully including education in the core practice of physicists. While it should be clear that affecting students' choices and preparation is a long-term endeavor, we may assess the preliminary impact of these programs. First, it is worth considering whether students choose to participate in these voluntary programs. In the graduate program, participation has increased since its inception; starting with fewer than ten students, the UCSD program now regularly supports twenty to twenty-five students. Over the five to six year period of graduate studies, a student is about as likely to participate in PFPF as not. In the CU version of PFPF, average attendance is roughly thirty graduate students and over 100 individuals have participated. In the course, Teaching and Learning Physics, ten to fifteen students have participated annually since its inception at UCSD, and in its first offering at CU, 23 students enrolled. Graduate students are clearly interested in engaging the issues addressed in these programs, and there are few other outlets for this interest².

As measured by surveys of the participants, each of these programs has been successful at building bridges between physics and education, and infusing physics education research into traditional practices in physics. We have surveyed PFPF participants on their attitudes about the importance of teaching and what they have learned from the program¹⁵. While 18% feel education is valued by the physics research community, 94% of PFPF participants plan on incorporating the results of PER in their own teaching. Furthermore, former participants who are now teaching report following through on these intentions. Students enrolled in the course on teaching and learning physics report it to be among their most favored and useful

courses. Evaluation of student understanding of education reveal a shift from the more transmissionist perspectives to a more progressive, constructivist perspective¹¹. The course model has been employed elsewhere, and colleagues have conducted versions of this course at five different research institutions.

Implementing these programs requires little more than a motivated, capable person and modest institutional support; considering the impact, both programs are relatively easy to implement. They are independent and modular, but seemingly at their best when the programs form a mutually-supportive continuum of increasing level of engagement, allowing students to participate at a level they find appropriate. Interactions between the programs lead to benefits for both; for instance, PFPF creates a pool of students interested in further study, while Teaching and Learning Physics creates 'expert' participants that enrich PFPF discussions and activities. Institutional support is ensured by broad student interest, the value of the programs' "products" (curriculum development, instructional reform), and the benefits to the graduate participants.

Conclusion

We have described two activities designed to broaden physics graduate students' conception of and preparation for their profession by focusing on education and education research. These efforts are part of a broader goal of including education as an essential part of what it means to "be a physicist". Our experience suggests that through participation in these programs, graduate students come to value education more deeply as a core practice of physicists. More broadly, these programs can lead to similar shifts in local culture. While it is not certain that these shifts will be sustained, by creating layered and complementary programs these changes are more robust.

Continued on page 20

Continued from page 19

Though many graduate program reforms have the intent of changing the preparation of graduate students in order to support the changing job market, it may turn out that graduate students involved in the programs described above will change the nature of the discipline.

References

- 1 Committee on Science Engineering and Public Policy (COSEPUP), *Enhancing the Postdoctoral Experience for Scientists and Engineers*, National Academy Press, (2000)
- 2 C.M. Golde and T.M. Dore, *At Cross Purposes: What the experiences of doctoral students reveal about doctoral education*, The Pew Charitable Trusts, (2001)
<http://www.phd-survey.org>
- 3 E. Price and N.D. Finkelstein, *Seeding Change: The Challenges of Transfer and Transformation of Educational Practice and Research in Physics (Part I)*, in 2004 Physics Education Research Conference (AIP Publishing, 2004)
- 4 K. Adams, *What colleges and universities want in new faculty*, Association of American Colleges and Universities, (2002)
http://www.aacu-edu.org/pff/PFFpublications/what_colleges_want/
- 5 C. Langer and P.J. Mulvey, *Initial Employment Report: Physics and Astronomy Degree Recipients of 2002 & 2003*, American Institute of Physics, Statistical Research Center, (2005)
<http://www.aip.org/statistics/trends/reports/emp.pdf>
- 6 R. Ivie, S. Guo, and A. Carr, *2004 Physics & Astronomy Academic Workforce Report*, American Institute of Physics, Statistical Research Center, (2005)
<http://www.aip.org/statistics/trends/reports/awf.pdf>
- 7 A. S. Pruitt-Logan, J.G. Gaff, and J.E. Jentoft, *Preparing Future Faculty in the Sci-*

ences and Mathematics: A Guide for Change, Association of American Colleges and Universities, (2002)

<http://www.preparing-faculty.org/PFFWeb.PFF3Manual.htm>

8 Committee on Graduate Education, *Report and recommendations*, Association of American Universities, (1998)

<http://www.aau.edu/reports/GradEdRpt.html>

9 Committee on Science Engineering and Public Policy (COSEPUP), *Reshaping the education of scientists and engineers*, National Academy Press, (1995)

10 D.R. Sokoloff and R.K. Thornton, *The Physics Teacher* **35**, 340 (1997).

11 N.D. Finkelstein, *Journal of Scholarship of Teaching and Learning* (2004).

<http://www.iupui.edu/~josotl/>

12 N.S. Podolefsky and N.D. Finkelstein, in *The Physics Teacher*, Vol. to appear.

13 K.K. Perkins, M.M. Gratny, W.K. Adams, N.D. Finkelstein, and C.E. Wieman, *Towards characterizing the relationship between students' self-reported interest in and their surveyed beliefs about physics*, in Physics Education Research Conference (PERC) (AIP Press, 2005)

14 L.C. McDermott and P.S. Schaffer, *Tutorials in Introductory Physics* (Prentice Hall, Upper Saddle River, NJ, 2002).

15 E. Price and N.D. Finkelstein, *Seeding Change: The Challenges of Transfer and Transformation of Educational Practice and Research in Physics (Part II)*, in 2004 Physics Education Research Conference (AIP Publishing, 2004)

Noah Finkelstein, is an Assistant Professor of Physics at the University of Colorado. With colleagues in the Physics Education Research group, he directs several programs supported by the NSF and the APS PhysTEC. More information is available at:

<http://per.colorado.edu>

Edward Price is an Assistant Professor of Physics at California State University at San Marcos. He can be reached via e-mail at eprice@csusm.edu

A course on integrated approaches in physics education

Michael C. Wittmann and John R. Thompson

Abstract

We describe a course designed to teach future educators the different elements of physics education research (PER), including: research into student learning, content knowledge from the perspective of how it is learned, and reform-based curricula together with evidence of their effectiveness. Course format includes equal parts of studying physics through proven curricula and discussion of research results in the context of the PER literature.

PACS: 01.40Fk

Introduction

With the growth of physics education research (PER) as a research field [1,2] and the ongoing desire to improve teaching of introductory physics courses using reform-based approaches [3], there has been an opportunity to move beyond an apprenticeship model of learning about PER toward a course-driven structure. At the University of Maine, as part of our Master of Science in Teaching program, we have developed and taught two courses in “Integrated Approaches in Physics Education.” These are designed to teach physics content, PER methods, and results of investigations into student learning.

Course materials were inspired by conversations in 1999 and 2000 with Noah Finkelstein (now at University of Colorado in Boulder). Materials development was led by Michael Wittmann, with assistance from Dewey Dykstra (Boise State University), Nicole Gillespie (now at the Knowles Science Teaching Foundation), Rachel Scherr (University of Maryland), and John Thompson, who later joined the University of Maine and has since modified the materials while teaching the courses.

The goal of our course is to build a research-based foundation for future teachers as they move into teaching. We describe the origins of

the course and the activities that make up a typical learning cycle. We also give one example of student learning in the course, showing the types of reasoning our future teachers are capable of and how they use research results to guide their reasoning. We are engaged in a large study to examine student learning of PER results, though we do not report extensively on these results in this paper.

Course Goals

Our objectives in designing the Integrated Approaches course are that practicing and future teachers will: learn relevant physics content knowledge at an appropriately deep level, become familiar with “best practices” research-based instructional materials, and gain insight into how students think about physics through education research into student learning and curriculum effectiveness.

The goals of our course are consistent with those of the Master of Science in Teaching (MST) program sponsored by the University of Maine Center for Science and Mathematics Education Research. We wish for participants to learn content in courses taught using research-guided pedagogy and curricula, including hands-on, inquiry-based methods. We offer courses that integrate content and methods learning.

Continued on page 22

Continued from page 21

By taking such courses, students learn how to design and conduct science and math education research and are better able to interpret the results of this kind of research to benefit their target population. They apply these ideas when carrying out their own discipline-specific education research projects as part of their master's thesis work.

The course exists under several constraints due to the population targeted for the MST program. We have designed the course to be relevant to in-service physics teachers wanting either a deeper understanding of the physics content they are teaching, experience and exposure to physics education research, or research-based pedagogical tools. Many from this population are teaching "out of field," and have little physics background. Many of our MST students are transitioning from careers in science or engineering into careers in education, and have little pedagogical content knowledge (which we use to mean knowledge about how to represent the content appropriate to teaching) [4]. However, the course is also taken by second- or third-year physics graduate students who are doing PER for their Ph.D. work or wishing to improve their teaching skills as they prepare for careers in academia. This population typically has not taught outside of teaching assistantships in college courses. Finally, we have many MST students

from other science and mathematics fields. As a result, there is a great variety in physics pedagogical content knowledge among our students. The differences in these populations have led to interesting discussions which illustrate the importance of both physics and pedagogical content knowledge for a complete understanding of PER results and implementations, as well as a deeper understanding of student learning in physics.

Course Design

The Integrated Approaches courses are 3-credit graduate courses that meet twice a week for a total of 150 minutes. We teach content knowledge, education research results, and research methods using a three-tiered structure. Class time is spent approximately equally on each of the three elements of the course. A research and development project is carried out in parallel, primarily outside of class time.

We split each course into content-based units in which we discuss leading curricula, the research literature related to that material, and emphasize one or two education research methods. The fall and spring semester instructional units are presented in tables 1 and 2. In addition to the primary curricula listed in the tables, we also discuss curricula and instructional strategies such as *Just-in-Time Teaching* [22] and *Physlets* [23]. The two courses are designed to be independent of each other.

Continued on page 23

Continued from page 22

Physics content	Curriculum emphasized	Research method
Electric circuits	<i>Tutorials in Introductory Physics</i> [5] and materials from Gutwill et al.[6]	Analysis of free response pre- and post-test responses[7,8]
Kinematics	<i>Activity-Based Tutorials</i> [9,10], <i>RealTime Physics</i> [11], and <i>Powerful Ideas in Physical Science</i> [12]	Free response questions, multiple-choice surveys (TUG-K[13] and FMCE[16])
Forces and Newton's Laws	<i>Tutorials in Introductory Physics</i> [5] and <i>UMaryland "epistemological tutorials"</i> [14]	Multiple-choice surveys (FCI[15] and FMCE[16])

TABLE 1: First semester instructional units.

Physics content	Curriculum emphasized	Research method
Wave physics and sound	<i>Activity-Based Tutorials</i> [9,10] and <i>Physics by Inquiry</i> (in development)	Student interviews [17], comparing multiple-choice to free response questions [18]
Work-energy and impulse-momentum	<i>Tutorials in Introductory Physics</i> [5]	Student interviews [19], comparing multiple-choice to free response questions [20]
Heat and temperature	<i>UC Berkeley lab-tutorials</i> and <i>Physics by Inquiry</i> [21]	Classroom interactions, research-based curriculum development and modification

TABLE 2: Second semester instructional units.

Having advanced science students work through conceptually-oriented research-based materials is a necessary component of many teaching assistant preparation seminars. By going through instructional materials, students focus on conceptual understanding by building simple models of physical phenomena and looking to understand the physics that is taught in a new way. In the process, students with weak physics strengthen their content, while those who are stronger see the physics from a new point of view. Our course benefits the students even more by having them work through multiple instructional materials and subsequently participate in classroom discus-

sions comparing the pros and cons of different curricula. These discussions can be very helpful in teaching physics content and pedagogical content knowledge. For example, when first presenting Newton's Second Law, *Real-Time Physics* [11] uses dynamic situations with a single horizontal force while *Tutorials in Introductory Physics* [5] uses static situations with many forces acting at once.

Curriculum discussions are guided by education research results on a given topic. Students read papers on student learning of a given physics topic, evaluation of a given curriculum

Continued on page 24

Continued from page 23

(in best cases, the one we are using to teach content knowledge at the time), and ways in which different models of student reasoning affect curriculum design by researchers and developers. Because we choose papers directly connected to the curricula we are studying, students can gain deeper insight into the origin of the instructional materials and the specific issues that curriculum developers were hoping to address. Because developers typically use results beyond their own work, we have a rich collection of literature to reach back to. We usually assign influential and well-known papers in PER, typically found in the 1998 AJP Resource Letter in PER [24] or more recent results as outlined in the Forum *Fall 2005 Newsletter* article [2]. We also include relevant preprints or drafts of papers associated with ongoing research as a way of promoting the idea of PER as an active, growing, dynamic field.

Research methods are introduced by readings from the PER literature, and students learn research skills by carrying out research projects in the course. Skills for developing research tools such as written questions, surveys, and interviews are developed during class time. Students also spend class time practicing data

analysis. For example, we introduce students to the process of analyzing written free-response questions by having them categorize 20 anonymous student responses to the “5 bulbs” question [7,8,25] (see Figure 1) – before reading the research results on this question. We have found that students unfamiliar with the well known PER results will give wildly varying (though meaningful, each in their own way) interpretations of the data. By listening to each other’s methods, comparing their work to the literature, and discussing their interpretations, students develop a better sense of the purpose and possibilities of research. Similar activities are carried out when analyzing the Force and Motion Concept Evaluation [13] or the Test of Understanding Graphing – Kinematics [10]. Students are given data tables with student responses and asked to build models of student reasoning about specific physics content. Furthermore, we have students learn about and practice clinical interview techniques in class before doing their own interviews in their class-based research projects. Finally, we have students analyze video of students working in a classroom situation. By studying interactions in social groups without teaching assistants, students can gain a deeper perspective on learning in all elements of a course.

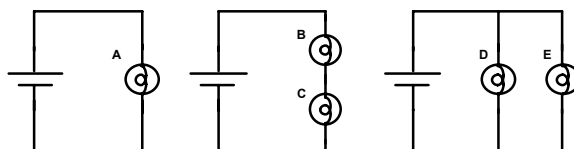


FIG. 1: “5 bulbs” question. Students must rank the brightness of each bulb.
Correct response for ideal batteries and bulbs: $A = D = E > B = C$.

A final part of the course is to pull together physics and pedagogical content knowledge, understanding of research methodologies, analysis skills, and research-based curriculum design into research projects. These research projects were originally done individually, but are now done in small groups (2-4 students) as

either large, semester-long, projects or a series of smaller projects, depending on the semester. Typically, students carry out one cycle of a research and development process. Building on a literature review, students design interview protocols and conduct individual interviews on

Continued on page 25

Continued from page 24

a topic, use results to develop free-response and multiple-choice surveys to get written data, and analyze data from a relevant population to gain perspective on student reasoning about a given topic. Using their results, they must design a draft set of narrowly focused learning materials that are appropriate to the data they have gathered, the literature, and what is known about learning in physics.

Learning in a Typical Instructional Unit

We outline one instruction unit from Table 1 in detail, including data on student's learning of pedagogical content knowledge in the course. In the electric circuits unit, we emphasized materials from the *Tutorials in Introductory Physics* [2] while reading papers related to the creation of the curriculum materials [4,5] and developing skills in analyzing student written responses on the associated pretest questions.

Before instruction, students must answer the “5 bulbs” question (Figure 1) and discuss – predict, one might say – what an “ideal incorrect student” might answer in a similar situation. An incorrect student response would match results from the research literature and be self-consistent throughout the response (though, of course, students aren't always consistent when giving wrong answers). In addition to content instruction, students are given a stack of anonymous student pretest responses to the “5 bulbs” question and asked to categorize student understanding. They are not given suggestions on categories and are asked not to read any literature before undertaking the task. One class period is spent on discussions of different categorizations. In three years of instruction with more than 20 students, we have discussed more than 15 different kinds of categorizations, with variations including: single- or double-counting responses, looking for what students do right compared to what they do wrong, tabulating all responses independently of what model might have driven their reasoning, and

finding different ways of interpreting incorrect answers. Not all the categorizations are correct, as can be imagined with students learning the material and the method the first time. In sum, we teach and test whether students themselves learn the correct physics concepts and whether they can predict, analyze, and classify incorrect reasoning they are likely to encounter when teaching. (In later parts of the course, we also ask students to suggest, design, or critique instructional materials which address typical incorrect responses.)

Class sizes are typically small (between 6 and 10 students) with roughly 3/4 physics specialists and 1/4 in-service teachers. It is often useful to break up data according to the student background. We present data compiled from two semesters with a total of 13 students. Of the 9 physics students, all got the “5 bulbs” question correct, while only 1 of 4 non-physics students did. Only 6 of the 13 were asked for an “ideal incorrect student” response. Answers given included current being “used up,” a constant current model, or bulbs closer to the battery being brighter. Notably, students in the class who were themselves wrong had far less explicit incorrect answers to give. Unsurprisingly, we regularly find that students without deep content knowledge in the form of conceptual understanding are rarely able to predict incorrect reasoning they might encounter in a classroom and do not know how to address it when they do encounter it.

In a slight modification to the original “5 bulbs” pretest question, Bradley S. Ambrose at Grand Valley State University has added a question that asks students to rank the *current through the battery* in each of the three circuits in Figure 1. We have anonymous data from questions asked using his modifications. The “current question” was not given to the students in our course when they first took the pretest. Instead, our students were asked to analyze five anonymous student pretest

Continued on page 26

Continued from page 25

responses to the extended “5 bulbs” question on a take-home exam. As part of their response, they had to discuss the purpose of the “current question,” namely what insight the question gives into student reasoning that was not already apparent in the original question. (They also had to analyze student responses to each question and discuss consistency of student responses as part of the take-home test.)

Student responses illustrate the types of learning we wish them to attain. A biology student with little background in physics stated:

[The current question] gives insight into whether or not the students truly consider the battery as a constant current source. The correct ranking of B and C being equal, but dimmer than A because current is “shared” might not fully bring forth the idea of the battery as a constant current source. This is shown in the answers of Student 5. ... Although Student 1 shows a similar idea in question 1 that the battery is a constant current source and doesn’t state it explicitly, the answer given to question 2 confirms the model.

Note that the student compares two student responses to illustrate the value of the question in giving a more complete interpretation of student thinking. A physics student (familiar with *Tutorials* but not the unit on circuits) stated:

[The current question] is useful in prying reasoning from the students. By asking what is happening at the battery, it is far easier to elicit a clear “constant current” model, if that is indeed a model which the student uses. It also allows us to discover if a student is thinking holistically or piece-wise, by comparing what the student believes is going on in the battery to ... the rest of the circuit.

In this response, the difference between holistic or piece-wise analysis of the circuit is

pointed out. In both examples, we find that students after instruction are able to carefully interpret student reasoning in a way that is useful for interpreting curriculum materials and facilitation of student learning.

We have similar results from all the course units, in which students who begin the course with little or no content or pedagogical content knowledge attain a much deeper insight into student reasoning (both correct and incorrect) and how to affect student learning in the classroom. In each situation, we find that correct understanding of the physics is necessary before pedagogical content knowledge can be applied well.

Acknowledgments

This work was supported in part by US Dept. of Education grant R125K010106.

References

- ¹ M.C. Wittmann, P. Heron, and R.E. Scherr, “Overview of the Foundations and Frontiers in Physics Education Research Conference,” APS Forum on Education **Fall 2005 Newsletter**, 7 (2005).
- ² J.R. Thompson and B.S. Ambrose, “A Literary Canon in Physics Education Research,” APS Forum on Education **Fall 2005 Newsletter**, 16 (2005).
- ³ C.E. Wieman and K.K. Perkins, “Transforming Physics Education,” *Physics Today* 58 (11), 36 (2005).
- ⁴ L. Shulman, “Those who understand: Knowledge growth in teaching,” *Educational Researcher* 15 (2), 4 (1986).
- ⁵ L.C. McDermott, P.S. Shaffer, and The Physics Education Group at the University of Washington, *Tutorials in Introductory Physics*. (Prentice Hall, Upper Saddle River, NJ, 2002).
- ⁶ J.P. Gutwill, J.R. Frederiksen, and B.Y. White, “Making Their Own Connections: Students’ Understanding of Multiple Models in Basic Electricity,” *Cognition and Instruction* 17 (3), 249 (1999).

Continued on page 27

Continued from page 26

- ⁷ L.C. McDermott and P.S. Shaffer, "Research as a guide for curriculum development: An example from introductory electricity. Part I: Investigation of student understanding," *American Journal of Physics* **61**, 994 (1992).
- ⁸ L.C. McDermott and P.S. Shaffer, "Research as a guide for curriculum development: An example from introductory electricity. Part II: Design of an instructional strategy," *American Journal of Physics* **61**, 1003 (1992).
- ⁹ M.C. Wittmann, R.N. Steinberg, and E.F. Redish, *Activity-Based Tutorials Volume 1: Introductory Physics*. (John Wiley & Sons, Inc., New York, 2004).
- ¹⁰ M.C. Wittmann, R.N. Steinberg, and E.F. Redish, *Activity-Based Tutorials Volume 2: Modern Physics*. (John Wiley & Sons, Inc., New York, 2005).
- ¹¹ D.R. Sokoloff, R.K. Thornton, and P.W. Laws, *RealTime Physics*. (John Wiley & Sons, Inc., New York, NY, 1998).
- ¹² AAPT, *Powerful Ideas in Physical Science*. (AIP, College Park, MD).
- ¹³ R.J. Beichner, "Testing student interpretation of kinematics graphs," *American Journal of Physics* **62**, 750 (1994).
- ¹⁴ E.F. Redish, D. Hammer, and A. Elby, *Learning How to Learn Science: Physics for Bioscience Majors*. (NSF grant REC008-7519, 2001-2003).
- ¹⁵ D. Hestenes, M. Wells, and G. Swackhamer, "Force concept inventory," *The Physics Teacher* **30** (3), 141 (1992).
- ¹⁶ R.K. Thornton and D.R. Sokoloff, "Assessing student learning of Newton's laws: The Force and Motion Conceptual Evaluation and the Evaluation of Active Learning Laboratory and Lecture Curricula," *American Journal of Physics* **66** (4), 338 (1998).
- ¹⁷ M.C. Wittmann, R.N. Steinberg, and E.F. Redish, "Understanding and affecting student reasoning about the physics of sound," *International Journal of Science Education* **25** (8), 991 (2003).
- ¹⁸ M.C. Wittmann, R.N. Steinberg, and E.F. Redish, "Making Sense of Students Making Sense of Mechanical Waves," *The Physics Teacher* **37**, 15 (1999).
- ¹⁹ R.A. Lawson and L.C. McDermott, "Student understanding of the work-energy and impulse-momentum theorems," *American Journal of Physics* **55**, 811 (1987).
- ²⁰ T. O'Brien Pride, S. Vokos, and L.C. McDermott, "The challenge of matching learning assessments to teaching goals: An example from the work-energy and impulse-momentum theorems," *American Journal of Physics* **66**, 147 (1998).
- ²¹ L.C. McDermott and The Physics Education Group at the University of Washington, *Physics by Inquiry*. (John Wiley & Sons, Inc., New York, 1996).
- ²² G.M. Novak, E.T. Patterson, A.D. Gavrin et al., *Just-in-Time-Teaching: Blending Active Learning with Web Technology*. (Prentice Hall, Upper Saddle River, NJ, 1999).
- ²³ W. Christian and M. Belloni, *Physlets: Teaching Physics with Interactive Curricular Material*. (Prentice Hall, Upper Saddle River, NJ, 2001).
- ²⁴ L.C. McDermott and E.F. Redish, "Resource Letter PER-1: Physics Education Research," *American Journal of Physics* **67**, 755 (1999).
- ²⁵ P.S. Shaffer, "Research as a guide for improving instruction in introductory physics," Ph.D. dissertation, University of Washington, 1993.

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.

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.

Development of a Comprehensive Physics Program at a non-traditional upper-level undergraduate and graduate small university

David Garrison

Abstract.

As more students and universities become involved in life-long learning, it will become more important to develop physics programs which can cater to nontraditional students. We describe the development of a Physics Master's degree program at the University of Houston Clear Lake. This is a non-traditional university which only serves students at the Junior, Senior and Master's degree levels and had not previously developed a physics program throughout its thirty-year history. We show how we were able to establish a graduate physics degree in less than three years using community resources and effective marketing techniques although no significant university funds were committed towards the development of this program.

PACS numbers: 01.40.-d, 01.40.Fk, 01.40.G

Introduction

The University of Houston Clear Lake (UHCL) is a non-traditional upper-level undergraduate and graduate university. The university was established as a commuter campus for the University of Houston system, southeast of Houston near Clear Lake and the Johnson Space Center (JSC). About half of the university's students take classes part-time. The average age of undergraduates is thirty years old while the average age of graduate students is thirty-two. Beginning in the fall of 2002, we began the development of the university's first physics degree, an M.S. in Physics. The degree officially began operations in fall of 2004. Currently, the program teaches approximately forty to fifty graduate students per semester and graduated seven majors within its first year of its operation. Unlike most physics programs, almost all of our classes are offered in the evenings and a majority of our students work full-time. Many of these students have backgrounds in engineering and some hold advanced degrees. There is not currently an undergraduate Physics degree being offered at UHCL.

History

The University of Houston Clear Lake was founded in 1974 near NASA JSC in Houston Texas. During the planning stages, it was decided that the university would have no freshmen, sophomore or Ph.D. students. Most of the university's undergraduates transfer from local community colleges while many of its master's degree students work full-time in the local aerospace and petroleum industries. As of 2005, the university had yet to employ a provost or president with a background in science or engineering. Also, although the University is located in the heart of Houston's high-tech sector, the School of Science and Computer Engineering is the smallest of the university's four schools.

UHCL was originally structured with interdisciplinary divisions as opposed to large academic departments. The division handles many of the functions traditionally supported at the department level. Within these divisions there are several academic programs.

Continued on page 29

Continued from page 28

One of the original programs within the Natural Science division was the Physical Sciences program, a precursor to our Physics program. A major drawback to interdisciplinary programs, such as Physical Sciences, is that they do not always allow for advanced specialized research in a particular discipline or for the hiring of a critical mass of faculty within a specific discipline. As a result, by 2002, the Physical Sciences program, which originally consisted of faculty with backgrounds in Physics, Astronomy, Environmental Science, Geology and Chemistry, was reduced to a single faculty member whose focus was Planetary Science.

Many problems existed in the Physical Sciences program in 2002. Several students applied for the program but never attended classes. These students were given incentives at their place of employment for being enrolled in a technical master's degree program, but received little or no incentive to graduate. Advanced courses in physics were either not being taught or were only taught at a very low level because there was no requirement for students to take core physics courses. The core courses were not being taught regularly. There was very little on-campus research in Physics or Astronomy. Enrollment was declining and student satisfaction was low. As a result, the program was on the verge of either being closed down or dramatically changed.

Curriculum Development

The first challenge in developing a Physics program was to find a focus. An online survey was developed and distributed to potential students in the Aerospace and Petrochemical industries as well as to students at the local community colleges. Distribution was handled using a combination of electronic newsletters and direct contact with human resources personnel at each institution. The strongest re-

industry, both potential students and employers responded. They wanted a program that could prepare students with engineering backgrounds for Ph.D. study in Physics, Astronomy or related areas while at the same time being useful for broadening the technical backgrounds of practicing engineers. Because of this response we decided to forgo development of a Bachelors program and start with a Master of Physics degree. The Physical Sciences M.S. was to be phased out, as all its resources would be transferred to the new M.S. in Physics program. However, the B.S. in Physical Sciences remained and is being retooled to support the M.S. in Physics. We are currently in the process of expanding our undergraduate program to better serve students who are in need of preparation to enter the Physics M.S. program.

The most difficult part of developing the curriculum for this degree was working within the restrictions of the part-time students. Almost all classes are taught in the evenings and group learning is often used to maximize the effectiveness of the students' time. Using the survey data, we developed a curriculum consisting of five core courses: Mathematical Methods in Physics 1, Classical Mechanics, Quantum Mechanics, Electrodynamics and Statistical Mechanics & Thermodynamics with advanced areas of study in Orbital Mechanics, Astronomy, Plasma Physics and Relativity. The degree consists of thirty-six credit hours providing a balance of core courses, advanced courses and research. Although we included both a thesis and non-thesis option, the majority of our part-time students (who make-up over ninety percent of the program's student body) choose the non-thesis option. The capstone experience for the non-thesis option consists of at least one semester of independent study research and a Research Project and Seminar class where students are taught how to write and publish scientific papers and give oral presentations of their research.

Continued on page 30

Continued from page 29

Because of the immediate popularity of this program among working students, we developed a Professional Physics concentration focusing on the training of project managers. This plan of study uses the physics core to provide students with the broad technical background needed by project managers, while the Systems Engineering and Management programs provide business and organizational training. This concentration was developed thanks to a grant from the Council of Graduate Schools and the Alfred P. Sloan Foundation and follows the Professional Science Master's (PSM) degree standard.

Building Infrastructure

In order to function as a physics program we needed three things; students capable of contributing to research, research facilities and research projects. In 2002, very few resources existed in the Physical Sciences program. As the curriculum for the physics program was being developed and approved, we began training students to participate in research. The money to buy all the necessary research facilities was not available, so we had to build and develop them using freely available resources. External collaborators were not difficult to find due to our close proximity to JSC. However, JSC is primarily an operations center with very little fundamental physics research. We found that the best way to stimulate research collaborations and develop project ideas was by using seminars. This effectively made the UHCL Physics program a focal point for fundamental Physics and Space Science related research in the JSC community. The seminars then lead to research collaborations and became a powerful tool for recruiting students.

Recruiting Students

Recruiting students was done through both traditional and non-traditional means. As part of the needs assessment survey, respondents entered their email addresses to identify them as individual respondents. This became the basis

for an electronic distribution list of information on the developing physics program. Whenever the physics faculty gave a seminar or talk, everyone in attendance give their email address for inclusion on the list. Over time the list grew to several hundred people and many of them eventually became students. We also advertised the program at face-to-face events such as open houses and educational fairs. We found that a clear majority of the people who eventually became students had some direct contact with our faculty before joining the program. Eventually, word-of-mouth from graduating or current students, became just as effective for recruiting new students. To a lesser extent we also used websites and print advertisements, such as brochures and posters. These were not nearly as effective as the face-to-face recruiting, because potential students in the program tended to have many questions, which could only be answered by program faculty. As a result of this recruiting effort, graduate enrollment in physics and astronomy grew from around ten to as many as fifty students per long semester.

Initiating Research

In order to initiate a research program, we had to develop our on-campus research facilities. As a Physical Sciences program, we only had one wet laboratory which was being used for planetary science research and a teaching lab which was being shared with the Biological Sciences program. We needed to build a modern research laboratory but lacked the financial resources to do so. In order to do this, we decided to focus all on-campus research in the program on theoretical and computational work. The physics program then partnered with a laboratory at JSC that did experimental plasma physics and we began planning for the development of a remote observatory. This was all done under the assumption that would not receive additional space or funding from the university for laboratory development in the near future.

Continued on page 31

Continued from page 30

We built a computational physics lab, using the space formerly occupied by the planetary science lab. We utilized retired campus computers, now running Linux, as our primary computational architecture. We also acquired two Beowulf clusters, a 12-processor cluster built by a student and a 96-processor system donated by the Texas Educational Grid project.

Our part-time students work well in theoretical and computational research. They appreciate the flexibility that it gives them to work on research within the constraints of their schedules. This model also allows us the opportunity to build a synergistic team of faculty who can share equipment as well as ideas. Under the Physical Science program, students were more likely to do research on their own or with adjunct faculty while under the new Physics program they tend to work more with full-time faculty. This has resulted in a major improvement in the quality of the research being performed. Students are beginning to author or co-author research papers in refereed journals, something that was unheard of under the Physical Sciences program.

Discussion

So far the Physics program has been a major success in terms of enrollment growth, student satisfaction and research productivity. Although there was no significant initial financial commitment from the university to help with the development of the program, there has been an overall improvement in the quality of

education. Given that UHCL is a historically non-technical university with limited financial resources does not make all this easy. The biggest problem the program faces is the lack of full-time faculty. Although enrollment has more than doubled and research activity as increased dramatically, we still have only four FTE faculty and rely very heavily on adjuncts to teach at all levels. Because of this, we worked on ways to use adjunct faculty from JSC and elsewhere to make up for our lack of full-time faculty. The result was only partially successful. As a result, we are currently searching for more full-time faculty.

Acknowledgments

We would like to acknowledge the support of the Council of Graduate Schools and Alfred P. Sloan Foundation for their support in developing the Professional Physics concentration. We would also like to acknowledge the support of Conoco Phillips and the Texas Educational Grid Project for the donation of much needed high-performance computing equipment for the program.

References

- [1] UHCL Homepage, <http://www.uhcl.edu>
- [2] UHCL Physics, <http://sce.uhcl.edu/physics>
- [3] Professional Science Master's Degree, <http://www.sciencemasters.com>
- [4] Texas Educational Grid Project, <http://www.txgrid.org>

David Garrison is Faculty Chair and Assistant Professor of Physics and Physical Sciences at the University of Houston, Clear Lakes. He can be reached via e-mail at Garrison@uhcl.edu



A Note from the Teacher Preparation Section Editor

Chance Hoellwarth

In the last few issues, we have made the case that future physics teachers have different needs than typical physics majors. In the summer newsletter

(<http://www.aps.org/units/fed/newsletters/summer2005/index.html>), McDermott, Heron, and Shaffer made the case that K-12 teachers need special courses, in addition to their content courses, that address their special needs. Then in the fall issue

(<http://www.aps.org/units/fed/newsletters/fall2005/index.html>), we heard from four institutions that not only designed special courses for future teachers, but also designed special programs for their future teachers. This month I would like to continue in that vein and share with you two more programs designed especially for future physics teachers.

Ed van den Berg will tell us about a teacher preparation program that he helped develop at the University of San Carlos (located in the Philippines), which highlights the fact that

many of the features we heard about last issue (specially designed programs, recruitment, etc.) are important and transferable, even to other countries.

Dan MacIsaac will tell us about alternative certification, which refers to the re-certification of teachers from different disciplines and/or people making career changes into teaching from technical fields, and describe the program at The State University of New York (SUNY)—Buffalo State College designed especially for this group. You may not have heard anything about alternative certification, but the group of people interested in it have the potential to become new physics teachers. At any rate, the program itself has features that might work at your institution.

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

A Physics Teacher Education Program in the Philippines

Ed van den Berg, Jocelyn Locaylocay and Marilou Gallos

Introduction

Many high-income countries experience great difficulty in attracting talented young people into physics teacher education (e.g. Smithers & Robinson, 2005). The USA and Canada even recruit science teachers in the Philippines which itself experiences a serious shortage of qualified and competent physics teachers. How can one develop an exemplary physics teacher education program and attract a critical mass of students? The Philippine program described below increased its enrollment from 1 to 30 students per year and provides some answers to this question.

The Philippines is an island archipelago with 84 million inhabitants in SE Asia. It was a Spanish colony for about 350 years and then an American colony until 1946. The US established an education system for all, which was functioning quite well at the time of independence (1946) but has declined in quality since (Philippine Congress, 1993; TIMSS, 1999).

The Philippine High School covers grades 7 - 10. The science curriculum consists of General Science (mostly Earth Science plus some Physics) in grade 7, Biology in grade 8, Chemistry in grade 9, and Physics in grade 10. Higher Education starts after grade 10 instead of grade 12. Nationwide only 8% of the Physics teachers majored in Physics and about 20% of the Chemistry teachers majored in Chemistry. The other Physics and Chemistry teachers majored in subjects such as Mathematics, English, Social Science and Physical Education, and are forced to teach Physics or Chemistry. Even General Science teachers are often poorly prepared to teach Physics, as non-physicists often teach college level physics. As a result much High School physics teaching is superficial, memory oriented, frequently erroneous, inef-

fective and boring (Berg et al, 1998; Somerset et al, 1999).

Few universities offer a major in Physics or Chemistry teacher education because they lack laboratory facilities and qualified instructors. Most universities, which do have teacher education courses, have enrollments in the single digits. Thus Physics pre-service students enroll in whichever physics courses are offered (usually engineering physics) and then take teaching methods courses together with students of other subjects such as English, Social Studies, and Mathematics.

Through a cooperation program with the Free University (Amsterdam), financed by the Netherlands' Government, The University of San Carlos (USC, Cebu City, Philippines) invested in science teacher education. A deliberate choice was made to focus on *pre-service* teacher education and on recruiting a critical mass of 30 students per year. World-wide experience shows that several weeks of *in-service* teacher education does not lead to major improvements in teaching, particularly if the main problem of teachers is weak subject matter knowledge. Science concepts take years to develop, just like trees. The key issues identified in developing viable pre-service programs were: a) promotion and recruitment of students; b) the development of special science courses for prospective teachers; c) the development of science education courses which are subject specific; and d) support graduates in their first years of teaching and professional development.

Continued on page 34

Continued from page 33

Promotion and recruitment

The first step in producing better teachers is to attract top students for pre-service program. Every year we run a massive promotion campaign. Lecturers visit High Schools with a show of Physics and Chemistry experiments. Philippine students take great interest in the shows and it is easy to maintain attention of 100 - 200 students. Schools near the university are invited to semi-annual science exhibitions put on by pre-service students. The shows and the exhibitions do stimulate student interest and many take the selection test (500 - 800 annually). Only 10% pass and are interviewed. Of these, about half enroll making for an annual admission of about 30 students. The typical enrollment before the project was about 1 student per year.

Many students initially want to become engineers, lawyers or accountants, not teachers. They enter the program because of the scholarships and the possibility to go to the best university in the province rather than a 2nd or 3rd rate one. Through the block sections in Physics and Physics Education courses, the group atmosphere, and the inspiring dedication of lecturers, most students eventually commit themselves to a teaching career.

Science courses: Making science and mathematics interesting

Once you have top students, you have to keep them by offering an attractive program. This matches neatly with our first priority for improving Philippine science and mathematics teaching: to make lessons more interesting.

Seventy percent of the Physics and Chemistry teachers in our region are teaching more than one subject, so we opted for a Physics-

Chemistry and a Physics-Mathematics teacher education program. The Physics is offered in one block section for the two programs together, while Chemistry and Mathematics are taken together with the BSc in these respective subjects so that class size is still about 30. An added advantage of the teacher education double science major is that the total number of required credits in science courses remains below a BSc program such as BSc Physics, so prospective teachers cannot apply for industry jobs. Many science experts will consider this a "questionable" advantage, however we developed a Masters program for the alumni that includes more physics content (see below).

Science teacher education students will teach the way they were taught in *science* courses, **not** how they were told to teach in *science methods* courses. *That is why the science courses are more crucial as teacher preparation than the methods courses: the science courses should be exemplary for the future teachers.* They should have a stronger conceptual emphasis (McDermott, 1990). All science courses try to model teaching methods, which are possible and interesting, yet currently unusual, in the crowded and resource-poor Philippine High Schools. This has necessitated extensive redesigning of existing courses and in-class coaching of lecturers through team teaching.

The program starts with one semester of physics based on Hewitt's *Conceptual Physics* (1998) and in the spirit of that book presents many everyday examples of physics, exciting demonstrations, activities, and lots of reasoning. Students find it interesting and frequently read chapters other than the ones being taught. Laboratory work and theory are integrated in 1st and 2nd semester. In the second and third semester an Algebra-based Physics text is used but we frequently use questions and readings

Continued on page 35

Continued from page 34

from Conceptual Physics as well. In the fourth semester we switch to calculus based University Physics of Freedman and Young (1996). All these books are available in low-priced Philippine black & white editions. Although simple experiments with everyday objects are much emphasized, students also learn to work with modern science equipment and computer-based experiments. The Departments of Chemistry and Mathematics assign their best lecturers to the program and offer varied courses as well. Throughout exciting demonstrations, non-cookbook laboratory activities, and small research projects keep students stimulated and interested. Most science courses emphasize linking of science concepts with everyday phenomena. Instead of an abstract and deductive introduction of concepts, many lecturers try (and were trained) to introduce new concepts inductively through experiments, demonstrations, examples, and visualizations.

Pedagogical content knowledge, the heart of the matter

A series of four courses taught by Physics and Chemistry faculty provides a subject-specific introduction to teaching Science. A first course emphasizes interactive presentations and demonstrations and culminates in a small exhibition of science experiments to train demonstration and explanation skills. A second course focuses on selection and preparation of lesson materials, includes a first school teaching experience, and culminates in a large exhibition and science show. The first batch of students initiated a science theater tradition. Since then students in this course write and perform a play as well with a plot that involves many science experiments. The enthusiastic reactions of audiences reinforce the motivation of the prospective teachers. A third course is on *Alternative Conceptions in Physics and Remediation* and focuses on typical learning problems in the

different branches of physics including diagnostic assessment and teacher feedback. The fourth course is on *Assessment in Science*, which amongst others provides an opportunity to revisit the nasty scientific details in school science. Throughout emphasis is on teaching methods, which are realistic in Philippine High Schools: 50 - 70 students per class, heat, noise, and lack of textbooks and of laboratory equipment. This means interactive plenary demonstrations (Liem, 1987) combined with individual and small group work during the lessons rather than lecturing and dictation, which are so common (Berg et al, 1998). In these 4 courses physics gets a lot more attention than chemistry and mathematics. Therefore there is still a specialized Chemistry Education course (for PC majors) and two Mathematics Education courses (for PM majors). In the final year there is one semester of full-time student teaching split in two 8-week periods, each at a different school. In spite of model lessons in their science courses and emphasis on interactive and creative subject-specific methods, many students initially revert to the boring and ineffective teaching they experienced in their own high school before. Through intensive guidance from their university supervisors (science lecturers) students improve and develop quickly.

Placement and aftercare

All graduates are required to teach for at least 4 years in Philippine schools. During that time they cannot obtain a passport. Our Dean works closely with the Regional Education Office and with public and private schools in order to place students in High Schools and if possible in pairs so they can assist each other during the difficult first years of teaching. Our first batch established a good name and since then alumni have been much in demand.

Continued on page 36

Continued from page 35

The most critical period for the development of teachers' classroom practice is the first two years after graduation (Eraut, 2000) when they learn classroom management skills and gain mastery of the basics of teaching. We try to support them through occasional alumni meetings and extensive networking between alumni. Only after the first years can new teachers start applying the varied teaching strategies and skills they learned in their pre-service program. However, many may tend to adopt the more traditional teaching practices of senior colleagues, and assume that the new methodologies, which did not work for them in the first year of teaching, will never work. Therefore within two years, new teachers might benefit from a professional development program. A concrete method of sustaining long-term professional development in a private university is through a Masters program where expenses are covered by tuition. There was a Masters program but it suffered from poor quality control. The Masters program was revamped, better tailored to the needs of teachers, and designed to include a no-thesis option. Enrollment immediately increased. In 2004 about 40 of the then 139 alumni were enrolled. Many alumni are eager to advance their credentials before starting families. The science component of the Masters program requires a BSc or beyond level in several courses.

Support and faculty development

The following forms of outside support have been received during the development of the program: The Philippine Department of Science and Technology (DOST) donated science equipment, student scholarships, and faculty scholarships. The Philippine Commission on Higher Education has provided student scholarships. The University of San Carlos provided a new building and laboratories. The Dutch Government through the Free University provided funds for equipment and facilities, a l

long-term consultant (6½ years for physics education and 2 years for mathematics education), short-term consultants, and short courses for faculty.

Faculty development in the project was focused on gaining knowledge of typical Philippine classroom conditions, on developing pedagogic content knowledge, and on coaching lecturers to improve teaching. This was accomplished through Masters and PhD studies with research closely linked to the development of courses and teaching strategies for the science courses for teacher education, through team teaching in physics and physics education courses, and through joint course development. One Physics lecturer trained for 6 months with Fred Goldberg in San Diego and then implemented a Constructing Physics Understanding optics unit with extensive monitoring of conceptual development of individual students (Rosaroso & Berg, 2003). Teacher education students vividly remembered the intensive reasoning about concepts two years after the experience.

Copying the Experience

The promotion and recruitment campaigns would do well in low-income countries as for many students the scholarship is the only way of continuing their studies. In high-income countries it may not work, as there are many other ways of getting into more attractive and high status studies. However, just like in the Philippines, high-income countries have to invest heavily in promotion and recruitment and once a program is running, its students can take part in this. The important message is that one should strive for a critical number (20 – 30 per year) of students and thus concentrate physics teacher education programs at only a few universities per country. In that way one can create the needed special physics and physics education courses.

Continued on page 37

Continued from page 36

Alternatively different institutions with small numbers of physics teacher education students could cooperate and organize a joint intensive summer program which emphasizes physics pedagogy and teaching ideas. A large investment in one program is better than spreading investment over many programs with sub-critical mass. In the US one might want to focus recruitment on freshmen and sophomores rather than on High School students.

Literature

Berg, E van den., Alfafara, R., & Dalman, T. (1998). *Case studies of science and mathematics teaching in the Philippines and lessons for teacher and school development*. Paper presented at the annual conference of the National Association of Research in Science Teaching, San Diego, USA.

Congressional Commission on Education. (1993). *Making Education Work: An Agenda for Reform*. Congress of the Republic of the Philippines. Quezon City, Philippines.

Eraut, M. (2000). Teacher education designed or framed. *International Journal of Educational Research*, 557-574.

Hewitt, P.G. (1998). *Conceptual Physics* 8th edition, Addison-Wesley.

Liem, T.K. (1987). *Invitations to Science Inquiry* 2nd edition. Chino Hills (CA): Science Inquiry Enterprises.

McDermott, L.C. (1990). A perspective on teacher preparation in physics and other sciences; The need for special science courses for teachers. *American Journal of Physics*, 58(8), 734-742.

Rosaroso, N., Berg, E. van den (2003). The evolution of Philippine student conceptions of the formation of shadows and images.

Smithers, A., Robinson, P. (2005). PHYSICS IN SCHOOLS AND COLLEGES Teacher Deployment and Student Outcomes. Research University of Buckingham: Centre for Education and Employment . Carmichael Press University of Buckingham Buckingham MK18 1EG UK.
<http://www.buckingham.ac.uk/education/research/ceer/pdfs/physicsprint.pdf>

Somerset, A.H., Alfafara, R. & Dalman, T. (1999b). *Teaching and Learning Science and Mathematics in the Classroom: Effective and Ineffective Pedagogy Compared*. Cebu City: SMEI-USC, Talamban Campus.

Third International Mathematics and Science Study (1999). International Study Center, Boston College.

Young, H.D., Freedman, R.A. (1996). *University Physics* 9th edition. Addison-Wesley.

Ed van den Berg works at the AMSTEL Institute at the University of Amsterdam in the Netherlands. From 1996 - 2002 he was based at the University of San Carlos in Cebu City, Philippines, sponsored by the Free University, Amsterdam, Netherlands. He can be reached via e-mail at eberg@science.uva.nl, Jocelyn Locaylocay and Marilou Gallos work at the University of San Carlos in Cebu City, Philippines. Extensive documentation on project, program, and courses exists and is available from the authors.

A New Model Alternative Certification Program For High School Physics Teachers

Dan MacIsaac, Joe Zawicki, Kathleen Falconer, David Henry and Dewayne Beery

We describe the development and deployment of a model graduate level alternative certification program for physics teachers at SUNY-Buffalo State College. The *Masters of Science Education (Physics with NYSED Transitional B Certification)* program accommodates science and engineering professionals with appropriate bachelors degrees who wish to change career paths into physics teaching. The alternative certification program is distinctive in that candidates minimize their income disruption and bypass student teaching through an intensive full time Spring-Summer introductory component leading to NYSED Transitional B Certification, followed by paid, mentored teaching employment and evening coursework for two calendar years. This alternative certification program is made possible through intensive physics teachers' summer academy courses, supplemented by regular semester evening course and online offerings. Courses are shared with a second new program - the *Masters of Science Education (Physics)*, which serves already certified science teachers (usually in subjects other than physics) who wish to obtain a master's degree for permanent teacher certification and usually teacher certification in a second discipline -- physics.

Alternative Teacher Certification

Alternative certification refers to a teacher certification program that differs from standard college programs of teacher preparation, usually by avoiding the extended guided field experience of student teaching. Alternative certification is frequently insufficiently discrimi-

nated with emergency certification, which usually refers to a complete waiver of any teacher preparation to obtain a teacher who is otherwise unavailable. Other certification routes intermediate to these exist, particularly individual (transcript) evaluation in NY.

Although problematic, alternative certification programs can be done well, and can provide a viable pathway to physics teacher preparation. Alternative certification program candidates bring uniquely attractive backgrounds and interests to address needs for under-represented teachers sought by schools. Alternative certification programs can address needs not adequately met by traditional programs.

Overview of the Two Buffalo State College M.S.Ed. (Physics) Programs

The *M.S.Ed. (Physics)* programs are summarized in Figure 2. Admissions require either current NYSED secondary science certification (the right hand side of Figure 2), or for alternative certification (the left hand side of Figure 2), a bachelor's degree meeting NYSED language and content requirements for physics certification, and successful completion of the NYSED state teacher competency examinations (LAST and the Physics Content Subject Test) required for physics teacher certification. Certified participants do not have to take any additional education courses or workshops, unlike alternative certification candidates who must take an early field experience and some

Continued on page 39

Continued from page 38

education courses before they can be awarded the Transitional B certification and can accept classroom employment.

Alternative certification candidates typically complete their initial employment requirements through full-time enrollment in the spring semester, followed by an intensive summer academy, then teach the following school year under Transitional B certification under both SUNY- Buffalo State College Physics mentorship and an intense LEA induction program. Alternative certification candidates can be in the classroom employed as full-time transitionally licensed teachers after as little as two semesters of full time student study (one spring and one summer semester), and we have had several candidates succeed with this arrangement.

During the regular academic year, *M.S.Ed. (Physics)* candidates also take some combination of evening and distance education courses. Although coursework for the alternative certification program can be completed in the following summer academy, the NYSED Transitional B certification agreement requires a minimum of one full year of intensively mentored teaching experience for regular teacher licensure.

M.S.Ed. (Physics) program candidates who are already NYSED certified in another subject can add physics certification and complete their program in about four semesters if they enroll in two successive summer academies together with the regular fall and spring semester evening and web courses. Each summer, 18 credits of summer academy courses are offered for teachers (including six credits for K-8 teachers), with a minimum of 6 credits of evening classes (9 cr. this academic year) between regular Fall and Spring semesters. We have also placed some few of these offerings online as appropriate (E.g. PHY500 and PHY690)

and we are creating online support materials (and local tutorials) for NYSED Physics CST exam preparation. This greatly extends state-wide reach for our coalition and meets teacher demands. We accept transfer credit and some of our downstate candidates have taken some of the online course offerings for graduate credit in physics from the NTEN/NSTA and University of Virginia programs in particular (NTEN, 2004; University of Virginia, 2004).

The graduate physics courses for these programs include a mixture of undergraduate physics content and graduate level physics pedagogical content knowledge (physics and science education research PER and SER findings, and science teaching methods), presented at an undergraduate mathematical level. Physics content is largely shaped by research findings and state requirements, and frequently departs from traditional physics course curricula – for instance there is essentially no treatment of thermodynamics, while there is a significant treatment of modern physics dictated by the state via PER-informed curricula.

The two 600-level summer academy courses are particularly intensive fifteen day workshops modeled after the nationally renowned *Modeling Physics* workshops held at Arizona State University – in each course approximately thirty participants work through PER-informed curricular activities in both student and teacher roles. Besides Hestenes' distinguished and well-researched *Modeling Physics* curriculum, activities from the AAPT's *Powerful Ideas in Physical Science (PIPS)* and Goldberg's *Constructing Physics Understanding (CPU)* curricula also inform these workshops (Wells, Hestenes & Swackhamer, 1995; Hestenes, 1987, 1993; Modeling Physics Group, 2004; AAPT, 2004; Goldberg 2000). PHY510 is a locally developed workshop course originally intended to support new teachers who were assigned to teach physics without physics certification,

Continued on page 40

Continued from page 39
M.S.Ed.-Physics at BSC

<http://physicsed.buffalostate.edu/programs/MSEDPgms.html>

The *M.S.Ed.-Physics* degree programs at SUNY- Buffalo State College
Dr. Dan MacIsaac (716) 878-3802 <macisadl@buffalostate.edu> <<http://PhysicsEd.BuffaloState.Edu/>>

	M.S.Ed.-Physics (NY Alt Cert via Trans B) Cert for Science/Tech/Engg professionals	M.S.Ed.-Physics (usually 2nd NY Cert) STEM teacher certifies to physics	
Program admission requirements	Physics or related bachelor's degree 3.0 GPA 18 cr of non-physics science language req NYS Tchr Cert Ex (LAST & Physics CST) 3 written references & interview	NYS certification in a secondary science 2.5 GPA n/a n/a n/a 3 written references & interview	
Coursework	all courses 3cr unless indicated		E =evening course O = online course S = summer academy
Seminar (3cr)			
PHY500: Physics Education Research Seminar	3cr	3cr	O (Spr)
Physics Teaching Methods (6cr)			
PHY510: Process Skills in Physics Teaching (6 cr) w/ 40h early field experience grades 7-12	6cr Y	6cr NR	S (all) by arrangement
Physics Content w/Model Pedagogy (12cr)			
PHY620: Powerful Ideas & Quantitative Modeling: Force, Motion and Energy (6cr)	6cr	6cr	S (even years)
PHY622: Powerful Ideas & Quantitative Modeling: Electricity and Magnetism (6cr)	6cr	6cr	S (odd years)
Project (3cr)			
PHY690: Research Project	3cr	3cr	O (Fall)
Electives (6/9cr)			
PHY518: Wave Phenomena and Optics	6cr	9cr	E (Fall / Spr rotation)
PHY520: Modern Physics			E (Fall / Spr rotation)
PHY525: Nuclear and Particle Physics			E (Fall / Spr rotation)
PHY616: Advanced Dynamics			E (Fall / Spr rotation)
PHY618: Advanced Electricity and Magnetism I			E (Fall / Spr rotation)
SCI527: Current Topics in Science			E (Fall / Spr rotation)
SCI632: Curricular Trends in Science Teaching in the Secondary School			E (Fall / Spr rotation)
SCI664: Teaching Science with Media			E (Fall / Spr rotation)
SCI685: Evaluation in Science Education			E (Fall / Spr rotation)
Or other courses by advisement			
NYSED Teacher Cert Requirements (15cr)			
EXE500 or EXE600: Exceptional Education	3cr	NR	E (all semesters)
EDF503 or EDF529: Educ/Adolescent Psychology	3cr	NR	E (rotation)
EDU417: Adolescent Literacy	3cr	NR	E (rotation)
plus one of			
EDU416: Teaching Literacy in Middle and Secondary Schools	3cr	NR	E (all)
EDU609: Improving Reading in the Content Areas			E (rotation)
PHY502: NYSED 52.21(b)(3)(xvii)-regulated college mentored physics teaching experience paid employment for one year under NYSED Transitional B Certification	3cr	NR	by arrangement
Total number of required credits:	45cr	33cr	

Figure 2: The *M.S.Ed.-- Physics* programs at SUNY- Buffalo State College.

Continued on page 41

Continued from page 40

and focuses on meeting NYSED requirements through activities NY master physics teachers have selected on an *ad-hoc* basis, leavened with formal PER and SER touchstone activities.

Finally, though not accepted for *M.S.Ed. - Physics* program core credit, the summer academy includes at least one offering for K-8 teachers of physics, usually PHY507, a course dedicated to the appropriate NYSED standards incorporating the above curricula plus Goldberg's *Physics for Elementary Teachers* (Goldberg, 2004) curriculum activities, and frequently incorporating a PER or SER component by blocking it with a second graduate course in science curriculum research for K-8 teachers, EDU671.

The other two notably unique courses are PHY500 --an online seminar of PER readings and findings, and PHY690 -- a terminal masters' project producing a manuscript contributing to the physics teaching community, most of which are web-published, but some 40% of which have been published in peer reviewed practitioners literature for physics teachers. This last course is particularly challenging for instructor and candidates, but very rewarding. These last two, together with several topical courses, are offered during the Fall and Spring semesters.

Lessons Learned

There has been considerable demand for our *M.S.Ed. (Physics)* programs. We have stabilized our program size at approximately forty candidates by restricting acceptances to only the best qualified and most likely applicants. Since the programs were inaugurated in fall and summer 2002, eleven candidates have graduated, with four more to graduate shortly. About two thirds of our candidates are certified working teachers who are seeking either certification to physics and/or a permanent license,

with a small few candidates who don't require physics certification or a masters' degree for permanent certification who are simply improving their physics teaching skills. The remaining third of the candidates are alternative certification students. The Physics Teachers' Summer Academy acts as a recruiter for the *M.S.Ed. (Physics)* programs, attracting between ninety and seventy teachers each summer to the SUNY- Buffalo State College campus, with another twenty-five to fifty teachers attending the monthly Saturday morning alliance meetings of the Western New York Physics Teachers' Alliance (WNYPTA, 2003) supplementing the recruiting pool and candidate support network.

The non-certification *M.S.Ed. (Physics)* candidates are mostly (65%) HS science and math teachers seeking certification in physics, with some (30%) already holding initial physics certification and a small number (5%) of elementary and middle school teachers (usually those with minors in physics) seeking secondary physics certification. Second subject certification for science teachers via a discipline-specific masters degree intended for teachers is growing common and greatly improves employment flexibility for NY science teachers. A very few certified candidates have no NYSED need for another masters' degree and simply want to improve their physics teaching; we tend to attract these candidates to satisfy their NYSED graduate physics content credit requirements or to attend physics alliance meetings, and they sometimes stay for the reformed teaching and student-centered pedagogy. Although we have only two minority candidates to date, we have almost 20% women and we are trying to recruit both populations. We are particularly pleased to have candidates who are working teachers in urban, high-needs school settings, including several building new physics programs at their schools.

Continued on page 42

Continued from page 41

We hope to have these candidates support future recruiting of undergraduate student and graduate student physics and physics education candidates from amongst their own students and colleagues.

The remaining third of our *M.S.Ed. (Physics)* candidates and graduates (sixteen) are career-switching technical professionals; of these all save three (77%) hold bachelors' degrees in various fields of engineering. Most are young men who have practiced engineering for several years and are seeking more rewarding careers with greater employment stability. The other three include two alternative certification (AC) candidates with a B.S. in physics and a Ph.D. physicist switching careers to teaching. Our AC candidates are usually altruistic and reflective about their reasons for career change (we are not admitting simple economic refugees), and some have worked as substitute teachers, which is something we strongly encourage. Our AC candidates are almost universally looking to move directly into the classroom as quickly as possible, want to minimize their time in university classrooms and want to minimize the financial disruptions due to full time student enrollment. One exception to this is still working as an engineer and taking one program course per semester. They are frequently particularly hostile to education coursework, which can be problematic. Like many traditionally prepared teacher candidates, they also resent the unpaid-while-paying-tuition nature of traditional student teaching.

Alternative certification programs incorporating physics content for these individuals are quite rare, though these candidates could readily locate other certification programs without physics content such as an *M.Ed.* or *M.S.Ed. (Science)* or a post-baccalaureate non-degree program in general science teaching, and we don't believe we are cannibalizing such programs. Only one AC candidate holds a Buffalo

State Physics department undergraduate degree. We have seen that our alternative certification candidates present unique issues in physics teacher education; our candidates sometimes hold inappropriately optimistic estimations of their subject expertise and strong, under-informed and inappropriate preconceptions of good teaching practices. A reflective exposure to SER and PER instruments and literature, and explicit instruction via student-centered constructivist reformed teaching methods helps most of them address these issues, though three have simply left our program, partially due to a lack of interest and willingness to change these views, which has been noted in the AC literature (Koballa, Glynn, Upson & Coleman, 2005). Abd-El-Khalick (2003) has referred this as the expert-novice-expert problem; AC candidates need to recognize that their expertise in one area doesn't map onto a new subject area before they can progress in their development as teachers. Traditional undergraduate teachers in preparation move through a novice-expert development cycle (often holding naive images of good teaching), and experienced teachers from other science disciplines may need to move through a different kind of expert-novice-expert developmental sequence with regard to acquiring new pedagogical skills in inquiry-based, student-centered, constructivist (reformed) teaching (MacIsaac, Sawada & Falconer, 2001; MacIsaac & Falconer, 2002).

Because the AC candidates require monthly observation visits from a faculty member for a year and incumbent travel time, the program is currently limited to a small number of AC candidates (we are hiring local master physics teachers to help supervise), and we no longer advertise the AC program except by word of mouth and posters at state science conferences. We do advertise the non-certification program in yearly mailings to physics departments and high schools statewide.

Continued on page 43

Continued from page 42

We currently have three out-of-state candidates, and a few (less than 5%) out-of-state Summer Academy registrants every summer.

These forty-odd candidates represent maximum capacity for a program dedicating approximately 1.0-1.5 FTE year round faculty without research release (three graduate courses each semester year round). To staff these programs at SUNY-BSC, one new full-time faculty member was hired and is supported by another from physics, and faculty from two other departments to teach these course offerings. In particular, the summer academy courses require additional instructional personnel, both BSC faculty and master physics teachers, making the programs extremely faculty time intensive. Despite receiving NSF supplementary funding (for candidate scholarships and support), the *M.S.Ed. (Physics)* program courses alone are run on a cost-recovery basis; BSC makes money on the summer academy courses in particular (six graduate credits of in-state tuition cost approximately \$1800). Summer academy courses routinely fill to capacity and students are turned away. SUNY- Buffalo State College is historically a teacher preparation institution, famed for preparing high-quality teachers, and successfully competes with over a dozen regional teacher preparation institutions. BSC has no other graduate programs in physics, due to the close proximity of SUNY University at Buffalo which has a complete offering of physics graduate programs and is the Western New York regional flagship institute for physics research. As a result of the success in these endeavors, the *M.S.Ed. (Physics)* programs and associated activity (the *Summer Physics Teachers' Academy* and the *Western New York Physics Teachers' Alliance*) are viewed with considerable institutional pride, and we consider these as institutionalized.

Acknowledgements

The preparation of this manuscript was supported by the National Science Foundation (DUE 0302097), Buffalo State College and the Center for Excellence in Urban and Rural Education (CEURE). Dr. Tom O'Brien and the *M.S.Ed. (Physics)* program candidates contributed comments and insights.

References:

Abd-El-Khalick (2003). Alternative pathways to teaching: Quality teachers versus warm bodies in classrooms. Unpublished manuscript available from the author.

American Association for Employment in Education, Inc. (2003). *2003 Executive Summary: Educator Supply and Demand in the United States*. Columbus, OH: AAEE. Available from <http://www.aeee.org>

American Association of Physics Teachers (AAPT) (2004). *Powerful Ideas in Physical Science*. Available from <http://www.aapt.org/Publications/pips.cfm>.

American Institute of Physics (1999). *Maintaining Momentum: High School Physics for the New Millennium. The AIP's 1997 Nationwide Survey of High School Physics Teachers*. Melville NY: AIP. Available at <http://www.aip.org/statistics/trends/highlite/hs2/high2.htm>.

Committee of Science and Mathematics Teacher Preparation (CSMTP) (2001). *Educating teachers of science, mathematics and technology: New practices for the new millennium*. Washington DC: National Academy Press. Available at <http://www.nap.edu/books/0309070333/html/>

Continued on page 44

Continued from page 43

Darling-Hammond, L. (2000). *Solving the dilemmas of teacher supply, demand and standard: How we can ensure a competent, caring and qualified teacher for every child*. Washington: National Commission on Teaching & America's Future. ED463337

Darling-Hammond, L. (2001, May). The challenge of staffing our schools. *Educational Leadership* 58(8), 12-17.

Darling-Hammond, L. (2002, September 6). Research and rhetoric on teacher certification: A response to "Teacher Certification Reconsidered," *Education Policy Analysis Archives*, 10(36). Available from <<http://epaa.asu.edu/epaa/v10n36.html>>.

Darling-Hammond, L., Chung, R. & Frelow, F. (2002, September / October). Variation in teacher preparation: How well do different pathways prepare teachers to teach? *Journal of Teacher Education*, 53(4) p286-302.

Darling-Hammond, L., & Youngs, P., (2002, December). Defining "Highly qualified teachers": What does "Scientifically-based research" actually tell us? *Educational Researcher*, 31(9) 13-25.

Goldberg, F (2000). Constructing physics understanding (CPU) project.. Available from <<http://cpucips.sdsu.edu/web/CPU/default.html>>.

Goldberg, F. (2004). Physics for Elementary teachers (PET). Available from <<http://petproject.sdsu.edu/>>.

Harris, S.A., Camp, W.E., & Adkison, J. (2003). New structures and approaches for teacher preparation : Do they make a difference in teacher retention? Paper presented to AACTE 2003 Conference. ED472813.

Hestenes, D. (1987). Toward a Modeling Theory of Physics Instruction, *Am. J. Phys.* 55: 440-454 (1987).

Hestenes, D. (1993). Modeling Instruction in High School Physics (NSF Grant ESI 9353423), Information about the workshops can be obtained by visit

ing the Project's web site at <<http://modeling.asu.edu/>>

Ingersoll, R.M. (1999). The problem of under-qualified teachers in American secondary schools. *Educational Researcher*, 28(2): 26-37. Available at <<http://www.aera.net/pubs/er/arts/28-02/ingersoll03.htm>>

Ivie, R. & Stowe, K (2000). *Women in Physics, 2002*. Melville, NY: AIP. Available at <http://www.aip.org/statistics/trends/trends.htm>.

Koballa, T.R., Glynn, S.M., Upson, L. & Coleman, D.C. (2005). Conceptions of teaching science held by novice teachers in an alternative certification program. *Journal of Science Teacher Education* 16, p287-308.

MacIsaac, D.L., Sawada, D., & Falconer, K.A. (2001). Using the reform teacher observation protocol (RTOP) as a catalyst for self-reflective change in secondary science teaching. In developing and utilizing an observation instrument to define, quantify, assess and refine reformed teaching practice in K-20 science and mathematics. Peer-reviewed poster & paper. *American Education Research Association Division K*. <<http://www.klick.org/2000aera/rbfiledisp.asp?sheatid=980>>

MacIsaac, D.L., & Falconer, K.A. (2002). Using RTOP to Reform a Secondary Science Teacher Preparation Program. *American Association of Physics Teachers Announcer*, 32(2) p130.

Modeling Physics Group (2004). Modeling Instruction Program. Available from <<http://modeling.asu.edu/>>.

National Teachers' Enhancement Network (NTEN) (2004). Available from <<http://www.scienceteacher.org/>>.

National Evaluation Systems, 2002. New York State Teacher Certification Examinations, 2002. See <<http://www.nystce.nesinc.com/>>.

Continued on page 45

Continued from page 44

Neuschatz, M. & McFarling, M. (Feb 2000). Background and professional qualifications of high-school physics teachers. *The Physics Teacher*, 38(2), 98-104. Available at <<http://www.aip.org/statistics/trends/hstrends.htm>>.

New York State Education Department (2004). *Obtaining your certificate: Certification requirements*. Available from <<http://www.highered.nysed.gov/tcert/certificate/nyscertreq.htm>>

New York State Education Department (2001). *Resource Guide with Core Curriculum: Physics*. Available from <<http://www.emsc.nysed.gov/ciai/mst/pub/phycoresci.pdf>>

New York State Education Department (2000). *General education and diploma requirements: Commencement level (Grades 9-12)*. Available from <<http://www.emsc.nysed.gov/part100/pages/diprequire.pdf>>

Shen, J. (1998). The impact of alternative certification on the elementary and secondary public teaching force. *Journal of Research and Development in Education* 32(1) p9-16.

Shen, J. (1999). Alternative certification: Math and science teachers. *Educational Horizons*, 78(1) p44-48.

Urban Teacher Collaborative (2000). *The urban teacher challenge: Teacher demand in the great*

city schools. Washington, D.C.: Council of the great city schools. Available at <<http://www.rnt.org/publications/index.html>>.

United States Department of Education (2002). *Meeting the highly qualified teachers challenge: The secretary's annual report on teacher quality. Washington DC: US Dept of Education, Office of Postsecondary Education*. Available from <<http://www.title2.org/secReport03.htm>>.

United States Department of Education (2003). *Elementary and Secondary Education Act (ESEA) of 2001 (No Child Left Behind)*. Washington DC: US Dept of Education. Available from <<http://www.ed.gov/nclb/>>.

University of Virginia (2004). Available from <<http://galileo.phys.virginia.edu/outreach/Professional%20Development/>>.

Wells, M., Hestenes, D., & Swackhamer, G. (1995). A modeling method for high school physics instruction. *American Journal of Physics*, 63, 606-619.

Western New York Physics Teachers' Alliance (WNYPTA) (2003). Available from <<http://physicsd.buffalostate.edu/WNYPTA/>>.

Willie-Schiff, N. (2002). Private communication of NYSED physics teacher data 1970-present. Available from the authors.

Zawicki, J.L., Jabot, M., Falconer, K., MacIsaac, D.L., Henry, D. & Fischer, R. (2003). A preliminary analysis of the June 2003 New York State Regents examination in physics. *Perspectives on Science Education*, June 2003. New York State Science Education Leadership Association: Albany NY. Available from <http://physicsd.buffalostate.edu/pubs/NYRegentsPhysics/>

Browsing the journals

Thomas D. Rossing

- The National Science Board has formed a blue-ribbon panel on improving student achievement at the elementary, secondary, and undergraduate levels, according to a report in the 7 April issue of *Science*. The 15-member commission, to be appointed in mid-May, will, hopefully, produce an “action plan” covering needed improvements in curricula, teacher training, and evaluation. It will also describe the appropriate role for NSF and its Education and Human Resources directorate, which currently has a budget of some \$800 million. Whatever they decide, observers say, panel members will also need to sell their advice since federal intervention is often viewed as controversial by local and state governments.

- “Pseudoscience” is the title of a thoughtful editorial in the April issue of *The Physics Teacher*. Nearly half of our students can’t distinguish between science and pseudoscience. Data show, for instance, that around 40% of high school graduates admit to believing in astrology. At least as many believe in paranormal phenomena such as telepathy and extraterrestrial visitations. What has gotten our attention are the recent efforts to require the teaching of pseudoscience, such as creative design, in science classes. Over the years we have learned a great deal about ways of teaching that dispel all sorts of student misconceptions. We should now begin to direct more of our effort and expertise toward pseudoscience.

- Contrary to popular belief, many well-prepared underrepresented minority students, including both men and women, are interested in pursuing scientific or engineering careers, according to a forum article in the 31 March is

sue of *Science*. In 2005, the same percentage (44%) of African-American and Caucasian college-bound high school students indicated their intent to major in science and engineering fields. Many students with high SAT scores, impressive grades, and success in high school leave the college science pipeline, but the loss is disproportionately high among women and minorities. Thus other factors, such as cultural isolation, motivation and performance vulnerability must be causing underrepresented minority students from continuing in science and engineering.

- The Meyerhoff Scholars Program focuses on producing bachelor’s degree recipients, particularly African-Americans, who go on to doctoral programs in science and engineering.

- “Putting children off physics” is the title of an article in the November issue of *Physics World* that discusses some of the short comings of textbooks. The author believes that inadequate textbooks are partly to blame for the steady decline in the number of pupils taking physics at school. The blame for the deficiencies, she notes, should perhaps be directed less to the authors of the textbooks than to the peculiarities of the curriculum. The sensible desire to give pupils a greater general understanding of astronomy, geology and environmental problems is in danger of elbowing out explanations of basic physics.

- “Is the (NSF) Education Directorate Headed for a Failing Grade?” asks an article in the 24 February issue of *Science*. Although President Bush told science students in Dallas that the United States “needs a workforce strong in engineering and science and physics”

Continued on page 47

Continued from page 46

to remain the world's top economic power, three days later he unveiled a 2007 budget request that would cut—for the third straight year—a program at NSF aimed at doing exactly that. The decline of the Math and Science Partnerships program is one of many problems facing NSF's Education and Human Resources (EHR) directorate. EHR has been run for more than a year by a temporary head after its top official, Judith Ramaley, was denied an opportunity to stay on. (See following item).

- In the 7 April issue of *Science* is a letter to the editor from Bruce Alberts, former president of the National Academy of Science, entitled "Evaluating Education Effectiveness." The letter is an attempt to clear up a misconception readers might derive from the News Focus story "Is the education directorate headed for a failing grade?" (see previous item) which appeared in the February issue. In the story Alberts is quoted as saying "Maybe NSF education programs need to be rethought." In fact, Alberts points out that he believes that NSF education programs have been instrumental in creating a series of outstanding curricula for school science. He wanted to suggest that NSF rethink its requirement for formal project evaluations with greater attention to what does and does not work, and why. He also questioned an NSF tradition of discontinuing even the best programs after 5 years with the expectation that school districts (or others) will be able to cover the expense of continuing the programs thereafter.

- An article in the 26 March issue of *The New York Times* reports that a survey to be released later this week on narrowing the curriculum finds that since No Child Left Behind was passed in 2001, 71% of the nation's 15,000 school districts have reduced the hours of instructional time in history, science, music, and other subjects to open up more time for reading and math. "The intense focus on the two basic skills is a sea change in

American instructional practice, with many schools that once offered rich curriculums now systematically trimming courses like social studies, science and art," writes reporter Sam Dillon. The article reports the many ways district administrators are attempting to shore up their math and reading instruction, often barring students from taking anything but these subjects.

- Twenty-five foreign graduate students in science and engineering will receive generous scholarships under a new U.S. program designed to dispel fears that tighter security following 9/11 has discouraged the world's best and brightest from studying in the United States, according to a story in the 27 January issue of *Science*. The Fulbright Award program takes the name of the prestigious intellectual exchange program between the United States and some 150 countries begun after World War II. The awards are part of a proposed spending boost for academic exchanges in the president's 2007 budget request to Congress. Students will be chosen in a global competition rather than through the traditional bilateral agreements and they will be funded for longer than the typical 3 years.

- The April issue of *American Journal of Physics* is a theme issue on Teaching Electricity and Magnetism. It includes papers on experiments in electricity and magnetism, electromagnetic radiation, theoretical aspects of electricity and magnetism, curriculum development in electricity and magnetism, and problems in electricity and magnetism as well as an editorial by the editors of the issue.

- The author of a book written to help high school students improve their math SAT scores was one of 11 recipients honored with an IEEE Educational Activities Board Award in November, according to the 4 January issue of *The Institute Online*. Philip Keller, a physics and math teacher at Holmdel High School in

Continued on page 48

Continued from page 47

New Jersey, received one of three Pre-university Educator Awards for “inspiring a generation of students to excel in science, mathematics, and engineering. Keller also developed many simulations for the award-winning educational software program, Interactive Physics.

- A promised 10-year doubling for NSF, NIST, and energy research would be offset by no growth for NIH and NASA in President Bush’s spending request for 2007, according to an article in the 10 February issue of *Science*. In a lean budget year, says presidential science adviser John Marburger, scientists should be grateful for any increases. The 14% rise at the DOE Office of Science and the 7.9% boost for NSF, he says, represent “high-priority areas... that will create technologies to improve U.S. competitiveness.”

- John Rigden, former chair of the APS Forum on the History of Physics, was asked “What are three best popular-science books?” His selections, according to the Shelf life column in the October issue of *Physics World*, were Arthur Koestler’s *The Sleepwalkers*, Steven Weinberg’s *The First Three Minutes*, and Thomas Kuhn’s *The Copernican Revolution*. In response to the question “What science books are you currently reading?” Rigden cited Philip Kitcher’s *Science, Truth, and Democracy*. “I just finished *J. Robert Oppenheimer: The American Prometheus* by Kai Bird and Martin Sherwin, and am now reading *The Evolution-Creation Struggle* by

Michael Ruse,” he said.

- Foreign students flooded U.S. graduate schools with applications this winter, reversing a 2-year decline, according to a story in the 31 March issue of *Science*. The annual survey by the Council of Graduate Schools found that international graduate applications for the 2006-07 academic year rose by 11% over the previous year, with particularly significant increases in Chinese and Indian applicants. All fields enjoyed a boost, although life sciences and engineering led the way with 16% and 17% increases, respectively. University administrators have blamed the 2003-05 downturn in large part on tighter immigration policies following the 2001 terrorist attacks and perceptions that the United States was less welcoming of foreigners. However, applications from Middle Eastern students have risen steadily for the past 3 years, by 4%, 7%, and 4%. Many institutions have strengthened their recruiting efforts.

- EuroPhysicsFun, an alliance of 18 European member groups, has received funding from the European Union (EU) according to the March 17 edition of their newsletter. EuroPhysicsFun (<http://www.europhysicsfun.org/home.php?pageid=3>) arranges physics demonstrations in Europe and elsewhere, and their newsletter has many good ideas for demonstration experiments.

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
cummingk2@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