Forum on Education
American Physical Society

Fall 2006/Spring 2007 Newsletter

Karen Cummings and Paula Heron-Editors

IN THIS ISSUE

Greetings from the Chair!

David Haase, North Carolina State University

I surveyed the attendance of many of the contributed paper sessions at the APS March meeting in Denver. As you may know yourself, these sessions draw an audience of anywhere between 10 and 100 people. As a speaker it is always a gamble as to whether you will have a large audience. So, it was reassuring that each of the Denver contributed paper sessions on education had about 70 attendees. In fact, they were the liveliest sessions that I saw in Denver. There were many good questions asked, innovative ideas presented and a wide variety of topics discussed. Rightly, education related discussions–regarding all instructional levels and for all audiences–are featured and encouraged at APS meetings.

The APS allows members to contribute one first-author paper to each general meeting, but also allows an author to submit one additional "non-technical" paper. This means that, along with reporting on your non-educationally related research, you have the opportunity to report on that new graduate course you developed, your summer program for high school students, your collaboration with the local school system, or your research lab's new public education lecture series. You could even speak about the interdisciplinary course you co-teach with biologists and faculty from the college of education!

Forum on Education members contribute to all types of education. We should use the APS meetings to tell each other about what we do. The contributed paper sessions are great chances for you to make contacts, to get ideas and to cheer on your colleagues who lead the way. A faculty advisor who gives an education related contributed paper sets an example for her or his graduate students regarding the importance of teaching and learning in the professional life of a physicist. A contributed paper is also highly effective in disseminating the broader impacts of a research program.

I strongly urge you to take advantage of the education related contributed paper opportunity at the next APS meeting you attend. These papers are submitted through the same APS website (http://www.aps.org/meetings) with the same deadlines as any other contributed paper. While you are at it, please send suggestions for education related invited paper sessions and speakers to Ernie Malamud (malamud@foothill.net), F.Ed. Program Chair. He is planning the sessions for the March, 2008 meeting in New Orleans and the April, 2008 meeting in St. Louis. Our hope is that all of the invited and contributed paper sessions will draw overflow crowds.

Lastly, as the new Chair of the Forum on Education, I am pleased to recognize the contributions of Dr. Peggy McMahan, the outgoing Chair. Peggy has led outstanding education programs at the Lawrence Berkeley Laboratory for a number of years. As Chair of the F.Ed., she has increased our connections with the American Association of Physics Teachers including fostering the APS-sponsored invited paper sessions at the summer AAPT meeting which highlight the research of a different APS unit each summer. I am sure that Peggy's energy and enthusiasm for physics education will not lessen now that she moves on to Past-Chair and I thank her for all of her many APS and education related efforts.

David Haase is Professor of Physics at North Carolina State University in Raleigh and the new Chair of the Forum on Education Executive Committee. He can be reached via e-mail at david_haase@ncsu.edu.

Announcements, News and Congratulations!

Karen Cummings, Southern Connecticut State University

Loss of F.Ed. Executive Committee Member, Mary Creason

Dr. Mary Creason, of Duke University, and her husband William Creason were killed in an automobile accident in North Carolina on May 12, 2007. Along with her efforts on behalf of the F.Ed., Mary was very active in the American Association of Physics Teachers (AAPT), the North Carolina AAPT section and was a member of the local organizing committee for this summer's AAPT meeting in Greensboro. The F.Ed. Executive Committee is grateful to have worked with Mary. We clearly benefited from her enthusiasm and dedication. She will be greatly missed.

Congratulations to the First Excellence in Physics Education Award Recipients!

The Forum on Education is very pleased to announce the first *Excellence in Physics Education Award* was given to the Physical Science Study Committee (PSSC) and Implementers: John H. Dodge, A.P. French, Robert Gardner, Edwin Goldwasser, Rober Hulsizer, John G. King, and Uri Haber-Schaim for

" the revitalization of subject matter through the involvement of teachers and researchers at all levels, the elevation of the instructional role of the laboratory, the development and utilization of innovative instructional media, and the emphasis on discipline-centered inquiry and the nature of physics, PSSC Physics has had a major and ongoing influence on physics education at the national level."

More on the Excellence in Physics Education Award

This annual award was established in 2006 and endowed with support from the Richard Lounsbery Foundation, Vernier Software, WebAssign, Physics Academic Software, PASCO Scientific and numerous individual contributions. Its purpose is "To recognize and honor a team or group of individuals (such as a collaboration), or exceptionally a single individual, who have exhibited a sustained commitment to excellence in physics education".

The Excellence in Physics Education Award consists of a $5,000 monetary award, a certificate citing the achievements of the group or individual, and an allowance for travel expenses to the meeting where the award is presented. (Registration fees will be waived). The awardee will also be invited to present a talk at that meeting.

The award is given for such accomplishments as outreach programs; a specific program or project that has had a major ongoing influence on physics education at the national level; outstanding teacher enhancement or teacher preparation programs over a number of years; long-lasting professional service related to physics education that has had a demonstrated positive impact.

The deadline for submission of nominations for the 2008 prize is July 1, 2007. Previous nominations are active for three years. So, please submit your outstanding nominations even if you miss this year's deadline. Five (5) copies of nominations and supporting documentation for the 2008 Prize should be sent to the Chair of the 2008 Selection Committee:

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The other members of the Selection Committee are Alan Van Heuvelen, J.D. Garcia, Ruth Howes and Robert Semper.

Congratulations to Our Newly Elected Fellows

Congratulations to Howard S. Matis (Lawrence Berkeley National Laboratory) and Thad P. Zaleskiewicz (University of Pittsburgh) on their election as 2006 APS Fellows based on contributions to physics education.

Congratulations to Newly Elected F.Ed. Executive Committee Members

The F.Ed. Executive Committee would like to warmly welcome the following new members: Peter Collings, Swarthmore College,*Vice Chair and Chair of the Nominations Committee* Olivia Castelini, Museum of Science and Industry in Chicago, *General Member-at-Large* G. Samuel Lightner, Westminster College, *APS/AAPT Member-at-Large*

The Future of Physics in the Undergraduate Education of Biologists

Charles DeLeone, California State University at San Marcos

Introduction

The interface between physics and biology is one of the fastest growing subfields of physics. As knowledge of cellular processes and complex ecological systems advances, researchers have found that progress in understanding these systems requires more quantitatively rich approaches. Today, in general, there is a real demand for biological researchers skilled in quantitative and computational methods. Among researchers in the field there is also a growing concern that the undergraduate preparation of biologists does not provide them with these skills since most undergraduate students in the biological sciences still receive limited exposure to mathematics and computationally intensive modeling methods. But this situation is evolving.

There are now serious calls for change in the undergraduate biosciences curriculum. While it is not clear how these calls for reform will manifest themselves in the curriculum, whatever form these changes take will have an effect on those involved in the education of biology majors. In our role as educators, it is important that physicists understand the curricular changes that are being recommended for undergraduates, not only because of the effect these reforms might have on our classes, but also because of what physics educators can contribute to the discussion. The purpose of this article is to bring these threads together by discussing the current calls for change in the undergraduate biological science curriculum and considering the role of the introductory physics course for biologists along with physics education research (PER) inspired efforts to remake this course.

Biology Curriculum in Flux

The impetus for the re-evaluation of the undergraduate biosciences curriculum comes from the biology research community. In particular, researchers and funding agencies are concerned that many significant research problems will not be investigated because of a lack of quantitative and computational skills among prospective researchers. Thus the community has begun to study the current preparation of students and consider improvements.

The most comprehensive effort to consider the needs of future bioscience researchers was instigated by the National Institutes of Health (NIH) along with the Howard Hughes Medical Institute (HHMI). They requested that the National Research Council evaluate undergraduate education in the biological sciences with an emphasis on the needs of future biomedical researchers. Beginning its work in the fall of 2000, the committee conducted a comprehensive, interdisciplinary evaluation of the current state of the undergraduate curriculum and future needs in the biological sciences. The committee's product was BIO 2010[1]. BIO 2010 set off a community-wide discussion and prominent researchers such as Bialek and Botstein [2] have since written articles that include specific prescriptions for improving the state of the undergraduate curriculum.

The recommendations that have come out of this effort affect all disciplines that contributes to the training of undergraduate biologists. In the area of the biological sciences, BIO 2010 calls for a concerted effort to increase the amount of quantitative and computational work in the existing biology classes through the development of new instructional modules that can be included in existing classes. In the area of mathematics, there are calls for rethinking of the existing course requirements for biology majors, including the possibility of adding instruction in subjects such as linear algebra. The report likewise has suggestions for changing the nature of required chemistry courses including adding more organic chemistry and introducing it earlier. Across the science curriculum, the report emphasizes the need for inquiry based and active learning approaches in courses for future biomedical researchers.

Physics has not been ignored. Some of the suggestions from BIO 2010 and other published articles directly or indirectly concern the role of physics in the undergraduate curriculum. They include:

- *Increased emphasis on mathematical sophistication in physics courses [BIO 2010]*
- *Increased emphasis on computer modeling [BIO 2010]*
- *Creating a separate introductory physics sequence for students planning on doing biomedical research. [Bialek and Bottstein, BIO 2010].*
- *Updating standard introductory physics content for future biomedical researchers to include novel topics. Suggestions in cluded Forster Quenching and Chaos. [Physics Topic Group BIO 2010]*
- *Introducing a 3rd semester physics course requirement for future bioscience researchers [BIO 2010]*
- *Altering introductory physics labs to include more biological applications of physics [BIO 2010]*
- *Teaching introductory physics as part of an integrated interdisciplinary science and math curriculum [Bialek and Bott stein]*

Rethinking the Introductory Physics Course for Biologists

While researchers in the biosciences are concerned about the undergraduate curriculum of their students, physics education researchers have been making progress in identifying “better teaching practices” in undergraduate physics. Much of this work has centered on the lower division introductory physics courses where undergraduate biologists get the majority of their exposure to physics. The results of PER suggest that the traditional lecture and laboratory approach to instruction is inadequate for many students[3]. Based on these results, the physics community, with support from national, state and university-level funding agencies, has sustained an on-going effort to increase the effectiveness of instruction in introductory physics courses.

While the calculus-based introductory physics course has benefited the most from these PER inspired innovations, there are a number of reform efforts that have focused specifically on the introductory physics course taken by future biologists. These courses include the *Physics 7* effort at the University of California Davis and California State University San Marcos [4], the Humanized Physics Project [5] and the reformed courses at the University of Minnesota [6] and the University of Maryland [7].

These curricula share some commonalities. All of these courses include active engagement based pedagogy that makes use of our evolving understanding of how students learn physics. Most of them also include changes in the topic sequence, emphasize specific content areas and de-emphasize others. While these curricula were not specifically designed to meet the emerging needs of future biomedical researchers, the knowledge gained from the development and implementation of these courses may well help to guide the physics community in responding to the calls for change from our colleagues in biology.

Overall, the message from such PER inspired courses is that active engagement based approaches work well with the students from the biological sciences. The novel physics content sequences show that students do not suffer when there is a departure from the standard sequence and that alternate content sequences may contribute to improved student learning outcomes. A study of MCAT data from the UC Davis reformed course demonstrates that even though some traditional topics were dropped from the content sequence, and that many other topic areas were reorganized, student performance on the MCAT and in later classes did not suffer. In fact, in some cases student performance improved [8].

The Role of Physics Educators

Based on a more informed understanding of the current state of the undergraduate biology curriculum and the state of introductory physics instruction for biologists, it is possible to outline ideas for how physics educators can contribute to reworking the undergraduate curriculum for future biomedical researchers. Some general elements that might guide this contribution could include:

Reconsider the math level of the introductory course for students in the biological sciences

One approach to this would be to require that students who plan on going into biomedical research take the standard calculus based physics course. Another would be to redesign the “algebra-based” course to judiciously include the use of calculus and more mathematically intensive approaches.

Reevaluate the content emphasis and organization

Among the recommendations of BIO 2010 is the inclusion of more examples from biology in the content of service courses for biologists. This report also has a list of physics topics that it deems more important than others. But with this list comes the caveat that"…the emphasis in course design should be on learning and developing relationships between observations and mathematical descriptions and modeling rather than slavishly covering every topic." [1]

When considering content modification in the introductory physics courses for students in the biological sciences it is important to look at the results of existing research inspired curricula. Non-traditional content sequences such as the energy first approach used at UC Davis may offer a template for other physics educators interested in revamping their curriculum.

Expand the use of interactive methods in the physics classroom

Physics educators have developed a number of non-traditional introductory physics courses that have shown marked improvements in student achievement in physics. Many of the successful reforms make use of active-learning methods. Some of the better-known efforts include Tutorials in Physics, Workshop Physics, SCALE UP, Real Time Physics, and Peer Instruction. These efforts generally report improvements in student achievement in physics [9].

Engage in cross-disciplinary collaboration with our colleagues in the biological sciences

Effective preparation of future biomedical researchers will require contributions from many different disciplines. By working with our colleagues in biology, we can assist them in their effort to develop more quantitatively rich content for their biology courses. Likewise, the physics courses designated for students in the biological sciences will benefit from our interactions with our colleagues in biology. Their sense of the most important curricular elements can inform our discussion of modifications to existing courses or our development and implementation of new curricula.

Conclusion

Advances in understanding biological systems rest more and more on quantitative and computational approaches to these systems. Better training for future biological researchers will require rethinking their undergraduate preparation across the disciplines. This should include rethinking the role of the physics course. As solutions to this problem are considered locally, physics educators may be able to make the largest contributions if they are informed of the situation, engage with colleagues in biology and recall the lessons learned implementing PER inspired curricula.

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College Physics with Biomedical Applications at Cleveland State University: A Two-Year Experience

Ulrich Zurcher, Cleveland State University

The report *BIO2010*, by the National Research Council (NRC), offers refreshing ideas for the introductory physics sequence taken by biology majors. It suggests the inclusion of three broad themes: (1) biological systems obey the laws of physics and chemistry, (2) collective behavior of complex structures emerges from simpler units, and (3) living systems are far from equilibrium. The report makes recommendations for a course geared towards future research biologists without restrictions like those imposed by standardized exams such as the MCAT.

In this article, I will report on some of my experiences teaching a course with biomedical applications at Cleveland State University (CSU). CSU is an urban, public university in which a fairly large segment of the approximately 7,000 undergraduate students enrolled are the first in their families to attend college. In the spring 2004, I proposed a new College Physics course with biomedical applications. I have taught this course every year since then and I have found that my focus on biomedical applications creates a "storyline" that is helpful in providing connections between the various topics we cover. Our course meets twice a week for 75 minute-lectures, and once a week for a two-hour laboratory session.

Methods

In my experience, one of the greatest obstacles to teaching a course geared toward biomedical applications relates to the number of "required" topics that one might feel must be covered. This is reflected in standard textbooks, which run between 950 and 1,100 pages. I have found that two approaches are particularly helpful in navigating this difficulty.

1. <u>Students explore new material in the lab</u>. They do not simply "confirm" what has already been covered in the lecture. This is accomplished using a lab manual that I have written with which students are guided through the material by answering a series of questions.

2. <u>Students are expected to read through the relevant sections of the text before coming to class</u>. My choice of the textbook is conventional [currently J. D. Cutnell and K. W. Johnson, *Physics*, 7th ed. (J. Wiley and Sons, New York, 2006)]. I use *Wiley-Plus* for both homework and daily quizzes. The online quizzes are essentially reading assignments, and are always multiple-choice questions. These quizzes relate to the material covered the next day. The combined score of daily online and in-class quizzes accounts for 10% of the course grade. To my surprise, I receive only a few complaints about excessive workload from the students.

Content

The biological and medical fields are an ideal source for physics problems that are rich in context. For example, how fast can an animal walk or run? What is the maximum height an animal can clear during a jump? How tall can a tree grow? Such problems cannot be solved by simply following a recipe. One must first identify the important components and then construct a model. In contrast, the typical end-of-chapter problems in textbooks are often quite "formulaic" with little relevance to realistic situations. Students can often solve such problems by simply looking for patterns, identifying the relevant equation(s), and inserting the numerical values given in the problem.

In the problems cited above, students explore how various biomechanical functions [e.g. locomotion] depend on the size of the body. Such relations are referred to as *allometric scaling* in the scientific literature. My experience is that students find these discussions stimulating. In the first semester, I also discuss the properties of surfaces (e.g. surface tension) and how it determines the metabolic rate of animals. I have expanded my coverage of thermodynamics to include topics such as diffusion.

Another important idea for biology students is that macroscopic objects are typically electrically neutral and the weak gravitational force dominates interactions between them. Yet electrical forces are at the root of microscopic properties of materials [e.g., elasticity], and determine the form and function of molecules like proteins. Standard texts often fail to make this point. So, in the second semester, I emphasize these distinctions and focus on problems with realistic applications. I discuss, mostly quantitatively, how electricity is generated by the charge separation of ions (electrolytic solution). I also talk about how electrical signals travel along neurons. We cover various methods that can be used to "look inside the body". For example, we discuss ultrasound, MRI and X-ray imaging.

I have developed several completely new laboratories for this revised course. For example, I wrote a lab on exponential growth and decay. I introduce the notion of rates and rate equations by using interest rates and inflation. Students use *Excel* to calculate the growth/decay of an initial quantity, and then compare it with exponential behavior. Finally, students explore why exponential behavior is so common in many areas of science, technology, and society.

Summary

The report *BIO2010* is a challenge to physics faculty who teach physics to biology and pre-medical majors. Proper course management makes it possible to incorporate discussion of context-rich problems with biomedical content. The *BIO2010* report is a starting point for a broader discussion within the physics community regarding which should be the core topics in the algebra-based course sequence and which topics are optional. It also invites authors (and their publishers) to supply teachers and their students with slimmer texts that focus exclusively on these core topics.

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Physics Teacher Education Coalition

Section on Teacher Preparation

A Note from the Teacher Preparation Section Editor

John Stewart, University of Arkansas, Fayetteville

This article was prepared during the first few weeks of a new school year. Like every year before, since the time of Eisenhower, the local newspapers contained a number of articles about the desperate shortages of teachers and the extraordinary lengths local school boards have had to resort to in order to fill teaching positions. Teacher shortages are extremely acute in STEM disciplines. The September 2006 issue of Physics Today reports on the outcomes of the 2003 class of physics majors. In that year, 4553 bachelor's degrees in physics were awarded with only 5% of the students, or 228 students, listing pre-college teaching as their first career goal. Studies suggest that 50% of these new teachers will leave the profession within five years. The underproduction of physics teachers has lead to many students being instructed by teachers without a major in physics. In the 1999-2000 school year 67% of high school students were instructed by a teacher without a major or certification in physics. These numbers suggest that teacher recruitment and training must be a high priority for every physics department and for the profession as a whole.

To address the need for more well-trained teachers, with physics content knowledge as well as knowledge of pedagogically sound methods of presenting physics, the APS, the AAPT, and the AIP initiated the Physics Teachers Education Coalition (PhysTEC) with financial support of the NSF, FIPSE, and contributions to the APS. This project seeks to build model programs which form connections between physics departments, colleges of education, university administration, school systems, and local teachers. The PhysTEC program brings expertise from the school systems into physics departments. It forms connections which foster recruitment of new physics teachers, training of those teachers both in physics and in sound educational method and placement of teachers in schools. Our first four articles come from primary PhysTEC sites at the University of Arizona, the University of Arkansas, the University of Colorado and Western Michigan University. Each will discuss the specific features of their programs that support recruitment and their experiences with increasing the number of physics graduates going into education.

One of the more promising methods for providing the emphasis on education and the personal contact needed for recruiting is to bring a master teacher with strong K-12 experience into the physics department, a Teacher in Residence or TIR. The TIR is an integral part of all PhysTEC sites. Our fifth article is by two TIRs who discuss their roles in the recruiting and education of teachers at the University of Arizona and Western Michigan University.

The National Science Foundation offers a number of programs to help with the recruitment and training of new STEM teachers. Our final article, by Joan Prival, an NSF program officer, reviews these programs. The programs cover both key elements of teacher recruitment: increasing the number of STEM graduates (thus increasing the pool from which new teachers can be drawn) and specific programs for students considering teaching as a career.

John Stewart is a Visiting Assistant Professor of Physics at the University of Arkansas and Co-Principal Investigator for the Arkansas PhysTEC site. He can be reached via e-mail at johns@uark.edu.

Recruiting the Next Generation of Science Teachers

Ingrid Novodvorsky, University of Arizona

Undergraduate students at the University of Arizona who wish to become middle or high school science teachers have a unique opportunity to pursue their goal in the company of other science majors and under the guidance of science educators and experienced mentor teachers. In this article, I present some of the methods we have used to recruit science majors into our program, as well as our plans to increase the number of students recruited.

As described in an article in the Spring 2005 issue of this newsletter, the Teacher Preparation Program (TPP) was established at the University of Arizona in 1999 to provide preparation for prospective middle and high-school science teachers within the College of Science. Students in the program have two different degree options that lead to eligibility for teacher certification. They may remain in their science-degree programs, and take an additional 33 credits of coursework in science teaching, or they may enroll in a B.S. degree in Science Education, with concentrations available in biology, chemistry, earth science, or physics. Each of the concentration options includes the 33 credits of science-teaching coursework, and at least 45 credits of science coursework. Faculty members in the program are affiliated with various content departments, including physics, chemistry, molecular and cellular biology, astronomy, and biochemistry, and function as members of an interdisciplinary program in managing the program, teaching its courses, and advising students.

The table below indicates enrollments over the life of the program. We currently have the capacity to support the preparation of 20 teachers a year, and so our recruitment efforts are focused on increasing the number of students in the courses leading up to student teaching.

We have worked on recruiting students into our program in a variety of ways. First, we have established a presence for the program in the New Student Orientation Sessions presented by the College of Science. All incoming freshmen are required to attend a two-day orientation session, and the TPP is highlighted in the overview of college programs. Those incoming students who are already committed to teaching can select Science Education as their major when they enter the University of Arizona, and we meet with those students during the orientation sessions to help them plan their schedule, and keep in contact with them via e-mail until they start taking courses in our program, typically in their sophomore year. This recruiting effort has yielded 11 students over the past two years; this small number is not surprising, since we have found that few students enter college already planning to teach high-school science.

Since most of our students do come to the program after they have been at the university for two years or more, another avenue of recruiting has been in second-year introductory science courses. This recruiting is done in connection with small scholarships ($750/semester) that we offer students simply to take our first course, in order to see if teaching is a good fit. The scholarships are funded through the proceeds of a sales-tax increase approved by state voters and earmarked for workforce development. Each semester, faculty members in the program visit science courses in various departments to announce the scholarships and describe the program. This recruiting path has resulted in 19 students who enrolled in our first course upon receiving a scholarship. Nine of those students only completed the first course and decided that teaching wasn't a good fit. The other ten completed all or most of the courses in the program. (Students can also select a Science Education minor, which includes all of the science-teaching courses except student teaching.)

Another recruiting avenue, which we have just established, is the Noyce Scholars Program. This is a program funded by NSF, and is designed to support students in mathematics and science teacher preparation programs who agree to teach in high-needs schools upon completion of their programs. We awarded ten scholarships for the 2006-07 academic year, the first year of our funding, and we have funding to support up to 14 Noyce Scholars each year.

All of these recruiting avenues have attracted some students to our program. However, our most powerful recruiting tools have been the advisors and students in the departments within the College of Science. We send the advisors regular updates on the program, provide them with program brochures, and encourage them to send students who express an interest in teaching to one of the faculty advisors in the program. In addition, as our program has grown, the word-of-mouth advertising by students in the program has brought many new students into our program. It is difficult to quantify the impact of this avenue of recruiting, but given the steady increase in the number of students in our program courses, we expect that most of the students who enroll do so after talking with one of the students in the program or one of the faculty advisors.

We have developed two additional recruitment tools that we will be utilizing this year. The first is our student chapter of the National Science Teachers Association; we plan to solicit the advice of the students in this group, who are already committed to teaching, on how we might recruit more students to the program. We also plan to ask some of these students to accompany us on recruiting visits to science classrooms, to provide a student perspective. The second new tool is a showcase of science inquiry projects developed by prospective science teachers in our subject methods courses. (We have three of these courses, focused on Biology, Earth Science, and Physical Science.) Students in all of these courses will complete science inquiry projects and present their results in a poster session at the end of the fall semester, to which we will invite other science majors. We anticipate that these two recruit-

	2000-01	**2001-02**	**2002-03**	**2003-04**	**2004-05**	**2005-06**
Individual students in CoS TPP courses	26	35	67	100	114	135
CoS TPP completers	5	1	5	14	8	13
Physics teachers prepared#	0	0	2	1	1	4

#Prior to TPP, ~ 6 science teachers graduated each year from the College of Education; 2 physics teachers graduated in 4 years *3 of these 4 are women ment strategies will tap into the "student network" to recruit more prospective science teachers.

We have been successful in recruiting students into our first program course, and approximately 2/3 of the students who complete that course go on to complete additional science-teaching courses. Our future recruitment efforts will be focused on attracting even more students into that first course, in an effort to increase our overall production of secondary science teachers.

Ingrid Novodvorsky is the Director of the College of Science Teacher Preparation Program at the University of Arizona.

Teacher Recruitment at the University of Arkansas

Gay Stewart , University of Arkansas

At the time of my arrival in Arkansas 12 years ago, there were about 300 school districts in the state and two high school physics teachers holding a degree in physics. The University of Arkansas is the only PhD granting institution in Arkansas. As such, the University of Arkansas physics department should be at the forefront of increasing the number of high school teachers training in physics. Twelve years ago the department was graduating an average of two physics majors each year. Since nationally only a small fraction of physics graduates choose K-12 education as their career, there seemed little hope of the university having much impact on the state's need for physics teachers. To greatly increase the number of physics majors going into K-12 education we faced two problems, first to increase the number of physics majors and second to encourage a higher percentage of majors to choose K-12 education as a career. It is not enough to produce new teachers with a background in physics; the new teachers must also have a strong grounding in pedagogically sound methods based on current education research. The PhysTEC program has been invaluable in accomplishing all these goals.

Growing the Physics Program with Pedagogically Correct Introductory Science Classes

The introductory calculus-based electricity and magnetism course was updated to a more inquiry-driven format through funding under the NSF-CCD program. Funding from the PhysTEC program allowed the reconstruction of the rest of the introductory course sequences and further refinement of the electricity and magnetism course (where most of our new high school teachers have been recruited). The classes taken by scientists and engineers were transformed from a traditional three hours of lecture, one hour of recitation, and two hours of standard laboratory featuring prepackaged cookbook experiments to a much more open and inquiry-driven experience. The class format was changed to two 50-minute lectures and two two-hour labs each week. The additional lab time allowed the addition of a large number of qualitative exploratory activities that allow the students to confront their misconceptions directly. The laboratory experience was greatly improved for both student and instructor. Many of the activities could be performed with very low-cost equipment and have been successfully transported to high school and middle school classrooms. The modified class not only provided students with examples of pedagogically correct instruction, it also provided them with role models, instructors who were actually enjoying teaching. The reconstruction of the other sequences is not yet complete, but the level of inquiry and student engagement has been increased through improved laboratory activities and pedagogical tools such as Just In Time Teaching and Concept quizzes.

The physics department has seen a marked growth in its undergraduate graduation rate since the introduction of the modified introductory physics sequence. The number of physics graduates grew from one in 1994 to 25 in 2005. The increased production of physics graduates was accompanied by an increase in the number of graduates choosing to pursue teaching careers. In 2005 the program produced four physics majors who received teacher certification and are now teaching, generally at the high school level. Also, two science students, who were not physics majors but took the course, entered the teacher preparation program citing university physics as where they started thinking about teaching.

It would be nice to be able to claim that the source of the increase in production of physics majors and teachers was the switch to a pedagogically correct introductory course sequence, and this has certainly helped. However, I feel the most successful innovation of the course is the course structure itself. Both of the large service courses, University Physics I and II, are structured so the lecturer, a faculty member committed to physics education, also teaches the first lab section. Since the lab sections are designed to be active learning experiences, this places the faculty member in an environment where not only can they see exactly "where the students are" with the material, but they can freely interact with students. This serves to break down the wall between lecturer and class that often exists in large service classes, even classes that use interactive techniques. The personal connections formed in this setting and the level of comfort the students feel with the lab instructor is invaluable in recruiting new majors. These connections are not limited to students in the instructor's lab section, since students from that section will bring friends to office hours, who then bring their friends, etc. I believe the class format that places the lead lecturer in a small interactive lab environment has been the key to producing a more personally integrated class and the key to drawing more students to the physics program.

Advertising Education as a Career

The students who leave our program as teachers come to the profession of teaching at different points in their undergraduate careers. Some enter the physics program with education as a career goal, some choose education after their first taste of junior level physics, some choose education as they are making career decisions at the beginning of the senior year, and some choose education at the time of graduation. To keep a career in education as one of the choices a student is considering, information on physics teaching careers is offered through all department-student interactions. The introductory class web sites contain links to information for future teachers. Information for future teachers is an integral part of the beginning of the year presentation given to all undergraduates. Several of the physics advisers are well trained in physics education careers, and any student who demonstrates an interest is routed to them. Outreach opportunities are strongly supported to provide a first teaching experience for undergraduates.

Flexibility in Degree Planning

Since students choose to begin training to be teachers at different points in their academic career flexible degree plans are vital.

Close Ties with the College of Education

Producing a certified teacher through a normal licensing program requires coordination of classes between the physics department and the College of Education. Close ties between these two entities are vital. Course work in the College of Education provides a sound basis in general education and is invaluable in process of obtaining certification. Beyond the course work, the College of Education is well placed to provide early field experiences for the students, mentors with first hand knowledge of the K-12 classroom who can provide advice on teaching methods and teaching as a career, and professional contacts to aid in placement of students after graduation.

Flexible Financing

For those students who choose education as a profession late in their undergraduate career, the additional classes originally required for the education track could add a semester or a year to their undergraduate career. The College of Education made a change this year so that is no longer the case. The physics teaching internship course can count for up to 40 of the required 60 hours of teaching internship, portfolios can demonstrate proficiency instead of required coursework, and the one required class that cannot be substituted for is available in the summer session immediately before entrance into the College of Education's Master of Arts in Teaching program.

However, the post baccalaureate requirements for certification may present a financial barrier to becoming a teacher because of the expense of the additional year since most scholarships end in four years. Only our highest honors students may extend their fellowships for the 5th-year teacher certification program. We work with each student who expresses an interest in teaching to make sure finances do not prevent the student from entering the profession. If possible students are supported by scholarships. We will be applying for the Robert Noyce Scholarship (See the article by Joan Prival in this issue) and continue to seek other funding mechanisms. If the student is sufficiently advanced and TA positions exist in the department, the student may be encouraged to pursue a Masters of Arts in Physics with a focus in education. Once again, flexible degree plans are vital.

Teaching Experience for Undergraduates

The experience of teaching is unique. Some people love it, some do not. A student must try teaching before they can really determine if the career is for them, therefore undergraduates who are already pursuing an education career are encouraged to spend time in a K-12 classroom as early in their career as possible. For students who have not decided on education as a career, two mechanisms to provide teaching experience are provided. The Society of Physics Students holds a number of outreach events each year for K-12 students. These events take physics demonstrations to local schools or invite students to the University for demonstrations and physics related contests. This gives the students some one-on-one instructional experience.

For advanced undergraduates who think they may wish to consider teaching as a career, a more complete teaching experience is provided. Under supervision and with strong training these students are allowed to teach one of the interactive lab sections in the redesigned introductory sequence. The interactive courses are fun to teach and these courses give the students a very positive teaching experience. Since the courses are designed based on current educational research, they also provide the student with a strong model of how physics instruction should be carried out.

Recruiting is Easier with Student Role Models

As more students graduate from the program and pursue teaching careers, it becomes easier to recruit future teachers. When one or two students were graduating each year, a teacher pursing a physics degree was likely to be the only teacher in the program. Now with many teachers graduating each year, a future teacher has peers going through the same experience for support and role models of successful students who have graduated and gone on to teaching careers. As the program has grown, the percentage of students approaching advisers about teaching careers has also grown.

Conclusion

Each physics department must greatly increase its output of teachers to meet a critical national need. This requires a coordinated effort between advisors, the introductory sequence, financing agencies, the College of Education, and even student organizations. Substantial growth is possible if there is sufficient attention to personal detail.

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Teaching to Learn: The Colorado Learning Assistant program's impact on learning content

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This piece discusses the Colorado Learning Assistant (LA) program, and focuses on its impact on the content expertise of future physics teachers. We draw from more extensive descriptions published in Science [*i*], and Physical Review [*ii*].

Introduction

By now the calls for increasing the number of future physics teachers and the quality of preparation of those teachers are familiar. It is widely recognized that we are not educating our youth adequately in mathematics and science. One need only look at political reports [*iii*], international [*iv*] or national [*v*] studies, or research on student learning [*vi*] for evidence that we are missing our mark. Two out of three high school physics teachers have neither a major nor a minor in the discipline [*vii*] and there are no other subject matter specialties that have a greater shortage of teachers than mathematics and physics [*viii*]. Recently, the National Academies listed four priority recommendations for ensuring American competitiveness in the 21st century [*iii*], the first of which was to "Increase America's talent pool by vastly improving K-12 science and mathematics education."

Several national initiatives have developed to address these critical shortfalls in teacher recruitment, preparation and mentoring [*ix,x,xi*]. A major focus of the American Physical Society's education efforts seeks to increase the number and quality of physics teachers in the United States; the APS Physics Teacher Education Coalition (PTEC) [*xi*] now includes a coalition of 60 physics departments dedicated to these challenges. These communities recognize that teacher preparation is not solely the responsibility of schools of education.

Content knowledge is one of the main factors positively correlated with teacher quality [*xii*]; yet, those directly responsible for teaching science to undergraduates, specifically science faculty members, are rarely involved in teacher education. As part of the PTEC coalition, we have expanded the Colorado Learning Assistant (LA) program in order to address the needs of teacher preparation and support.

The Colorado Learning Assistant Program

At the University of Colorado at Boulder, we have developed a program that engages both science and education faculty members in addressing national challenges in education. Currently the LA program supports 60 potential future science teachers, and runs across six different science departments. Undergraduate Learning Assistants (LAs) are hired to assist science faculty to make their courses student-centered, interactive, and collaborative. These types of course transformations are known to significantly improve the educational experience for students [*xiii*].

The LAs help initiate and sustain course transformation by facilitating student collaboration in the large-enrollment science courses. LAs receive a modest stipend for working 10 hours per week in three aspects of course transformation. First, LAs lead student-focused learning teams of roughly 4 students that meet at least once per week. LA-led learning teams work on collaborative activities focusing on group problem solving. This segment is where students put into practice both their understanding of pedagogy and their relative expertise in content understanding. Second, LAs meet weekly with the faculty instructor with whom they work to plan for the upcoming week, to reflect on the previous week, and to provide feedback on the transformation process. The faculty meetings provide opportunities for LAs to reexamine content, explore teaching strategies and focus on specific challenges that the introductory physics students might face. Finally, LAs from all participating science departments attend a required course, *Mathematics and Science Education* that complements their LA-teaching experiences. In this course, co-taught by a school of education faculty member and a K12 teacher, LAs reflect on their own teaching, evaluate the transformations of courses, and investigate theories and practices of teaching and learning.

These students engaged in course transformation are the pool of LAs from which we recruit K-12 teachers. Thus, our efforts toward course transformation integrate with our efforts to recruit and prepare future K-12 science teachers. The result is improved recruitment and preparation of future science and mathematics teachers as well as improved education of all students enrolled in our transformed courses [*i,ii*].

Learning Assistants in Physics

In the physics department, roughly 20 LAs are hired (from roughly 50 applicants) per semester to work across four courses. The majority of the LAs (14 or so) are hired to facilitate the implementation of *Tutorials in Introductory Physics* [*xiv*] in our first and second semester calculus-based physics sequence. *Tutorials* are among the best-researched and documented curricular innovations in introductory physics [*xv*] and have been shown to improve student mastery of physics concepts [*xvi*]. Learning Assistants team up with the departmentally funded graduate TA in each recitation section of the introductory sequence and lower the teacher-to-student ratio to 1:14, which approaches the suggested ratio of 1:10 [*xiii*].

The impact of implementing *Tutorials*, and associated course transformations, such as the use of *Peer Instruction* [*xvii*], a supported help room, and an online computer homework system have been significant–the students in our introductory sequence post learning gains two to three times the nationally reported average for traditional courses [*ii*]. We assess student learning in every transformed course with pre and post evaluations. To evaluate student understanding of physics concepts in the introductory sequence, we use the Force and Motion Concept Evaluation (FMCE) [*xviii*] and the Brief Electricity and Magnetism Assessment (BEMA) [*xix*]. In transformed courses, students have achieved average normalized improvement of as much as 66% (±2%) for the FMCE test, nearly triple national average gains found for traditional courses [*xx*]. In the second semester, with the significantly more difficult BEMA exam, the average normalized learning gains for students in the transformed courses ranged from 33% to 45%. Figure 1 displays a histogram of the fraction of students vs. pre and post test score on the BEMA for two semesters of implementation. These similar results occurred for two different semesters led by different professors, both of whom are involved in physics education research.

The normalized learning gains for the Learning Assistants in this environment is just below 50%, with average post-test scores matching average scores for incoming physics graduate students (TAs). The first semester that the Tutorials were implemented in this sequence, the LAs were drawn from a population of students who themselves had not participated in a transformed course. Notably, while they were among the high performing students in their courses, their pre-test scores (denoted by the left-most arrow in Figure 1) are lower than those LAs who subsequently are drawn

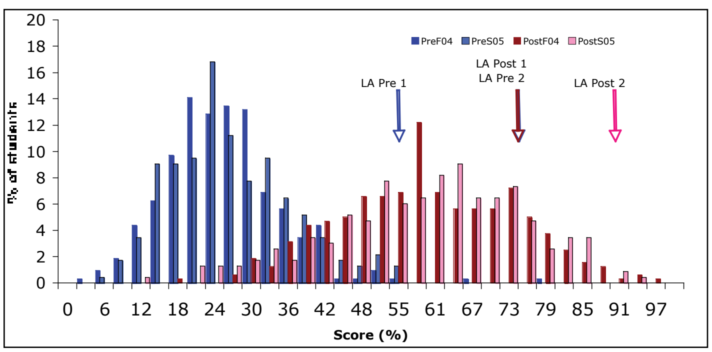

Figure 1: Pre- and Post- Scores for students on the Brief Assessment of Electricity and Magnetism in a second semester calculus based physics course. Arrows above histogram plot mean scores for Learning Assistants for two subsequent semesters

from a population that had participated in the course reforms as enrolled students (denoted by the middle arrow in the figure). In both cases, the LAs are drawn from the highest performing students in their cohorts of students taking the introductory sequence. Our strong students are recruited to teach and they learn as a result of teaching this material.

The Learning Assistant program has been running in the second semester physics sequence for the past two and a half years, resulting in five semesters of data. Each course has been directed by different faculty members, and variations in the use and framing of particular course curricula (*Tutorials, Peer Instruction*, etc.) and Learning Assistants are the subjects of current research. Despite variation in student performance, we have accumulated 1427 matched scores of students enrolled in the second semester course, 27 matched pre-post LA scores (of 31 possible), and 14 matched graduate TA scores (of 20 possible). Figure 2 plots the pre- and post-scores for students in each of these categories.

We know that content mastery is only one piece of the puzzle in supporting the development of future physics teachers. Areas of

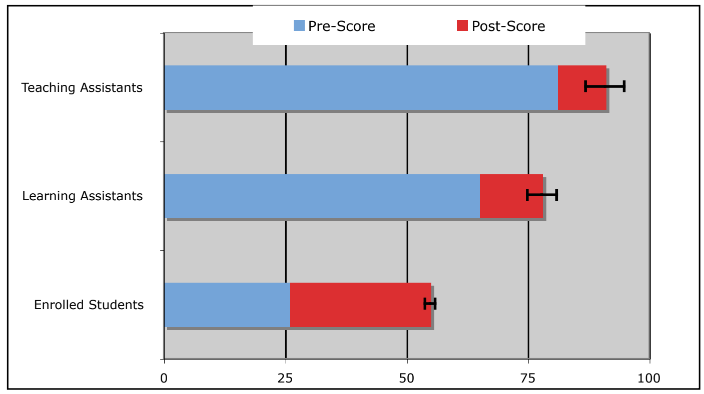

Figure 2: Pre and Post Score averages on BEMA for three populations involved in second semester calculus based introductory physics, over 5 semesters: Teaching Assistants, Learning Assistants, and Enrolled students.

current investigation include the impact of the LA program: on student beliefs about the nature of physics and the nature of learning physics (using interviews and the Colorado Learning Attitudes about Science Survey [*xxi*]), and on student views and practices of the nature of teaching physics (using the Flexible Application of Student Centered Instruction survey [*xxii*]).

Conclusion

The Colorado Learning Assistant program demonstrates that it is possible to improve student achievement in our large-scale introductory physics sequences, and that the same practices that allow course transformation support the development of future physics teachers. The experience of teaching in these transformed environments improves the education of those students who teach. Over a five-semester study we observe consistent improvement of both the undergraduate Learning Assistants and the graduate Teaching Assistants. Our undergraduates, those who we recruit for careers in teaching, exit the experience with mastery of the conceptual content that is indistinguishable from the graduate students entering our program, and our graduate students exit with near perfect scores on these assessments of conceptual mastery.

We note that the process of developing teacher content mastery is thoroughly integrated with the development of student interest and ability in teaching, with the transformation of course practices, and ultimately, we hope with the cultural shift of the physics community to consider education and teaching a core practice of physicists.

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A Quiet Revolution in Preparing Future Teachers of Physics

Julia Olsen, University of Arizona and Drew Isola, Western Michigan University

As noted in other articles in this newsletter, numerous reports, position papers and research studies, we face a crisis in mathematics and science teacher preparation in the United States. This is especially true in regard to physics teachers. As the political uproar has increased, the pressure on institutions of higher learning and on physics departments in particular has become more intense, leaving many to wonder about possible solutions. How can we, as physicists, take on such an overwhelming task in an area where we have little experience or training?

This article deals with one approach to addressing these issues. The use of exemplary K-12 teachers as agents of change in universities has been quietly making its way into teacher preparation programs around the country over the past decade. While it is not unheard of for K-12 teachers to work on college campuses as an entry level or temporary instructor, it has rarely been the case that they are sought out specifically for their expertise in the K-12 classroom. However, more and more K-12 teachers are employed to directly apply their classroom wisdom to the many facets of identifying, recruiting and supporting K-12 teachers of physics. In this role, they are commonly called *Teachers-in-Residence* (TIRs) or *Master Teachers* (MTs).

We will attempt to summarize here the TIRs' or MTs' many roles. Several of these are discussed in more detail Isola and Poel's article which follows. In addition, we encourage readers to contact us with information you may have about similar scenarios. We would like to continue documenting the emerging trend of including classroom practitioners in university teacher preparation programs. Our long term goal is to make detailed data available to those who wish to explore this promising option, specifically focusing on the positive impact a TIR/MT can have on the preparation of future teachers of physics and physical science.

The TIR/MT, as defined by the institutions that have utilized them, is more than just a person with K-12 teaching experience who begins to work in a teacher preparation program as an instructor or supervisor. For the purposes of this article, the TIR/MT is defined as:

- An experienced K-12 classroom teacher who has been identified as an exemplary educator; one who has extensive knowledge of physics concepts as well as experience teaching and a strong footing in the realities of K-12 classroom management.
- One actively recruited and hired by a teacher preparation program and/or physics department specifically for the purpose of providing a 'reality check' and improving the preparation of future teachers of physics.
- Having as their main duties: 1) working side-by-side with physics and teacher preparation faculty as an integral member of the teaching team and participating in college level physics course reform projects; 2) building bridges between various departments/colleges on-campus and with area K-12 schools; 3) providing mentoring and follow-up support to pre-service teachers, recent graduates, and local area teachers of physics and physical science at all grade levels.
- Perhaps having a Ph.D. and/or research experience but not considered 'traditional faculty' in the sense that they are not assigned a regular teaching load nor are they expected to carry out scholarly research. However, they are expected to share their expertise with the department and the greater physics community.

The utilization of TIRs/MTs is not without support in the literature. It has been recommended, and even encouraged, in a number of influential reports and position papers over the past decade. For example, the NRC report *Educating Teachers of Science, Mathematics, and Technology: New Practices for the New Millennium (The National Academy of Sciences, 2000)* recommended that "colleges and universities should reexamine and redesign introductory college-level courses in science to better accommodate the needs of future teachers." The report went on to say that they "envision master teachers in partner school districts [having] adjunct faculty appointments in the partner two- and four-year colleges and universities." The master teachers would "take on a much more significant role in the mentoring of future teachers." The TIRs/MTs described in this article were specifically brought on-campus to fulfill this particular need.

TIRs/MTs at institutions around the country have taken on a wide range of roles and responsibilities that play a significant part in a high quality teacher preparation program. While many of these responsibilities are important and worthwhile, many physics faculty find themselves ill equipped to perform them or are unaware of their potential impact.

The Fall and Spring 2005 APS Forum on Education Newsletters (http://units.aps.org/units/fed/newsletters/) contain articles describing programs which utilize K-12 TIRs/MTs in ways that are consistent with what we describe here. Some examples from these articles include:

- Hiring experienced, certified, secondary school teachers as coordinators of teacher preparation programs with the goal of overhauling and improving the program.
- Using graduates of one's own program as cooperating teachers during student teaching experiences.
- Utilizing retired secondary science teachers as adjunct instructors.
- Bringing together area secondary science teachers in advisory groups to provide input on program decisions and feedback on mentoring student teachers.
- Hiring full-time TIRs/MTs to oversee activities such as those described below.

Some of the specific responsibilities connected with the improvement of teacher preparation programs that TIRs/MTs are carrying out at sites nationwide include:

- Reforming existing physics and teaching methods courses as well as developing new ones that focus specifically on the use of Physics Education Research (PER) based teaching strategies.
- Mentoring and building community among pre-service physics teachers and providing support as they navigate their way through the preparation program.
- Developing and maintaining contact lists of pre-service teachers, recent graduates and area physics teachers.
- Utilizing those contact lists to stay in meaningful contact with these groups and to gather data on graduates' career progress.
- Mentoring and community building among novice K-12 teachers of physics to provide support as these individuals learn and implement new PER based teaching strategies.
- Developing bridges and interactions between physics departments, colleges (or departments) of education and area

K-12 schools.

- Supervising and mentoring student teachers in order to relieve other faculty who may lack either physics background or K-12 background.
- Providing first-hand information on the realities of K-12 teaching to college-level course reformers, committees, and departments.
- Planning and implementing activities specifically focused at the recruitment and retention of K-12 physics teachers.
- Supporting pre-service teachers through personal, one-on-one interactions including spending time talking with students about what it's like to be a teacher, listening to their fears and concerns and giving them encouragement whenever it is needed.
- Supervising and coaching graduate Teaching Assistants and undergraduate Learning Assistants to improve the quality of the experiences they provide for students and to refine their teaching skills.

Again, more detail on examples of several of these activities is provided in the next article by Isola and Poel.

The list of potential TIR/MT activities above might seem extensive. Still, one might ask "Why should a research intensive department bother?" First, many physics teacher preparation sites that have utilized TIRs/MTs have seen a three fold increase in the number of physics teachers produced over the past 5 years. (Specific data is available at www.phystec.org). Since these students are often *additional* students, the increasing enrollment in physics teaching programs often benefits the whole department. In addition, we believe that the techniques employed to increase the number of students going into physics teaching also improve the general physics major/minor enrollment. Second, the pressure to produce more physics teachers will likely increase as the shortages become more acute. Implementing some of the strategies we have described will proactively move departments to the forefront of this issue. Lastly, we argue that for departments that care about improving science education TIRs and MTs are exceptionally well positioned to act as agents of change. They are individuals who are familiar with the often separate worlds of K-12 and college-level education. They can move back and forth between these worlds, speaking with credibility and insight to both cultures. Hence, they are very well positioned to transmit developments in physics teaching. For example, we have learned a lot about how students learn, which teaching strategies work and which ones don't and we've developed and are utilizing new technologies to demonstrate physics concepts and challenge students' thinking. This paradigm shift, from traditional to reformed teaching, has been trickling its way down into our local school systems. TIRs and MTs can lead the way on this by calling for change in K-12 schools and providing the support needed to make it happen. Physics departments that utilize this important human resource take the lead in developing and supporting quality teachers of physics for the next generation.

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Recruiting a New Generation of Physics Teachers at Western Michigan University

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Recruitment, recruitment, recruitment. This seems to be the buzzword of late in the world of physics teacher preparation; however, this issue is not new. The need for more physics teachers, and efforts to recruitment them, have been ongoing for decades. But the calls for action have been taking on a new sense of urgency since the call for "10,000 teachers, 10 million minds" was issued in the 2005 National Academies report *Rising Above the Gathering Storm* (The National Academy of Sciences, 2005). Historically, states that have routinely placed science teachers, without a physics major or minor, into physics classrooms are finding that they are no longer able to do so. In these states, the avenues to producing highly-qualified physics teachers are not well established, or well traveled, and so pressures to meet this need are increasing on physics departments and teacher preparation programs. It's important to point out, however, that increasing the number of future physics teachers is more than a recruitment issue, it is also a retention issue.

The Physics Department at Western Michigan University (WMU) has been focusing heavily on the recruitment and retention of future physics teachers since the 2000-2001 academic year. These efforts are beginning to show signs of paying off with our latest cohort of high school physics teachers. WMU produced 14 high school physics teachers from our Secondary Education certification (SED) program last year (2005-2006 academic year), including 4 women. We also have approximately 44 undergraduate students currently in the physics teacher preparation pipeline (14 are women). It's worth pointing out that these numbers contain predominantly juniors and seniors because we find that many freshman and sophomores do not initially declare their degree intentions and so tend to be undercounted. Hence, we are fairly confident that last year's results are more of a trend than an anomaly. However, it is also true that the number 'in the pipeline' is a difficult number to accurately report at any given time, because counting undergraduates and their future career plans has an uncertainty principle all its own.

At WMU we focus our recruitment and retention efforts on three groups of students: 1) students who are officially enrolled in the SED program as physics majors or minors; 2) students who have officially indicated to their advisor that they are interested in becoming a high school physics teacher and are designated as a pre-Secondary Education (PED) physics major or minor; 3) students who are taking, or have taken, one or more of the required SED physics courses and have indicated to us in some way that they are planning on becoming a high school physics teacher. This last group is the most fluid of the three groups and is mostly composed of freshman or sophomores, recent transfers, and students who have recently changed their major (usually from engineering). The distinctions between these 3 groups are relevant because we have found that recruitment and retention efforts must be focused differently for each of these groups. Groups 1 and 2 do not need recruiting and tend to require more focused support and professional community building efforts, while Group 3 students are prime recruiting territory and are most impacted by informational and promotional efforts related to future job opportunities.

By far, the single biggest factor that improves recruitment and retention efforts is the presence of an individual in the physics department who has specific responsibilities related to the training of future physics teachers. Based on our experience, if no one is in charge of recruiting and supporting pre-service teachers, it probably will not happen or will remain a low priority in the department. If it is delegated to someone as a supplementary responsibility above and beyond all other regular faculty duties it may get done, but only with a minimal amount of time, energy and enthusiasm. Our increased efforts in recruitment and retention were made possible by the presence of a full-time Teacher-in-Residence (TIR) these past 5 years whose position was funded by a PhysTEC grant (http://www.phystec.org/about.html). The WMU TIRs are individuals with many years of high school physics teaching experience who were specifically selected from area high schools for the purpose of recruiting and improving the preparation of future physics teachers.

The importance of the role of a TIR, or TIR-like person, cannot be overstated. Without the activities that our TIRs have planned and implemented since the start of these renewed efforts, much of the progress we have made would not have happened. These activities fall into two categories: 1) increasing physics SED enrollment and 2) supporting the students who are enrolled in the program. We have found that to increase the number of future physics teachers physics departments should focus on activities that are designed to get more students to enter the program *and* keep the students in the program once they enter. Fortunately, these categories are not mutually exclusive, but rather are complementary. Many activities serve both functions.

One such activity for a TIR is maintaining a highly visible presence in introductory and intermediate level physics courses. The nature of this presence often includes team teaching with a faculty member, sitting in on class and helping students with group work, engaging students in active discussions during lab work, and re-designing and rewriting lab activities to increase students' understanding of basic physics concepts. This presence gives students, who are already enrolled as physics SED/PED majors or minors a familiar face to turn to with questions about the physics SED program. It also helps prevent feelings of isolation for these students, amidst a sea of future engineers and scientists. In addition, this presence gives the TIR easy access to groups of students who are potential physics teaching candidates. Many students in the introductory courses are still uncertain as to their future career plans.

A number of our graduates have remarked, anecdotally, that they never seriously considered teaching as a career option until one of our TIRs discussed teaching with their physics class.

Of course, we are not advocating an approach where students need to be convinced or sold on the idea of becoming a physics teacher. Rather, we are pointing out that there are many students sitting in physics classes around the country who may have never considered this option. An important part of recruitment is making this option visible enough for students to consider. We find that we have many more students enroll in the physics SED or PED program after their 1st or 2nd year of post-secondary education than we do as entering freshman. This observation indicates that this group of students, already sitting in our physics classes, is "ready to listen" and is a worthwhile group on which to expend substantial recruiting energies.

A second major type of activity the TIR takes responsibility for can best be described as "community building". Community building activities are meant to strengthen connections between the individuals who regularly participate in them as well as to built connections between new members and the existing community. Some of the community building activities used over the years include evening workshops in which people share 'tried and true' teaching strategies, make-n-take activities, 'Demos and Donuts' and 'Pizza with the Profs'. We have observed many of our recent graduates making positive use of the connections formed while on-campus with their peers and local teachers long after they have graduated and moved on. Some have even remarked that it was these types of activities that helped convince them to stay enrolled in the program when things got difficult, or helped them stay in teaching when they felt overwhelmed their first few years.

A third type of activity the TIR engages in is frequent, substantive, and focused communication with individuals who are enrolled in, or interested in, the SED/PED program, student teachers, recent graduates and local teachers of physics and physical science. Maintaining contact with these groups by sending out informative updates and announcements on issues, activities and opportunities (local, state and national) aids greatly in raising your department's credibility as a resource and source of support. This also increases the feelings of 'connectedness' among students and recent graduates thereby increasing the likelihood of returning for their post-graduate education.

Another important area of TIR activities is support of pre-service teachers. A TIR who has a good working relationship with physics students making their way through the secondary education pipeline can be a tremendous source of academic and emotional support for students who are at times overwhelmed. Sometimes short-term tutoring is all that is needed or helping to organize groups of like-minded students together into study groups. These types of small group and personal supportive interactions have provided the impetus for our TIR's to also offer further assistance to students in the form of study groups for the Michigan Test for Teacher Certification and classroom visits to some of our student teachers when they have requested another physics teaching resource person to help them. In general, activities that focus on reducing the dropout rate from a physics teacher preparation program are valuable.

The reform of college-level introductory physics courses is also important in attracting and retaining future physics teachers. Since it is widely accepted that most teachers teach the way they were taught, this has the added benefit of improving the teaching skills of our future physics teachers. Quite a few of our physics SED students, who were originally engineering students, have remarked that it was their experiences with a dynamic, interactive physics instructor that increased their interest in physics as a discipline and teaching as a profession.

Another activity that we find produces results is in-service K-12 teacher support. High school teachers can be an institution's best (or worst) recruiters. Our goal is that the graduates of our physics SED program, as well as other area physics teachers, view the WMU program as a supportive program that produces well-prepared teachers. When these individuals need physics teaching support, we want them to turn to us for assistance and we then do our best to try to meet their needs.

We have reported on several successful efforts above. However, there are some activities, or aspects of activities, that we have found did not work well. For example, mass distribution of brochures or large scale attempts to communicate through mail or email without a personal contact seem to get lost in the vast array of other publicity that is continually bombarding the students and teachers. Activities that do not include substantial refreshments, parking passes and relevant, useful materials quickly turn people off and make it harder to get them to return for future events. Inviting people to any activity without frequent reminders up to the day of the event tends to result in poor turnout. Paying for students' registration costs, travel and meals for professional meetings greatly increases the participation level of undergraduates.

In summary, the main issues that need to be addressed by a department or an institution seeking to improve the recruitment and retention of future physics teachers are:

- Select a person whose primary responsibilities are pre-service teacher recruitment, retention and training. It's very useful if that person has extensive physics teaching experience them selves and is familiar with both K-12 schools and your institution.
- Remember, while it is important for one person to take the lead in these areas and serve as the motivator, coordinator and implementer, they can't do it alone. This effort takes department wide support in the form of money, time and personnel.
- The primary person needs to maintain a highly visible presence and involvement in classes that future physics teachers take. Focus recruitment on students who are already taking your introductory physics classes but have not yet commit ted themselves to a specific career track.

- Build a professional community among students in your pro gram and between these students and in-service physics teach ers.
- Communicate well and often. Stay in close contact with as many future and in-service physics teachers as possible. Get to know them and let them get to know you and your department.
- Provide support to individuals at every stage from students who have recently entered your teacher education program to those in their first few years of teaching and even to your more experienced teachers.

Drew Isola is Teacher-in-Residence and Bob Poel is Professor Emeritus, both at Western Michigan University.

Strengthening the K12 Teacher Workforce

Joan T. Prival, National Science Foundation

Recent national reports, calling attention to the need to increase and enrich the nation's science and engineering talent pool, are placing an increased emphasis on expanding and strengthening the teacher workforce. For example, the report of the National Academies' Committee on Prospering in the Global Economy of the *21st Century, Rising Above the Gathering Storm*, called for the annual recruitment of 10,000 math and science teachers as well as strengthening the skills of current teachers. These recommendations are, in part, a reaction to data indicating that many students are taught by teachers lacking a major or certification in the subject area taught. These figures are highest in physics classes where 67% of the students are taught by teachers who are not certified to teach physics or who lack a major in physics. In addition, analyses of national databases indicate that teachers with Bachelors' or Masters' degrees in mathematics and science are associated with higher student performance scores. These findings have led to an increased interest in attracting individuals with strong mathematics and science backgrounds into teaching.

The National Science Foundation offers a number of programs of interest to the Physics Teacher Preparation community. In addition to programs focusing on recruitment and retention of students in science, technology, engineering, and mathematics (STEM) fields, including teaching, NSF programs support research on science and mathematics teacher education, development of materials for educating teachers, and the general improvement of undergraduate STEM education which will impact future teachers as members of the undergraduate student population. The improvement of undergraduate courses and teaching responds to the need for STEM faculty to model best practices for those who are likely to teach in the way they were taught.

The *Robert Noyce Scholarship Program* is of particular relevance to institutions that are trying to recruit Physics and other STEM students into teaching. This program provides funds to colleges and universities with strong teacher preparation programs to provide scholarships and stipends for prospective mathematics and science teachers. The program offers support for undergraduate students who are majoring in a STEM discipline and support for STEM professionals who are seeking a career change to become a K-12 teacher. In both cases, scholarship and stipend recipients must commit to teaching in a high need school district for two years for each year of financial support. Features of successful proposals under this program include a high quality teacher preparation program, the involvement of STEM faculty in the leadership team, support for new teachers, evidence of a strong partnership with a school district, plans for tracking students to ensure compliance with the service requirement, and a strong evaluation plan that will measure the effectiveness of the project in attracting and retaining exemplary teachers. Consult the Noyce program website for the solicitation and a list of current awards: http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5733&org=DUE&from=home

The *Course, Curriculum, and Laboratory Improvement* (CCLI) program seeks to improve the quality of science, technology, engineering, and mathematics (STEM) education for all undergraduate students, including preservice teachers. The program supports efforts to create new learning materials and teaching strategies, develop faculty expertise, implement educational innovations, assess learning and evaluate innovations, and conduct research on STEM teaching and learning. The program supports three types of projects representing three different phases of development, ranging from small, exploratory investigations to large, comprehensive projects. Competitive proposals feature quality, relevance, and impact. They are student-focused, draw from and contribute to the STEM education knowledge base, include expected measurable outcomes and a strong evaluation plan, and engage in STEM education community-building. CCLI information can be found at http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5741&org=DUE&from=home

To increase the number of students (U.S. citizens or permanent residents) pursuing associate and baccalaureate degrees in STEM fields, the *STEM Talent Expansion Program (STEP)* solicits Type 1 proposals to support full implementation efforts at academic institutions and Type 2 proposals to support educational research projects on associate or baccalaureate degree attainment in STEM. Efforts may include, for example, activities that focus on improving the quality of student learning, interdisciplinary approaches, mentoring, and/or student internships or research experiences. The goal of the project must be to increase the total number of students receiving degrees across all STEM fields. Clearly, increasing the number of STEM majors will expand the pool of potential science and mathematics teachers who have a STEM degree. More information about STEP can be found at http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5488&org=DUE&from=home

The NSF Scholarships in Science, Technology, Engineering and

Mathematics (S-STEM) provides funding to institutions of higher education to support scholarships for academically talented, financially needy students majoring in mathematics, science and engineering disciplines. This expands the previous CSEMS program to include the biological sciences, physical sciences in addition to computer and information sciences, mathematical sciences, and engineering. Projects are expected to offer support programs and services and a quality educational program for the S-STEM scholars. More information about the S-STEM program can be found at http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5257&org=DUE&from=home

NSF's *Math and Science Partnership Program* held its fourth competition this year. Prior to the 2006 competition, the program funded 48 Partnerships aimed at building capacity and integrating the work of higher education with that of K12 to strengthen and reform math and science education. These partnerships have engaged substantial numbers of STEM faculty in the work of improving K12 teaching and learning. Included in the portfolio are Institute Partnerships which are offering Teacher Institutes focusing on the development of school-based intellectual leaders and master teachers. In addition, 32 Research, Evaluation, and Technical Assistance (RETA) projects have been funded and are developing instruments and conducting research on areas relevant to the work of the partnerships. The MSP website contains information about funded projects and resources as well as a link to MSPnet, a rich website with further information about MSP funded projects as well as other resources. http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5756&org=EHR&from=fund

A new program, *Discovery Research K-12*, incorporates aspects of the former Teacher Professional Continuum, Instructional Materials Development, and Centers for Learning and Teaching programs. DR-K12 supports research, development, and evaluation activities to improve K-12 learning and teaching. The program addresses three Grand Challenges in K12 STEM education: 1) K-12 Mathematics and Science Assessments, 2) Elementary Grades Science, and 3) Cutting-Edge STEM Content in K-12 Classrooms.
Proposals may be submitted in the following areas:

- *Applied Research* that supports three categories of projects: Evaluative Studies of NSF-Funded Resources and Tools, Studies of Student Learning Progressions, and Studies of Teachers and Teaching.
- *Development of Resources and Tools* that supports two categories of projects: Assessment of Students' and Teachers' Learning and Instruction of K-12 Students and Teachers.
- *Capacity Building* that supports two categories of projects: STEM Systems Research and STEM Education Research Scholars.

In addition to these three areas, conferences related to the mission of the DR-K12 program are also supported. Information and the current DR-K12 solicitation can be found at http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=500047&org=EHR&from=home

The *National STEM Digital Library (NSDL)* http://nsdl.org/ offers an online network of learning environments and resources for STEM education at all levels, including the collections of ComPADRE, which provides educational resources for the physics and astronomy communities through a collaboration involving the American Association of Physics Teachers (AAPT), the American Astronomical Society (AAS), the American Institute of Physics/Society of Physics Students (AIP/SPS), and the American Physical Society (APS). The NSDL program has three tracks: (1) *Pathways* projects are expected to provide stewardship for the content and services needed by major communities of learners. (2) *Services* projects are expected to develop services that support users, resource collection providers, and the Core Integration effort and that enhance the impact, efficiency, and value of the library. (3) *Targeted Research* projects are expected to explore specific topics that have immediate applicability to collections, services, and other aspects of the development of the digital library. Additional information about the NSDL program can be found at http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5487&org=DUE&from=home

Proposers should consult the individual Program Solicitations for specific guidelines for submitting proposals. To receive email notifications of program solicitations as they are released on the Web it is helpful to enroll in MyNSF at www.nsf.gov or check the homepages of the NSF Directorates for news about funding opportunities.

The views expressed are those of the author and do not necessarily reflect those of the National Science Foundation.

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