



## Fall 2014 Newsletter

Beth Lindsey, Editor

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*Disclaimer—The articles and opinion pieces found in this issue of the APS Forum on Education Newsletter are not peer refereed and represent solely the views of the authors and not necessarily the views of the APS.*

## From the Chair

*Michael Fauerbach, Florida Gulf Coast University*

Fall is usually the time for elections and this year is no different. Soon you will be asked not only to participate in local and national elections, but also cast your vote on the APS governance changes and elect new members to the Forum on Education (FEEd) Executive Committee. Tim Stelzer and the nominating committee have been hard at work fielding a strong and diverse slate of candidates. A strong voter turnout is crucial for meaningful elections, so I would like to ask you to take time out of your busy schedule, read through the candidate profiles and statements and actively participate in the Forum elections. When you read through the candidate profiles, questions that I often get asked might come to mind: 'What exactly does the Forum on Education do? Why should I be (more) engaged in it?' Well, as usual, there is a short and much longer version of the answer to this. The short version: *'The FEEd represents all aspects of education in the American Physical Society. The forum organizes invited sessions at the March and April national meetings, distributes a newsletter 3 times a year, bestows Awards and selects Fellows'*. The longer version of the answer is usually much more personal. To me, **education is central to all our endeavors as professional physicists**. It might be easy to agree with this statement for those of us engaged in different aspects of K-20 education. However, I strongly feel that my statement is also true for physicists not directly involved in K-20 education, like those working in industry or at national labs. After all, maybe more than other professions we are life-long learners and are able to adapt to the ever changing work environments. We are all mentors to colleagues and/or students, we 'educate' our bosses about the progress our work has made, our products only sell, if we 'educate' clients about the advantages of these products over those of a competitor, we 'educate' funding agencies on the benefits of our work over those of competing groups. For those of us who have children, grandchil-

dren, nieces, nephews, etc., we serve as role models for them, nurture their interest in the world, and showcase the importance of a good education. I could go on, but I hope I showed how education is weaved into our daily lives, whether we recognize it consciously or not.

Now, back to the original question of *'What does the FEEd do?'* Are we really covering all these aspects? Well, we are trying to, but of course, there is always room for improvement. I encourage you to look over the invited sessions the FEEd hosted in the past and will host in the future. Collaborations with other units and forums, as well as the AAPT, help us cover a wide range of topics. Randy Knight and the programming committee have worked diligently to not only have a wide variety of topics at the 2015 meetings, but also to invite the best speakers. Still with limited budgets and limited sessions in each meeting judgment calls have to be made. *'Why should I be (more) engaged in the FEEd?'* because we cannot do it without you!! The forum is only as strong as the members who actively participate in it. If you are reading this, you obviously are reading the newsletter. Our newsletter editor Beth Lindsey is doing a great job, and she always looks for topics that people are interested in. If you liked/disliked an article give feedback. When a call for nominations or suggestions for future sessions goes out, participate in it. If you attend the national meetings, make it a point to visit one -or hopefully more- of our sessions. If you plan to be at the 2015 April meeting, stop by at our business meeting, or come to the reception where we honor or Award winners and new Fellows. Contact me or other members of the Executive Committee with questions, comments, suggestions. And finally tell your colleagues/students about the FEEd and why they should be engaged in it.

## Letter from the Editor

*Beth Lindsey, Penn State Greater Allegheny*

This past year has been an especially active year for collaborations between Physics Education and Biology Education. In March, the Conference for Introductory Physics for the Life Sciences was held in Arlington, VA. This conference focused on both content and pedagogical issues for the physics courses taken by life sciences students, including pre-medical students, students interested in research biology or biotechnology, and students in ecology and related areas. Then, in June, the Gordon Research Conference on Physics Research and Education was held. The theme of this conference was “the complex intersection of biology and physics.” In this issue of the Fed newsletter, Dawn Meredith gives an overview of the major outcomes of the IPLS conference in her article. Mel Sabella and Matthew Lang, co-chairs of this year’s GRC, present an article summarizing that conference and the themes they saw emerge there.

In addition to these overview articles, I present several con-

tributions from participants in either the IPLS Conference, the GRC, or both. Michael Klymkowsky and Steven Vogel each present their view on the connections between physics and biology from the realm of biology. Simon Mochrie describes an innovative IPLS course that he has been teaching at Yale for the past several years. I hope that the experiences and insights presented here might provide you with inspiration or guidance if your own department is seeking to reform its IPLS course, or to offer more Biophysics options.

Finally, in this issue of the newsletter, I would like to welcome Alma Robinson as the editor of the Teacher Preparation Section. She takes over the section from John Stewart, who served as Teacher Preparation Section Editor since the Fall of 2006. Alma is currently serving as the PhysTEC Teacher-in-Residence at Virginia Tech. I look forward to seeing how her voice will shape the Teacher Preparation section in years to come.

## FEd-Sponsored Sessions at the 2015 March and April Meetings

*Randy Knight, California Polytechnic State University*

One of the primary tasks of the Forum on Education is to sponsor education sessions at the March and April meetings of APS. The details are still being working out, but the sessions for the 2015 meetings are shaping up nicely. If you plan on attending one of these meetings, please look for us and attend.

### March Meeting

The March Meeting will be held March 2-6 in San Antonio, Texas. This will be the second year in which the FEd hosts the award session for the winner of the Jonathan Reichert and Barbara Wolff-Reichert Award for Excellence in Advanced Laboratory Instruction. The winner will speak first, then four other invited speakers will address various aspects of the topic “Reimagining the Advanced Lab.”

If you’ve ever applied for or had NSF funding for an education project, you probably know Duncan McBride. Duncan has recently retired from NSF after a lengthy career. We will honor him with a session “NSF-Funded Physics Education: Celebrating Accomplishments and Looking Forward.”

Would your department like to increase the number of physics majors? Get the inside story from several departments that have succeeded in the session “Growing the Physics Major.” They’ll tell you how they did it and pass along suggestions that other departments can use.

We will be part of two co-sponsored sessions. FEd and the Forum on the History of Physics will co-sponsor the session “Inspirational Teaching of Physics” where several speakers tell us how they use anything from history to technology to current events to inspire their students. And FEd and the Division of Biological Physics will co-sponsor a session “Reform Efforts in the Introductory Physics for Life Science Course.”

Finally, we’ll be co-sponsoring with the Forum on Industrial and Applied Physics a contributed session on Physics Innovation and Entrepreneurship. If you’ve done anything interesting with the entrepreneurial side of physics, please submit an abstract.

### April Meeting

We will sponsor five invited sessions at the April Meeting, April 11-14 in Baltimore. Foremost will be the award session for the winners of the 2014 Excellence in Education Award.

With the meeting’s proximity to the movers and shakers in Washington, DC, we’ll have a session on “What’s Happening in STEM Education.” And because April is the divisional meeting of the Division of Astrophysics, we’ll run a session on “Astronomy Education.”

Two of the April sessions are always co-sponsored by AAPT.

For 2015, we'll be hearing about "Research-Based Teaching of Quantum Mechanics" and "AP Physics 1 and 2: Some Things Old and Some Things New."

Look for detailed information about these sessions in the Winter FEd Newsletter.

*Randy Knight is Professor Emeritus at California Polytechnic State University (Cal Poly) in San Luis Obispo, CA. He is Chair-Elect of the Forum on Education and FEd Program Committee Chair for the 2015 meetings.*

## Director's Corner Fall 2014

*Ted Hodapp, APS Director of Education and Diversity*

For many years the APS has repeatedly received requests such as: Why doesn't the APS develop standards for the undergraduate physics major – The ACS has done this for decades! There are, of course, a number of issues this touches, but especially for programs at smaller universities and colleges, it is has the potential to provide a rational basis for creating and building excellent programs. To investigate this issue further, the APS has formed a small group to look into issues related to professional standards, certification, or program "approval." Various groups already have related programs: the IOP accredits all physics programs in the UK, Canada has a "Professional Certification" designation for individual physicists, ABET accredits Engineering Physics programs, and the American Chemical Society has "ACS approved" chemistry degrees. To understand issues that programs face, the APS circulated a survey in late August to all physics department chairs. The APS Committee on Education's subcommittee on undergraduate education and the group assembled to investigate this issue will be considering these responses this fall to make recommendations to the APS leadership on next steps. Contact [education@aps.org](mailto:education@aps.org) if you have thoughts on this issue.

In 2015, the APS will again assist universities as they host regional conferences for undergraduate women in physics (APS CUWiP). Even with the 2015 conferences still a few months off, plans are underway by the project's leadership (the current chair is Kevin Pitts at UIUC) to solicit sites for 2016. If

your department is interested in hosting such an event, please refer to the project's website ([aps.org/link/cuwip](http://aps.org/link/cuwip)) for details. The deadline is November 1st, but even if you are not ready for 2016, you may want to plan ahead for a future year, and attend one of the 8 regional gatherings this coming January to get a feel for the excitement generated by these events (and some of the logistical concerns too!). Better yet, encourage your female undergraduates to attend the 2015 conference – some travel assistance (thanks to the NSF and DOE) is available.

Finally, we have just put up on the APS website a set of lists of top performing physics departments ([aps.org/programs/education/statistics/topproducers.cfm](http://aps.org/programs/education/statistics/topproducers.cfm)). These are departments that graduate the largest number of majors, women, and underrepresented minorities, separated by the highest physics degree offered at the institution. Congratulations to these departments for their efforts, and we recommend you contact departments if you are interested to hear more about how they have been successful. Aligned with this, the APS is sponsoring a second "Building thriving undergraduate physics programs" workshop 7-8 February 2015 in conjunction with the annual PhysTEC conference (6-7 February 2015) in Seattle, WA. Several of the programs listed in our "Top Producers" lists will be featured at this workshop, and you may want to come a day early to learn more about how educating high school teachers contributes to improving your program. More details are available at [phystec.org](http://phystec.org).



Physics Teacher Education Coalition

# PhysTEC 2015 Conference

The nation's largest meeting dedicated to physics teacher education

**February 5-7, 2015**  
**Marriott Seattle Waterfront**  
**Seattle, Washington**



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- Participants will analyze their departmental situation and decide how to take actions that will help them sustainably achieve their goals.

**February 6-8, 2015**  
**Seattle, Washington**  
**Registration now open**  
<http://www.phystec.org/conferences/thriving15>

## Updates from the Topical Group on Physics Education Research

*Eric Brewe, GPER Chair, Florida International University*

During this first year of our existence, GPER, the Topical Group on Physics Education Research, has grown to over 500 members. This growth shows the importance of PER as a research field within the APS. We take the membership growth and our initial accomplishments as indicators that we are fulfilling the mission of GPER - to the advance and spread of knowledge concerning the learning and teaching of physics. We support the growth of PER within the APS and the executive board serves as your representative to the APS administrative organization and broader membership.

We are pleased with our successes over our inaugural year. The elected GPER Executive Committee meets monthly along with a representative of the Forum on Education (FEd), a member of American Association of Physics Teachers' Topical Group on PER (AAPT – PERTG), and the APS staff liaison.

Ongoing efforts:

- The Grand Challenges in Physics Education Research initiative to identify physics education research questions of broad importance was endorsed by the APS GPER, AAPT – PERTG, and the FEd. Invitations to the Working Group and Advisory Board have been issued. For more information, see the upcoming GPER Newsletter.
- Outreach to professional societies and national agencies has begun with introductions sent to 20 professional societies (e.g. American Chemical Society, American Society for Engineering Education) and national agencies (e.g. NSF, Dept. of Education).
- New member recruitment has included a flyer distributed

at the Summer AAPT meeting and a slide posted at APS Education & Diversity exhibits.

- Guidelines are being established for how GPER monies will support the goals of the topical group and serve its members.
- Institutional memory and practices of the Topical Group are being documented to support future Topical Group Executive Committees in functioning efficiently.

Upcoming:

- Two GPER invited sessions will be held at the APS April Meeting in 2015, one on the Grand Challenges effort and one on the *Physical Review - PER* Focused Collection on Upper Division Physics. All are encouraged to submit contributed talks and posters on physics education research to the April Meeting. The call for proposals for the April meeting will open in October.
- Elections will open in Mid-October for one At-Large member and one member in the Chair line (Vice-Chair).
- GPER will nominate two APS Fellows in Spring 2015. If you have suggestions for nominations, please contact a member of the Executive Committee.

I would like to thank the other members of the Executive Committee for their service so far: Karen Cummings, Rachel Scherr, Scott Franklin, Noah Finkelstein, Adrien Madsen, and Peter Shaffer. I am also grateful to MacKenzie Stetzer of AAPT – PERTG, Michael Fauerbach of the Forum on Education, and Renee-Michelle Goertzen of APS for their contributions to GPER.

## AAPT-ALPhA Award

An exciting new award is now available to upper level undergraduate physics majors. The AAPT-ALPhA Award recognizes outstanding work by a student who has developed an advanced laboratory apparatus/experiment. The Award includes a \$4,000 cash honorarium for the student, as well as an invited talk at the AAPT meeting where the award is presented. At the same AAPT meeting, the faculty supervisor will be recognized with a citation. All travel and meeting expenses for both the student and advisor will be covered. National recognition of projects such as these will encourage their proliferation and help build the next generation of experimental physicists and educators.

Please advertise this opportunity to your faculty colleagues, especially those who are teaching advanced laboratories, and to upper level undergraduate physics majors. Deadline for student

projects is September 1, 2015. Faculty members are encouraged to submit a prospectus by July 1, 2015, to receive feedback on the student project. For more information about the Award including the submission process, please see [http://www.aapt.org/Programs/awards/aapt\\_alpha\\_award.cfm](http://www.aapt.org/Programs/awards/aapt_alpha_award.cfm). A flyer that can be printed and posted throughout your department and in student lounges is also available for download at the Award webpage. We anticipate presenting the first award at the 2016 AAPT Winter Meeting.

Jonathan Reichert, Chair, AAPT-ALPhA Award Committee ([jfreichert@teachspin.com](mailto:jfreichert@teachspin.com))

Beth A. Cunningham, AAPT Executive Officer ([bcunningham@aapt.org](mailto:bcunningham@aapt.org))

## Overview of the outcomes of the March IPLS meeting

*Dawn Meredith, University of New Hampshire*

The March 2014 “Conference On Introductory Physics For The Life Sciences (IPLS),” held in Arlington, Virginia and sponsored by the National Science Foundation and the American Association of Physics Teachers, brought together biologists, IPLS developers, physics instructors, and curriculum reform experts to discuss changes in this course. The conference included plenary speakers, posters, and working group sessions where attendees discussed the many issues related to implementing IPLS reforms. Conference presentations and posters can be found on the ComPADRE website <http://www.compadre.org/ipls/>. Soon ComPADRE will also include a full conference report. (You will need a ComPADRE account to login.)

This article summarizes the key concerns expressed by conference attendees, as well as some possible solutions. There are also references to resources to help support the work of course reformers.

**The need for course reform:** Several national policy documents over the past decade have brought to light the need for improvement in the education of life science professionals. [1-3] This education needs to be quantitative, interdisciplinary, and inquiry based. A decade ago, the typical IPLS course did not meet the needs of these students. We have come to understand that the students need a course that foregrounds how physics both constrains and provides opportunities for biological systems, and prepares them to appreciate and use the power of the quantitative models that are at the heart of physics.[4,5]

**Sustainability of reforms and course goals:** One key to sustainability is including all of the stakeholders in the discussions of goals and objectives: physics faculty, biology faculty, biology students, pre-professional advisors, the college, and the institution. The work of physics education researchers at U of Colorado at Boulder can provide guidance on sustainable course reform, including beginning with such conversations.[6]

One challenge in setting goals for this course is how to balance the physics department’s focus on the elegance, beauty, power, and coherence of physics, with the life scientists’ (both professors and students) desire for physics to inform their understanding of biological systems. We do not want this course to become an “un-organized overwhelming bucket” of biology applications (to quote an attendee), a course without a coherent story line, or a course dictated entirely by needs of life science faculty and students. And yet, those needs should be addressed.

A possible approach proposed at the conference is that physics can dictate the storyline, while biology can inform which topics are covered in what depth. For example, there was overwhelming agreement of conference participants that forces and con-

servation laws must remain at the core of this course, however, many applications of forces might be done in the context of fluids and viscous flow where the biological applications are numerous.

**Topic coverage:** As courses are redesigned, one vital decision is what topics to cover and in what depth. In asking this question, we must be aware that the different specialties within the life sciences (e.g., molecular, cellular, organismal, ecological) can have quite different opinions about what is important, and we need to listen to all the voices at our own institution. There is general agreement that topic coverage should be determined equally by the physics story line and the needs of biologists. [7,8]

**Goals related to Mathematics, Modeling, and Beliefs about Learning:** Students in this course often do not come with strong mathematical skills, therefore one of the main goals is to improve those skills in meaningful ways. This includes developing an understanding of scaling, units, linear relationships, proportional reasoning, graphs, and statistics. The two other skills most widely cited as priorities were the ability to build models (i.e., to be able to identify basic physics principles in a complex situation) and problem-solving skills. Key epistemological goals (i.e., goals related to students beliefs about learning and knowledge) included students coming to appreciate that physics is useful to understand the real world (especially biology), that numbers and equations should make sense, and that memorizing is not learning.

**Pedagogical issues:** We agreed that while the content is being changed, it is vital to maintain sound pedagogy. We cannot forget all that we have learned in the last few decades from Physics Education Research about active engagement; formative assessment; and attending to conceptual, mathematical, and epistemological growth of students. The national policy documents from the biology/pre-professional community are also calling for inquiry-based, active learning environments.

**Local support for those making reforms:** There are some very practical concerns for those taking on the huge task of course reform. First, reformers should be sure that their chair and department buy into the reforms, as evidenced by participation in conversations about goals and/or commitment of resources (e.g. equipment for new laboratories, and course release or summer salary for the time required for faculty to prepare the new course). This is especially important in departments where the IPLS course is less well resourced than the course for engineers and physical scientists (e.g., the IPLS course is commonly taught by adjuncts, or given fewer faculty and TA’s per student).

To make the effort required manageable, reformers should not try to change everything at once, but make a few meaningful, cumulative changes each year. For many, changes in the lab might be the most straightforward and have the largest impact. Reformers should also not work in isolation. They should recruit a biology colleague (or someone from another relevant department) to be the content expert and provide connections to other biosciences faculty; many of us have found such a collaborator is essential for on-going negotiations between the cultures of biology and physics. Biophysics faculty, where present, can be an invaluable resource even if they do not lead the reform. Advanced undergraduate biology students who have taken the IPLS course, can be learning assistants[9] and biology experts in the physics classroom.

**Repository of curricular materials:** Course reformers need easy access to tested curricular materials (labs, tutorials, homework and exam questions, peer instruction questions). Attend-

ees stated strongly the need for a central on-line repository of materials that is lean, searchable, and annotated (e.g., “this works well under the following conditions...”) The conference organizers are currently working with the ComPADRE staff to create such a repository. In the meantime, below is a table of resources currently available on the web. This is by no means complete, but a place to start.

**Student buy-in:** Will our IPLS students accept the changes? While we hope that these reforms should be widely appealing to students, and assessment data from many institutions indicates that it is, if the reformed course is perceived as more difficult and requiring more effort than the standard course, students might be resistant in spite of the biological focus. The value of the reformed course can be greatly enhanced if students see physics used in at least some upper division biology courses, but this then requires that physics is a pre-requisite for the course, and students are advised to take physics before their

Institution	Website and other details & brief description of resources
American Association of Medical Colleges	<a href="https://www.mededportal.org/icollaborative/about/initiatives/prehealth/">https://www.mededportal.org/icollaborative/about/initiatives/prehealth/</a> This is a searchable repository of curriculum for pre-professional students.
Kansas State University	<a href="http://web.phys.ksu.edu/mmmm/student/">http://web.phys.ksu.edu/mmmm/student/</a> Labs related to medical devices (MRI, PET, Vision, Wave front aberrometry, locating bullets). Includes instructor resources.
Mercy College	<a href="https://mercy.digication.com/biomechanics_activities_/Home//">https://mercy.digication.com/biomechanics_activities_/Home//</a> Human biomechanics activities and experiments.
<a href="#">Portland State University</a>	<a href="http://web.pdx.edu/~ralfw/biomedical-projects.html">http://web.pdx.edu/~ralfw/biomedical-projects.html</a> Labs related to medical devices (CT, EKG, Pulse-ox, BIA, and more....). Includes instructor resources.
Rockhurst University	<a href="https://www.mededportal.org/icollaborative/about/initiatives/prehealth/">https://www.mededportal.org/icollaborative/about/initiatives/prehealth/</a> Student activities available now: <i>Fiber Optics in Medicine</i> Module and <i>Investigating the Respiratory System</i> . Coming soon: <i>Fiber Optics in Medicine</i> and <i>Investigating the Cardiovascular System</i> . These are for a <i>Physics of Medicine</i> course, after a first physics course, and take about 3 weeks to do for each module. Email Nancy Donaldson ( <a href="mailto:nancy.donaldson@Rockhurst.edu">nancy.donaldson@Rockhurst.edu</a> ) for instructor guides.
Swarthmore College	<a href="http://materials.physics.swarthmore.edu/iplsmaterials/">http://materials.physics.swarthmore.edu/iplsmaterials/</a> Second semester resources (focus on optics and electromagnetism). Includes labs, clicker questions and homework.
University of Maryland	<a href="http://nexusphysics.umd.edu/">http://nexusphysics.umd.edu/</a> Need to request access on line.  This is a complete set of resources for their IPLS class (on-line text, clicker questions, lab, homework, instructor guides, related publications) for both semesters. Includes instructor resources.
UMass Amherst	<a href="http://people.umass.edu/rossj/Teaching.html">http://people.umass.edu/rossj/Teaching.html</a> This describes a full course on building a microscope.
University of New Hampshire and University of New England	<a href="http://ipls.unh.edu">http://ipls.unh.edu</a> First semester materials (annotated bibliographies, lecture slides, questions, with an emphasis on fluids, materials (e.g., stress/strain), and trigonometry). Includes instructor guides.



final year. It may also be possible to have at least a few significant references to physics in introductory biology courses. Having biology instructors attend your discussions of IPLS course goals will greatly facilitate discussions on this matter.

**Local flexibility:** There was also discussion about the need to tailor the IPLS course to the important differences in institutions. There will not be a one-size fits all IPLS course. For example small institutions may not be able to offer a course specifically for life science students. Different institutions will have different mixes of the many different kinds of life science students (future research biologists, nursing students, physical therapy students, and/or pre-medical students), and some will have non-life science students (e.g. architects) in the same course. Some institutions offer calculus-based courses while others offer an algebra-based course. Many institutions must be concerned with articulation agreements with other institutions and/or large number of transfer students.

**Assessment** also arose as a concern. How do we know if our reformed course is meeting our objectives? Inventories such as the FCI or FMCE do not target IPLS specific goals, though they may be of some help in assessing the pedagogy, so there is a need for more appropriate assessment instruments. Some are under development or have recently been developed: DJ Wagner and colleagues are developing a statics fluid assessment. [10] Kristi Lyn Hall has developed a Maryland Biology Expectations Survey, [11] similar to the MPEX, to assess student attitudes and expectations. However, assessment for IPLS courses remains an area in need of a great deal of work.

In summary, there are many resources for those considering reform of their IPLS course: identification of key issues, tested curricular materials, and best practices in course reform in general and IPLS in particular. Important work is still needed to create a repository of curricular materials and assessment targeting specific IPLS goals.

*Dawn Meredith is an Associate Professor of Physics at the University of New Hampshire. She is active in the field of PER, particularly focusing on curricular materials for the IPLS course, and on helping students connect meaning and mathematics.*

#### Endnotes

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## The 2014 Gordon Research Conference on Physics Research and Education 2014: The Complex Intersection of Biology and Physics

*Mel Sabella, Chicago State University, and Matthew Lang, Vanderbilt University*

The Gordon Research Conference on Physics Research and Education (GRC:PRE) brings together a diverse community of scientists, educators and education researchers every two years to explore the rich intersection of research and education and connect instructors, content researchers and education researchers.

This conference is unique among the Gordon Research Conferences because of the ties it fosters between education and cutting edge research, its diverse set of participants, and its broad goal to make exciting physics topics accessible to undergraduate students in diverse learning environments. Only seven of the roughly 840 GRCs focus on science education. The GRC:PRE also has a different mission than most of the other education-focused GRCs which almost exclusively involve education researchers as speakers, discussants, and participants. This particular GRC, which began in 2000, changes its specific topic each time. In 2014, the focus was the “Complex Intersection of Biology and Physics.” In 2012, the focus was “Astronomy” and in 2016 and 2018 the topics will be “General Relativity and Gravitational Waves” and “Energy,” respectively.

The fields of biological physics and physics education research, with specific focus on the needs and resources of life science students, have experienced tremendous growth in recent years. During the past year and a half, the community of biologists and physicists working in this area have organized theme issues on this topic in the June 2013 *CBE - Life Sciences Education*<sup>1</sup> and in the May 2014 *American Journal of Physics*.<sup>2</sup> In addition to the 2014 GRC, the Introductory Physics for Life Science (IPLS) Community held a conference, described in the previous article, in March 2014. While the focus of the IPLS conference was on introductory physics courses taken primarily by life science students, this GRC:PRE broadened the focus to include talks about research and education at both introductory and upper undergraduate levels. The 2014 GRC also connected scientists within biology and physics and those at the intersection of the two disciplines. Bridging these strands at the GRC provides unique opportunities for collaboration and brings together groups that typically do not regularly interact in more traditional academic venues.

GRCs are designed to encourage open and inclusive discussions. In 2014, a typical day at the GRC:PRE involved five invited talks by leaders in biology, medical physics, biophysics, and education research. Discussants, at each of the sessions, with expertise on the particular topic, engage both the audience and the speakers in thought provoking questions that clarify key issues and move the field forward. Contributed poster sessions in the late afternoons provided an opportunity for participants to present exciting work that often addressed the theme of the

biology and physics intersection while engaging in dialogue. Early afternoons at a GRC are free of formal programming and allow participants to have open, unstructured conversations. Because of the diversity of the participants at the GRC:PRE there are also opportunities to address themes that might be outside specific conference topics. In 2014 we organized informal discussions centered on key questions for the community such as: How do biologists, chemists, and physicists think and talk about energy? What topics in Physics might matter to the contemporary biologists and how do we integrate these topics into our respective disciplines? How do the systems we investigate in biology and physics differ in terms of historic contingency and complexity? How does the messy world of real data look in the biology and physics curriculum? These questions were often a focus of individual talks and questions at both the IPLS Conference and the GRC, where spirited controversy was embraced, fostering rich conversations among the participants. Those who needed a break from the science during the afternoon could participate in hiking, fishing, GRC-led trips, or the game of cornhole, complete with cornhole goals displaying the GRC logo.



Mike Klymko leads a discussion on how biologists and physicists think about energy

A number of overlapping themes emerged, from the GRC, the IPLS Conference, and the two theme issues that emphasize the complexity of the intersection of biology and physics and of education and research in this area. We often heard that learning respect for each other and each other's disciplines is extremely important and that we need to recognize our differences and similarities. Redish et al. state that “Biology and physics faculty tend to have dramatically different views about the nature and structure of knowledge that is appropriate to teach in classes ... Including biological authenticity shows respect for the interdisciplinarity.”<sup>3</sup> A clear message from both conferences was: take your fellow biologist or physicist to lunch, engage them as a friend and “pick up the check.” We also often heard that there are many ways to motivate students at this intersection. Exam-

ples included engaging students in biologically rich contexts or bringing in the social commitment of the students to tie activism and policy work to topics in medical physics.<sup>4</sup> One example of a rich context that relates to the everyday life of many of our students can be seen in the Harvard Course on Science and Cooking, which was highlighted in *Harvard Magazine* and the *New York Times* in 2010. Students in “Science and Cooking: From Haute Cuisine to Soft Matter Science had just burst into applause ... because Professor Michael Brenner had just unveiled the “equation of the week”: a heat transfer equation. The applause became a tradition in the course ... “ (*Harvard Magazine*, 2010) ... “Nearly 700 students wanted to enroll. By lottery, 300 got in ... “ (*NYT*, 2010).<sup>5</sup>

Bringing in diverse communities to explore the intersection of education and research and the intersection of biology and physics at the Gordon Research Conference proved to be very worthwhile for participants at the conference. Many participants stated that they were eager to go back to their institutions and foster connections between biology and physics topics and infuse their courses with exciting avenues of study and modify their courses to better meet the needs of their students. Our hope is that the 2014 GRC:PRE fosters ongoing discussions on this exciting interdisciplinary work.

The GRC was funded by the National Science Foundation, the American Physical Society - Forum on Education, the American Association of Physics Teachers, the Physics Education Leadership Organizing Council and the GRC. Funding from these sources allowed the 2014 GRC:PRE to support social functions and travel and registration for students from the undergraduate to graduate level, post docs, two year college faculty, our speakers and discussants, and faculty at

all stages of their careers at all types of institutions. This allowed us to involve an extremely diverse group of participants with a common goal of improving the teaching and learning of physics.

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## Physics for (molecular) biology students

*Michael W. Klymkowsky, University of Colorado Boulder*

Over the last decade or so there has been an ongoing discussion about how to best teach scientific subjects (see (Powell 2003; NRC 2011)). This has led to significant activity in the area known as DBER (discipline-based education research) (NRC 2012). While few would now argue that a lecture-only approach is appropriate for most topics, what seems to have been, rather surprisingly, neglected are the intra- and interdisciplinary discussions needed to define what a coherent curricula look like (Klymkowsky and Cooper 2012). What can, realistically, be conveyed to students in the time (credit hours) available? What topics are primary and which secondary or, except in highly specialized situations, superfluous, and what amount of time and practice is required by students to achieve the subject mastery expected of them? These are questions that require objective data (rather than personal empiricism) to answer. The answers to these questions are of practical importance for all students, particularly since a curriculum perceived, rightly or wrongly, to be designed to drive the “undeserving” out of a subject area produces unnecessary obstacles to inclusion and learning (Mervis 2011). A coherent, engaging, and rigorous curriculum is particularly critical for those students whose undergraduate experiences do not extend into graduate studies; here I am thinking specifically of students who will become science teachers. With various efforts to generate new (next generation) K-12 science standards (see (NRC 2012)), it becomes increasingly critical that students, that is, future science teachers, are adequately prepared to teach their disciplines in order to achieve the level of student understanding that these standards call for. Rather sadly, this is rarely an outcome that is foremost (or even secondary) in the thinking of disciplinary college science departments, deans, and provosts. If the situation is one of benign neglect or complacency within disciplinary departments, it is even more pernicious when these courses are taught to majors in other departments.

Let me present the case that I am most familiar with, molecular biology students. One could argue, convincingly I think, that together with an understanding of evolutionary mechanisms (surprisingly, a topic rarely addressed within the typical molecular biology curriculum), molecular biology forms the foundation for all of the various biological disciplines (Klymkowsky 2010). More and more molecular methods are used in these areas, both in the context of experimental manipulation and outcomes analyses. That said, it is often difficult to discern exactly what topics, and to what level of resolution, a typical molecular biology curriculum covers, or what level of working understanding students achieve. The problem is, if anything, more severe when it comes to the extra-disciplinary courses that are required of students: typically, these include a semester or two of calculus, generally delivered through courses designed for physics or engineering students, two semesters of general chemistry, often organized around a death march through buffer

and stoichiometry problems, followed by a semester or two of organic chemistry, often taught from the decidedly abiological perspective of a synthetic chemist, one or two semesters of biochemistry, and a semester or two of physics. These latter physics and chemistry courses are rarely designed to meet the needs of biology students, and in many cases, little thought has gone into articulating exactly why students should be required to take them. Without a compelling justification such requirements are akin to a doctor (the disciplinary faculty) prescribing a drug (a course) for a disease the patient (the student) does not actually have — a form of medical (pedagogical) malpractice. To follow the analogy further, we need to recognize the fact that all drugs have unwanted consequences.

In part to address the issue of relevance, over the past six years I have been working with Melanie Cooper (Michigan State University) to consider whether the structure of the typical general chemistry course addresses the disciplinary needs of the students who are required to take it. This analysis included both chemistry majors and students from other departments. The result of this process is a new general chemistry curriculum: Chemistry, Life, the Universe, and Everything (CLUE)(Cooper and Klymkowsky 2013). The development of the CLUE textbook and course materials was based on a rather intensive process that included many discussions about what chemical ideas were central - the resulting course is not “chemistry for non-majors” but rather a conceptually rigorous approach to the core ideas and skills required to understand chemistry. It involved going beyond course transformation (from lecture to various types of “active learning”) to a thorough consideration of content and performance expectations

(Klymkowsky and Cooper 2012). Through comparative and longitudinal studies we have found clear evidence that the CLUE course improves student understanding of key concepts in chemistry and that these effects persist into organic chemistry (Cooper et al. 2010; Cooper et al. 2012; Cooper et al. 2012; Underwood and Cooper in preparation.)

All of which, finally, brings me to the point of this essay - a call for an analogous discussion to define the physics content that is needed by, or better put, would justify a molecular biology department requiring its students to take an introductory physics course or two. An aspect of such a discussion that is worth explicitly acknowledging is the general asymmetry between molecular biology faculty and their physics and chemistry colleagues. For example, my own degrees are in biophysics, which entailed my taking a number of mathematics, physics, and chemistry courses. Most biologists have taken a similar mix of courses (see above). Yet, few physics (or chemistry) faculty have ever taken a single course in biology, much less the course sequence needed to have even a passing familiarity

with the concepts and skills employed in understanding, doing, and/or teaching modern biology. This makes the conversation rather skewed, if it occurs at all. More often than not physics faculty are called on to imagine what makes physics relevant to biology students, without a clear appreciation of core biological concepts. Attempts to make physics “relevant” can lead to the inclusion of cartoonish biological examples (blood flow in giraffes or spherical cows). While it is clear that physical principles are involved in a range of physiological processes (see for example (Vogel 2013)), physiology is not the most important aspect of modern biology and most molecular biology programs do not seriously consider the physical constraints on macroscopic systems (whether they should or not is another question). Understanding what is and what is not central to modern biology requires candid conversations between biologists and physicists, a realization reinforced by my experiences at the 2014 Introductory Physics for Life Sciences conference and the 2014 Gordon Research Conference on Physics Research and Education.

So what does a biology student, not to mention a working molecular biologist, need from a physics course? First, and rather emphatically I would reject the premise that physics per se is generically useful to understanding molecular biology. A poorly designed course, perceived as irrelevant to the disciplinary interests or needs of students could be viewed as an inappropriate imposition. What we need is a more explicitly relevant, molecular-level approach to the physicochemical foundations of non-equilibrium systems whose detailed organization and behaviors reflect their evolutionary history, that is, organisms (Mayr 1985). It is clear that the structure of atoms determines the nature and shape of the molecules they form. Why carbon is tetravalent is a physics question. While one might argue that bond formation lies within the purview of chemistry, the charge distributions within molecules determine how those molecules interact with one another, including the relative strengths and specificities of those interactions, a topic reasonably considered the focus of physics. Here the effects of thermal motion play a key role; the probability that an intra- or inter-molecular interaction will persist over time will depend upon collision kinetics, which of course relies on Newton’s laws of motion.

Understanding these topics involves a clear presentation of the concept of energy and the laws of thermodynamics, including the impact of system-level entropic factors. Energy itself is a complex and ill-defined concept (see (Cooper and Klymkowsky 2013)).<sup>1</sup> Here we are particularly concerned with system behaviors, behaviors that emerge from the molecular and produce the macroscopic. Biology, at all levels, is about the behavior of complex, non-equilibrium systems (Alon 2003; 2006; Klymkowsky 2010). If we think about where ever a reaction occurs,

whether it is the separation of oil and water to the synthesis of deoxyribonucleic acid, the “expression” of a gene, the folding, assembly, and behavior of proteins and molecular machines, or the transfer of information over time and space, we are talking about reactions characterized by both enthalpic and entropic effects. Much of the self-organizing behavior observed in biological systems, from the formation of membranes to the folding of proteins is based on entropic drivers. Moreover, in addition there are stochastic, but functionally significant effects that arise from the small number of interacting components often at play (see (Alon 2003; Ansel et al. 2008; Shahrezaei and Swain 2008; Eldar and Elowitz 2010)). The typical macroscopic physics course ignores such processes. So the question becomes, how to incorporate them into a physics course relevant to molecular level biological processes?

As a biologist it is not for me to design this type of course, it is for physics faculty. But I would propose that just as the collaboration between a chemist and biologist has been highly productive in the redesign of a general chemistry course, so a collaboration between physicists, chemists, and biologists would be extremely useful in designing a relevant, rigorous, and effective physics course that would serve both as an introduction to modern physics and which biology (and biochemistry) departments could, with a clear conscience, require their students to take.

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## Physics for Biologists—Beyond Biophysics

*Steven Vogel, Duke University*

One might expect that a perusal of either literature or programs listed under the heading “biophysics” might offer just what we need, a guide to the bits of biology to which physics bears immediate relevance. But, perhaps purely by historical accident, the term has unfortunately come to describe a far more limited domain and thus as guidance proves more likely to mislead than to guide a physicist attempting to devise a course.

“Biophysics” as a term traces to Karl Pearson, now best remembered as a pioneering statistician, who, in 1892, defined it in sweeping terms, “This branch of science which endeavours to show that the facts of Biology constitute particular cases of general physical laws” [1].

But a look at the faculty, their research areas, or the courses in any contemporary biophysics program, undergraduate or graduate, reveals something closer to molecular and a little cellular biology, with both merely viewed from a physical perspective. Scarcely a trace can be found of macroscopic physics. Even where one encounters “structural biology” no euphemistic neologism for anatomy is intended; “structure” here means macromolecular structure. The tacit definitional narrowing appears to have taken hold when the earliest specifically biophysics programs appeared during the 1950s in non-clinical medical science departments. It seems to have been echoed a little later as specializations within physics departments—although I cannot claim to have done a full historical trace.

The peculiarity was brought home to me when I found no reference to the Biophysical Journal among the over 800 sources cited in the 2013 revision of my textbook, *Comparative Biomechanics*. By design the book takes a macroscopic, organismal approach, and no paper apparently proved directly relevant. Similarly, I now find that no journal whose title includes the word “biophysics” or “biophysical” makes my list of the 90 for which over the past 50 years I have reviewed contributions.

So what items of physics ought a biologist be familiar? Without attempting any logical presentation, I offer two entry points. The first is a set of everyday examples of an essentially macroscopic, organismic character, ones that happen to be of little interest to biophysicists—examples admittedly reflecting my own interests.

**Example 1.** Feel your pulse at your wrist and you will experience the short systolic pulses of your left ventricle as expansions of the artery beneath the skin—blood flow has speeded up and the artery swells. But wait—Bernoulli’s equation says that faster flow should come with lower pressure and thus shrinkage of a compliant vessel. Why is its prediction exactly opposite reality? The usual physics course takes little note of *viscosity*, the *no-slip condition*, *Reynolds number*, or, of most immediate

relevance, the *Hagen-Poiseuille equation*.

**Example 2.** Hand-held infrared thermometers are now everyday items, most often used for checking heat leakage from homes. They provide a wonderfully enriched view of our thermal environment. I pointed one at a waist-high, sun-lit oak leaf on a still, hot (36° C) day; the middle of the leaf ran around 51°, fully 15° hotter. It occasionally dipped a degree as the leaf twitched in an air current too gentle for me to feel. A paper cut-out of a leaf became still warmer than a detached real leaf. A few months later I pointed the tool at a sky-exposed magnolia leaf on a cold (-8°), clear dawn; I got readings around -20°. Why doesn’t leaf temperature match air temperature, and why don’t leaves, when grasped, feel all that hot or cold? Does the physics course consider radiant heat exchange, with the *Stefan-Boltzmann equation* (and perhaps *Wien’s displacement law*), as well as free and forced convection, thermal capacity, and thermal conductivity?

**Example 3.** Ordinary trees grow to 30 or 40 meters in height and in a few places giants approach 100 meters. Evaporation from the leaves extracts liquid water from the interstices of the soil and raises it from the roots against both gravity and viscous pressure losses. By the time it reaches the leaves, hydrostatic pressure has dropped well below zero, often reaching negative tens of atmospheres by highly reliable direct and indirect measurements. No, capillary rise does not contribute significantly. For that to work, assuming perfect wetting, a 50-meter tree could have vessels no wider than 0.6 micrometers, vastly smaller than the typical value of 100 micrometers. The mechanism brings front and center the difference between gaseous and liquid *states of matter*; the near-*incompressibility of water*, the *speed of sound* in water and other media, as well as some highly instructive historical physical measurements. Not to mention the reason delicate marine organisms easily withstand the pressures at great oceanic depths, even if most fishes require quite special equipment to manage them.

**Example 4.** The same trees can profitably be viewed as mechanical devices. Spectacular failure of the simplest model can be used either as an introduction to specific treatment of real-world mechanics or as an open-ended assignment that will force students to discover for themselves the options missed by excessive idealization. How high might a cylindrical column of living oak extend upward before the wood on the bottom suffers compressive failure? Living oak has a density of about 600 kilograms per cubic meter, or a downward force of 6000 newtons per cubic meter [2]. It has a crushing strength of about 30 meganewtons per square meter [3]. Dividing the latter by the former gives a maximum height of no less than 5000 meters, fifty times the height of any tree. Examining what has been missed brings up other modes of compressive failure, in

particular *Euler buckling*, plus *Young's modulus*, *flexural stiffness*, and *second moment of area*. Further probing suggests that wind loading matters more, introducing *drag* and *drag coefficients* plus moment arms for both the load and the resistance to turning of the base plate and soil. Loading of bones follows the same logic if providing less tidy examples.

**Example 5.** Wet a piece of absorbent cotton and let it dry completely. Fluff has become dense mat as the receding air-water interfaces drew the hydrophilic fibers together. The relevance of *surface tension*, the culprit, goes far beyond determining just who can walk on water (although students might calculate the maximum weight of a water-walking human). Those same trees, again, could not manage without it. Only the surface tension of the sub-micrometer interfaces in the fibrous walls of cells within the leaves keeps air from being drawn into the open tops of the columns of water by the enormously low pressures within. The other critical variable, the size of the interfaces, operates via the *Young-Laplace relationship*, a recurring determinant in biology. Our own lungs need a special mechanism (a particular surfactant) to ensure that all alveoli will inflate simultaneously instead of, as would happen with simple elasticity, all the air going into whichever went first. And function in a diversity of systems commonly ties to the degree of hydrophobicity of surfaces, including some that have exceeded old textbook values,

so-called superhydrophobic ones.

The second viewpoint consists of a list of what one might call biopotentous physical variables. The list given in Table 1 is a heterogeneous one, with some items representing lumpings of what are multidimensional factors; it mainly gives a sense of the scope of the relevant. I assert merely that for each variable I can cite at least one biological situation for which it matters—with no claim of completeness. (Obvious universals such as force, temperature, and length have been omitted, and I have not fully plumbed the range of thermodynamic properties.)

Now one should not contrive a course based too heavily on external desiderata—pedagogical effectiveness requires some logical development, a “story-line” if you will. And packing in too much material, especially diverse material, assures ineffectiveness. But I do feel that two of these external considerations ought to be borne in mind. First, the physics that matters in the life sciences not only does not coincide with biophysics, it extends beyond the traditional purview of departments of physics. Electrical phenomena depend on conduction in aqueous solutions, not copper wires. Solids approach rigidity only where special conditions require it; otherwise, meaning normally, a whole complex of material properties comes into play. And so on. But the life science students you teach will rarely

**Table 1. A listing of biopotentous physical variables**

Acoustic transmissivity/ attenuation	Hydrophobicity/contact angle	Sound intensity
Angle of repose (maximum)	Illumination spectrum	Speed of sound transmission
Compressive modulus	Index of refraction	Static friction
Compressive strength	Kinetic friction	Storage/loss moduli
Conductivity/resistivity, electrical	Kolmogorov length	Strength (maximum stress)
Damping factor	Lift coefficient	Strain energy storage
Density	Lift-to-drag ratio	Surface tension
Dielectric constant	Luminous flux	Thermal conductivity
Diffusion constant	Magnetic flux	Thermal expansion coefficient
Drag coefficient	Magnetic susceptibility	Torsional modulus
Electric charge	Optical density/ transmissivity	Torsional stiffness
Extensibility (maximum strain)	Osmolarity	Turbidity
Flexural stiffness	Photoperiod	Turbulent intensity
Fluorescent efficiency (quantum yield)	Poisson's ratio	Viscosity
Gravitational constant	Porosity	Vorticity
Gravitational direction	Pressure	Wavelength, electromagnetic
Hardness	Radiant emissivity at relevant wavelengths	Wavelength, sound
Heat capacity	Radioactivity (several variables)	Wavelength, liquid-gas interfaces
Heat of combustion	Resilience	Work of fracture
Heat of fusion	Resonant frequency	Young's modulus of elasticity
Heat of vaporization	Retardation time	
Humidity (and dew point)	Shear modulus	



be exposed to much physical chemistry and even less often to mechanical engineering—so you are their last chance. Second, traditional courses emphasize the simple, regular, and law-abiding, in the process transmitting the misleading view that our science deals with an extremely orderly world. In biology we pick trivial characters that happen to be the rare observable features that follow the Mendelian laws; in physics you avoid the untidiness of fluids and real materials as part of an apparently analogous imperative.

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*on Biophysics and Bio-engineering at the March IPLS conference and the June Gordon Conference.*

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## Vision and change in introductory physics

*S. G. J. Mochrie, Yale University*

When biology and premedical students arrive in introductory physics courses, they are often skeptical about the relevance of physics and mathematics to their academic and professional goals. Often, students' skepticism is reinforced by the topics presented in introductory physics, which generally owe more to tradition than to what is most scientifically important and/or relevant to biology. A destructive feedback loop can then result: low student interest leads to low student engagement, which leads to low student performance, which leads instructors to "dumb down" the course, which further reduces student interest, leading to even less engagement, and so on.

By contrast, biology is experiencing an ongoing transformation into a quantitative science as eloquently described by Bialek and Botstein in a seminal 2004 paper [1]:

"Dramatic advances in biological understanding, coupled with equally dramatic advances in experimental techniques and computational analyses, are transforming the science of biology. The emergence of new frontiers of research in functional genomics, molecular evolution, intra-cellular and dynamic imaging, systems neuroscience, complex diseases, and the system-level integration of signal-transduction and regulatory mechanisms require an ever-larger fraction of biologists to confront deeply quantitative issues that connect to ideas from the more mathematical sciences."

Biology departments are now increasingly hiring faculty with physics backgrounds, and biological physics is now a major subfield of physics, represented in physics departments across the country and in the APS. In recognition of this new biology, a number of reports [2, 3, 4, 5] have highlighted the increasing importance of quantitative skills for students who are planning biomedical careers, and the need to modify and augment undergraduate biology and premedical education accordingly. Recently, the biology community, in *Vision and Change in Undergraduate Biology Education (VCUBE)*, has specified a number of core competencies that all undergraduate biology students should possess [4]. These competencies and examples of how each competency might be demonstrated in practice are summarized in VCUBE's Table 2.1, reproduced here as Table 1 (on the following page).

Inspection of Table 1 reveals that undergraduate biology education in the twenty-first century must embrace quantitative and mathematical approaches. Remarkably, many of the specified competencies are those that physicists seek for students to acquire in physics classes. In this context, the two-semester Introductory Physics for Life Sciences (IPLS) sequence, currently required for premedical students and biological science majors, presents a natural platform where these students could encounter quantitative and mathematical descriptions of biological and

physiological phenomena for the first time. Where better than IPLS to first develop problem-solving strategies? Where better than IPLS to first develop the ability to use quantitative reasoning? Where better than IPLS to start developing the ability to use modeling and simulation? Where better than IPLS to start developing the ability to apply physical laws to biological dynamics? Where better than IPLS to start developing the ability to incorporate stochasticity into biological models? Indeed, VCUBE can be read by physicists as a call to transform IPLS into an engaging and exciting subject that is appreciated as essential to every biologist's undergraduate education, in striking contrast to biology students' current preconceptions. If physics departments ignore this coming change in the nature of undergraduate biology, biology students will nevertheless have to acquire the required competencies. It is then possible to envision biology departments replacing their physics requirements with "quantitative biology" requirements, taught outside of physics, with ensuing negative consequences for physics departments.

Now in its fifth year, we have developed and taught the first semester of a calculus-based IPLS class at Yale, that re-imagines the introductory physics syllabus to effectively channel a number of VCUBE's competencies via a selection of biologically and medically relevant topics. This class is one of four introductory physics classes offered at Yale. The others comprise a course at a similar overall mathematical level, that follows a traditional syllabus, and two higher-level courses aimed at physics majors-to-be. Since 2010, approximately 580 students have taken IPLS. 66% are female; 34% are male. They are ethnically diverse: 40% self-identify as white, 60% self-identify as non-white, including significant numbers of students from groups underrepresented in STEM disciplines (e.g. 10% African American or African and 10% Hispanic). Most arrive possessing considerable biological and chemical sophistication, as a result of prior biology and chemistry classes. Their mathematical skills, however, are rusty, but improve tremendously over the course of the year. More than 80% identify themselves as premedical students. In many cases, they are involved in biological or biomedical research, and in medically-related volunteer work. After graduation, many go on to highly-ranked medical and graduate schools. All of them take the class in order to fulfill the physics requirement for medical school and/or the physics requirement of their major. It is the final physics course that they will ever take, and so there is no rationale to postpone compelling material for later.

The first part of the course is a traditional treatment of kinematics, Newtonian mechanics (excluding rotational dynamics), and energy conservation, although we follow recent advice [6, 7] to include a careful discussion of binding energies. We rely on this material in a number of subsequent modules. These later modules, however, deviate significantly from a traditional syllabus.

Core Competency	Ability to apply the process of science	Ability to use quantitative reasoning	Ability to use modeling and simulation	Ability to tap into the interdisciplinary nature of science	Ability to communicate and collaborate with other disciplines	Ability to understand the relationship between science and society
Instantiation of ability in disciplinary practice	Biology is an evidence-based discipline	Biology relies on applications of quantitative analysis and mathematical reasoning	Biology focuses on the study of complex systems	Biology is an interdisciplinary science	Biology is a collaborative scientific discipline	Biology is conducted in a societal context
Demonstration of competency in practice	Design scientific process to understand living systems	Apply quantitative analysis to interpret biological data	Use mathematical modeling and simulation tools to describe living systems	Apply concepts from other sciences to interpret biological phenomena	Communicate biological concepts and interpretations to scientists in other disciplines	Identify social and historical dimensions of biology practice
Examples of core competencies applied to biology practice	Observational strategies Hypothesis testing Experimental design Evaluation of experimental evidence Developing problem-solving strategies	Developing and interpreting graphs Applying statistical methods to diverse data Mathematical modeling Managing and analyzing large data sets	Computational modeling of dynamic systems Applying informatics tools Managing and analyzing large data sets Incorporating stochasticity into biological models	Applying physical laws to biological dynamics Chemistry of molecules and biological systems Applying imaging technologies	Scientific writing Explaining scientific concepts to different audiences Team participation Collaborating across disciplines Cross-cultural awareness	Evaluating the relevance of social contexts to biological problems Developing biological applications to solve societal problems Evaluating ethical implications of biological research

Table 1: Table 2.1 of the AAAS’s 2011 Vision and Change in Undergraduate Biology Education (VCUBE).

We include a module on random walks to introduce students to the ubiquitous role of stochastic processes in biology. Our first random walk example is Brownian motion. We point out that Albert Einstein’s theory of Brownian motion and its subsequent confirmation by Jean Perrin were pivotal in finally convincing skeptics at the outset of the twentieth century that atoms and molecules really exist. It is remarkable that biology works in spite of Brownian motion. What is truly amazing is that sometimes biology works because of Brownian motion, as the class sees when we discuss Brownian ratchets [8]. We also discuss that, in evolutionary biology, a random walk has a central role in evolution via “genetic drift”. Genetic drift is the random process – it can be conceived as a random walk – by which “neutral” mutations, that offer no selective (dis)advantage, become fixed in a population, leading the population’s genome to evolve, or drift, away from its initial state, over many generations, as such neutral mutations accumulate. Importantly, the

theoretical underpinnings of phylogenetic analyses, that seek to establish evolutionary relationships among organisms and populations of a single organism critically rely on the properties of evolution by genetic drift.

Starting from Newton’s laws, our module on fluid mechanics focuses on laminar fluid flow in microfluidic devices and especially on the flow of blood through the circulatory system. We discuss atherosclerosis and how you blush. We also discuss fluid flows in fluid circuits [9], which is precisely analogous to current flows in electrical circuits. The module concludes with a discussion of the principles that underlie the physiology of your circulatory system (Murray’s Law), which demonstrates how the physics of viscous liquid friction plausibly has determined human physiology.

A final example that stands outside usual introductory physics

is our module on rates of change, which focuses on how a number of interesting processes can be modeled mathematically. Several disparate processes are described by similar equations. We are thus able to point out that the solutions and understanding gained in one case can be transferred to another. When colleagues first hear our topics, some complain: “that’s not physics.” Our riposte is that the equations that describe the early time course of HIV viral load in an individual patient following infection can be re-interpreted to describe an atomic explosion; and the equations that describe the occurrence of retinoblastoma – the most common childhood eye cancer – that results from somatic mutations are formally identical to equations that describe the number of a particular species of radioactive nuclei in a certain (medically-relevant) radioactive decay chain. We explain these applications and point out their connections in the course of the module. The medical bona fides of these examples are compelling: The mathematical modeling of HIV progression in an individual was important in the development of HIV treatments [10, 11, 12]; and the age-dependence of retinoblastoma onset lead to the hypothesis of tumor suppressor genes, which proved a tremendously important step in understanding cancer [13]. The biomedical authenticity of these examples provide a powerful lesson for our students. In this year of Ebola, our upcoming discussion of the progression of disease through a population via the SIR model [14] is tragically topical. This module also well positions us to discuss genetic circuits in the second semester [15].

Of course, a key issue for any IPLS class is the level of mathematics to use and the mathematical approach to take. Because all students in the class at Yale would previously have taken a first course in calculus, our starting point was a calculus-based class. We also decided to emphasize the use of Wolfram Alpha (<http://www.wolframalpha.com>) to facilitate mathematical manipulations of all sorts. Using Wolfram Alpha empowers students to carry out more sophisticated mathematics than otherwise. Beyond calculus, the mathematics that we employ is dictated by the topics that we seek to treat, i.e. we carried out “backwards design” [16]. We also include a number of simulations and calculations, implemented as Wolfram Demonstrations, which students can conveniently run in their web browsers and interact with via sliders. To discuss Brownian motion and statistical mechanics, we incorporate probability and random walks; to discuss steady-state diffusion and laminar fluid flow, we use simple differential equations, which we solve by direct substitution. Our module on mathematical modeling leads us to simple linear algebra. The incorporation of eigenvalues and eigenvectors in IPLS might initially seem ambitious, but, in fact, the technical demands on the students are that they be able to take a derivative of an exponential function of time, and that they then be able to solve two simultaneous equations in two variables to find the eigenvalues and eigenvectors, both of which they are able to do. On the other hand, we avoid multi-dimensional integrals, removing a source of significant discomfort for these students. At the end of the semester, we carry out an anonymous survey to ascertain students’ opinions. Of 366

respondents in 2011-2013, when asked about the level of mathematics, it was “way too advanced for my current ability” for just 2% of the students, “advanced but manageable” for 19%, “about equal to my current ability” for 47%, “below my current ability” for 24%, and “well-below my current ability” for 8%. Concerning the level of calculus specifically, it is “too high” for 19%, “just right” for 65%, and “too low” for 16% of 474 respondents in 2010-2013. In view of these responses, we judge that the mathematics we use is appropriate.

Our approach stands in contrast to the point of view that IPLS should conform to a perceived difference in culture between the physical sciences and the life sciences, namely that the life sciences have generally not embraced mathematics and quantitative analyses, in contrast to the physical sciences. Instead, our view is that future biologists will be well-served by a version of IPLS that seeks to meaningfully contribute to closing the mathematical and quantitative gap between physical and life science students. Of course, because of varying student interests, motivations, and abilities, there cannot and should not be a one-size-fits-all IPLS course, suitable for every situation. However, we believe there is a place for a course like ours at many institutions across the country. As biology faculty introduce new upper-level biology electives and major tracks that demand mathematical sophistication, in quantitative and systems biology, for example, or as they incorporate more mathematical elements into upper-level classes in ecology, epidemiology, or evolutionary biology, a class like ours will serve as an essential prerequisite.

We close with a few anonymous quotes from biology and pre-medical students about IPLS (PHYS 170):

“I just want to thank you for making physics a lot of fun for me. It means a lot. I am from a traditional Indian education system, that emphasized on learning a science in order to get into a college, and not for the pure pleasure of it all. As a result, I developed a huge aversion to physics and really delayed the taking of this class. However, my views have changed a lot. I am fascinated by this subject and the amount of scope it has. Thank you for making that possible.”

“Thank you for an awesome semester! I can’t believe I’d ever say this but I actually like physics now. Thank you for showing me how cool it can be.”

“Thank you for class this semester. It has been really great to make links between all of my science courses at Yale, and in many ways (and I am shy to admit this, but against my expectations) PHYS 170 provided the platform for just that.”

“I was skeptical about 170 at first and I mainly chose it over 180 because I didn’t have the multivariable calculus background needed to take 181. You have really turned me around. The first third of this class was pretty standard physics (mechanics, momentum), but the latter part of the semester really tied

in to biological phenomena. Obviously, the models were oversimplifications of biological systems but they added another layer of understanding to concepts that I previously took as a given. The idea of diffusion as explained using probability is not something I would have ever thought of on my own. I doubt I would find that in a biology or biochemistry text- book either. I took biochemistry (MBB300) at the same time as 170 this semester and I was pleasantly surprised to see the Michaelis-Menten equation derived via different methods in both classes. It is wonderful to see the same ideas presented on a biological, chemical, and physical level.”

“This class is amazing if you genuinely like biology. If you’re a biology major because you’re premed or whatever you might not like it as much, but if you really care about biology this class is great. Physics is the future of biology, and this class gives you a taste of all the cool ways we can use quantitative techniques to describe living systems.”

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# Section on Teacher Preparation

## Teacher Preparation Section

*Alma Robinson, Virginia Tech*

This edition of the Teacher Preparation Section features four articles highlighting successful collaborations between physics departments and schools of education.

Julie Antilla-Garza and Stamatis Vokos of Seattle Pacific University (SPU) describe some of the challenges and benefits of establishing a strong physics-education partnership in a physics teacher preparation program as outlined by the National Task Force on Teacher Education in Physics (T-TEP). They discuss key aspects of SPU's collaborative efforts including the development of a Center for Physics Teacher Education and a new undergraduate pathway towards physics and math licensure.

Andrew Duffy and Peter Garik explain how the partnership between the Department of Physics and School of Education at Boston University (BU) has grown to include collaborations with other science departments through the Boston University Noyce Urban Science Scholarship and Learning Assistant programs. They also expound on the connections between their strong PhysTEC project and their thriving Improving the Teaching of Physics (Project ITOP) program.

Cody Sandifer, Ron Hermann, and David Vocke explain how the close relationships between physics and education faculty at Towson University have led to reforming the teacher preparation program, co-advising pre-service teachers, sharing resources across departments, and supporting their mutual students through programs such as PhysTEC, Noyce Scholarships, and UTeach. Because Towson University is one of the few insti-

tutions that has education faculty in the content departments, as well as a university-wide Teacher Education Executive Board, the institution inherently encourages these collaborations.

Chuhe Kwon of California State University Long Beach (CSULB) explains how a key partner in education can make all the difference in establishing and maintaining a successful collaboration between physics and education. She describes the characteristics of an ideal faculty partner in education and demonstrates the ways in which Dr. Laura Henriques, CSULB's collaborator in education, has helped to improve physics teacher preparation.

PhysTEC will hold its yearly conference, the nation's largest meeting dedicated to physics teacher education, in Seattle, WA from February 5th- 7th. The theme of this year's conference is Building Thriving Programs and will be held jointly with the Building a Thriving Undergraduate Physics Program Workshop. More information can be found on the PhysTEC website (<http://www.phystec.org/>).

As the PhysTEC Teacher in Residence at Virginia Tech, I've had the great pleasure of learning about the incredible physics teacher preparation programs around the country and meeting some of the dedicated educators who make these programs possible. I am delighted to serve as the new editor of the Teacher Preparation Section to help bring their stories to you. Finally, I would like to thank John Stewart for his guidance in helping me make this transition.

## Benefits of collaboration between physics departments and schools of education

*Julie Antilla-Garza, Chair of Undergraduate Teacher Education, Seattle Pacific University*  
*Stamatis Vokos, Professor of Physics, Seattle Pacific University*

In *Transforming the Preparation of Physics Teachers: A Call to Action*, the National Task Force on Teacher Education in Physics (T-TEP) presented the robust finding<sup>1</sup> that “[f]ew institutions demonstrate strong collaboration between physics departments and schools of education.” The significance of this finding lies partly in the realization that this statement is unsurprisingly consistent with the personal experience of most physics faculty. In the preparation of physics teachers, the usual approach is based on the stance that physics and education are *non-overlapping magisteria*<sup>2</sup>. Prospective teachers learn their physics-y stuff in physics courses and then take education courses (including science methods courses), which are aimed at preparing students to teach *undifferentiated* “science” using general pedagogical strategies. And never the twain do meet—except of course in the unprepared teacher’s classroom. On a daily basis.

There are many reasons for this separation. First, most often physics and education belong to different administrative units and therefore have different reward structures within the university. Second, the corresponding guilds impose different methodologies, different technical language,<sup>3</sup> and different lenses for analysis. Most significantly maybe, cross-campus collaborations require clear and compelling benefits for all partners. Absent a vision for what such benefits are or even might look like, dreams of collaboration are soon thwarted by vast increases in institutional entropy. To help give some shape to this vision, this article aims to highlight examples of productive collaboration between a physics department and a school of education.

We stress that the collaborative efforts described below are not good-for-the-soul service activities. Their core is located in the desire to prepare competent teachers of physics who can help students learn to think like physicists and to inspire them to seek to understand the world around us in a deeper sense. A physics department cannot do so by itself and neither can a school of education. The separation between content knowledge and

pedagogy has profoundly negative implications for the physics enterprise. To quote the T-TEP report again, because “[p]hysics teacher education programs do little to develop the physics-specific pedagogical expertise of teachers” [Finding 5], T-TEP recommends that “[p]hysics teacher preparation programs should provide teacher candidates with extensive physics-specific pedagogical training and physics-specific clinical experiences. To accomplish this goal, physics and education faculty have to work closely together and leverage each other’s professional expertise.

Collaboration between physics and education faculty and staff at Seattle Pacific University goes back ten years. (See, for instance, articles in the Forum on Education Newsletter probing different aspects of the collaboration.<sup>4,5</sup>) However, as Melba Phillips quipped, “The problem with physics education problems is that they don’t stay solved.” The departure of two key figures who had played a major role in being the “glue” between physics and education, one in the physics department and one in the School of Education, brought about a slowdown in the common work. This situation changed just prior to the start of the school year in 2013 with an invitation from the physics department to the chairs and deans of the education departments into a conversation about strengthening cross-college partnerships in an effort to better the teacher preparation programs in the sciences. In October the physics faculty met with the chair of the undergraduate teacher education program to discuss current programs that support physics majors seeking a teaching certificate, and by mid-November representatives from the physics department, the undergraduate teacher education program, and the teacher certification program initiated a series of meetings to audit the course requirements in the undergraduate physics teacher preparation pathway.

The certification staff provided expert knowledge, research, and resources regarding graduation and course load requirements throughout December and January as the physics and education faculty met and corresponded by email. Together, this cross-section of faculty and staff from cross-campus departments constructed proposals for co-listing physics and education courses and applying certification prerequisites toward university required curriculum credits. This resulted in a proposal

<sup>1</sup> Finding 4

<sup>2</sup> With apologies to Stephen Jay Gould, who introduced the term in a completely different setting. The analogy with his context is apt, though the characterization is incorrect in both settings.

<sup>3</sup> The fact that educational terminology sounds superficially familiar to the untrained ear can be an obstacle for communication. The term “self-adjoint density matrix” does not evoke everyday images whereas “cognitive apprenticeship” does. The dean of a College of Arts and Sciences, a geographer, told once a junior physics education researcher that his research articles on student understanding of special relativity were not as exciting as Brian Greene’s *The Elegant Universe*.

<sup>4</sup> Eleanor Close, “Leveraging Corporate Support for Science Education Reform at Seattle Pacific University,” <http://www.aps.org/units/fed/newsletters/summer2007/close.html>

<sup>5</sup> Lane Seeley and Stamatis Vokos, “Creating and Sustaining a Teaching and Learning Professional Community at Seattle Pacific University,” <http://www.aps.org/units/fed/newsletters/summer2006/seattlepacific.html>

for a new pathway leading to a physics major with physics and math endorsements for undergraduate students.

In April of 2014, the physics professor who initiated the collaboration between the physics department and the school of education launched a second round of conversational meetings on physics teacher certification at Seattle Pacific University. Over the summer he worked with a small cohort of writers, and by September of this year, he challenged the faculty and deans in both the school of education and the physics department, as well as university administration, to work together to create a program that graduates beginning teachers “who have the research-informed disciplinary preparation and the discipline-specific pedagogical preparation to engage students in meaningful physics learning.”

As the 2014-2015 school year begins, both the undergraduate teacher education and the physics programs support the well-established Learning Assistant program designed to give students interested in teaching a hands-on leadership experience inside a physics classroom. Both programs support the proposals submitted at the university level to maximize the contribution each course makes toward graduation requirements. They both have

their co-listed secondary methods course updated and ready for student advisement. And perhaps most importantly, the faculty and staff in these cross-campus programs have committed to continue working together to help develop a distributed Center for Physics Teacher Education to produce more and better-prepared physics teachers.

As stated above, these collaborative efforts between the physics department and the school of education at Seattle Pacific University were not good-for-the-soul service activities. They were initiated with the belief, and they continue under the consensus that, together we have the obligation and the privilege to prepare competent physics teachers.

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*Julie Antilla-Garza is chair of undergraduate teacher education and an assistant professor at Seattle Pacific University. She worked in public schools for 16 years as a teacher and principal before earning her PhD and joining the SPU faculty.*

## Collaboration fosters physics teacher preparation at Boston University

*Andrew Duffy (Department of Physics) and Peter Garik (School of Education), Boston University*

For the past ten years, the Department of Physics and the School of Education at Boston University have worked together developing programs for pre-service and in-service physics teacher development. This shared interest in physics teacher preparation dates back to the inception of the No Child Left Behind legislation and the adoption of a Physics First curriculum by the Boston Public Schools (BPS) in 2004. The number of “highly qualified” physics teachers was not nearly enough to satisfy the required BPS classroom demand. To address this problem, two physicists (Andrew Duffy in the Department of Physics and Peter Garik in the School of Education) designed the Improving the Teaching of Physics (ITOP) sequence of courses to serve as professional development (PD) for teachers who had to teach outside their content field and wanted to earn licensure in physics.

This shared interest in physics teacher PD led to membership by the Department of Physics in the Physics Teacher Education Coalition (PhysTEC), and the adoption and adaptation of PhysTEC supported programs at Boston University (BU). The outcome has been a collaborative effort by the two units at BU on physics teacher recruitment, preparation, and professional development. What was initially a collaboration between Physics and Education has now led to productive collaborations with other science programs at BU, including Biology, Chemistry, Engineering, and Neuroscience. These interlocking efforts include:

- **Improving the Teaching of Physics (Project ITOP).** The initial collaborative effort has continued

(<http://physics.bu.edu/teachers>). The ITOP program consists of ten two-credit graduate-level courses that combine physics, the conceptual history of physics, and readings from the Physics Education Research (PER) literature. Originally designed for teachers who did not have a strong background in physics, the courses have attracted teachers with a variety of backgrounds, and are also taken by Masters of Arts in Teaching (MAT) students. Well over 100 teachers from all over Massachusetts have taken at least one ITOP class. A key component of the program is that for part-time students, the courses are offered at a special tuition rate affordable for in-service teachers.

- **Learning Assistants:** The Learning Assistant (LA) program (<http://laprogram.colorado.edu/>) was first adopted at BU after faculty members attended a PhysTEC sponsored workshop at the University of Colorado-Boulder. First adopted by the Department of Chemistry, the Departments of Biology and Physics also initiated LA programs the following semester. Since then, there have been over 200 LAs who have taken the LA pedagogy course offered by the School of Education (SED), and worked in science and engineering courses. A motivation for SED to support the LA program was the prospect of science and engineering majors discovering that they enjoyed teaching, and then choosing to earn teacher licensure. Although the conversion rate has been small, it is nevertheless meaningful. This year two Physics LAs applied for a Noyce Scholar-



ship, and a former LA is in the Physics MAT Program. Most importantly, the LA Program has enhanced physics instruction, as well as instruction in other science departments. A collateral effect has been the initiation of a field placement in local schools for science and engineering students interested in a high school teaching experience.

The engagement by Boston University's science departments and SED in the LA Program led to BU's hosting the first Northeast Regional Learning Assistant Workshop (NERLAW) in March, 2014.

- **Comprehensive PhysTEC (Physics Teacher Education Coalition) grant:** The objective of PhysTEC grants is the transformation of a Department of Physics into one supportive of the preparation of physics teachers and supportive of the use of research-based methods for physics instruction. At BU, the grant has funded a Physics Teacher in Residence (TIR) with an appointment in the Physics Department for the past three years. Through commitments by the Department of Physics, the School of Education, and the Provost's Office, the TIR position will continue for the next three years. The TIR supports the undergraduate education program, but principally works to recruit interested physics students (undergraduate and graduate) into a career in teaching. At BU, this has included encouraging LAs to continue their development as teachers; advising physics graduate students who are interested in teaching; advocating for new physics programs to better prepare future teachers; and providing new Noyce Scholar physics teachers with mentoring support during their induction years. Another component of the TIR's work is interaction with in-service physics teachers. At BU, the TIR has organized a Physics Teacher Network (PTN) with regular meetings of Greater Boston physics teachers to discuss teaching and learning in their classrooms. These meetings attract potential ITOP participants, as well as ITOP alums and career changers interested in becoming physics teachers. Some of the ITOP teachers subsequently act as mentors for our Physics MAT students, and some of the career changers enroll in our MAT Program.
- **Noyce Scholarship Program in Science:** A capstone to the joint efforts by the Department of Physics and the School of Education is the preparation of physics teachers to work in high need districts where good physics instruc-

tion is very much needed. The Boston University Noyce Urban Science Scholarship (Project BoNUSS) program allows us to provide scholarship incentive for BU physics students we recruit for teaching, as well as financial support for external applicants to our program. Project BoNUSS has led to changes in the program offered by SED, such as an emphasis on providing equitable science education for diverse populations, and helped BU achieve a significant increase in the number of physics teacher graduates. Prior to the programs above, on average the number of physics teachers prepared at BU was less than one per year. This year we graduated three Noyce Scholars as physics teachers, two of whom were recruited from BU; our 2015 cohort of physics teachers includes four Noyce Scholars and two non-Noyce MATs of which three were recruited from within BU, and one who came because of Project ITOP.

From the initial Project ITOP collaboration between the Department of Physics and SED, an interlocking system of programs has developed that has transformed physics education (and science education more generally) at Boston University. The programs have depended on the investment of efforts by personnel from multiple departments. We are grateful for the time, effort, and advice received from Manher Jariwala, Bennett Goldberg (BU's Director of STEM Education Initiatives), Mark Greenman (TIR 2012 – present), and Juliet Jenkins (TIR 2011-12) in Physics; Kathryn Spilios in Biology; Binyomin Abrams, Natalya Bassina, Dan Dill, Nic Hammond, and Adam Moser in Chemistry; and Donald DeRosa, Nicholas Gross, and Meredith Knight in Education. We are also grateful for the advice and support from PhysTEC, without whose stimulus most of our programs would not have developed.

*Andrew Duffy is a Master Lecturer in Physics, is currently teaching algebra-based introductory physics in a studio classroom, and has a longstanding interest in applying new technologies to teaching and learning.*

*Peter Garik, Clinical Associate Professor in the School of Education, is a physicist (Cornell, 1981) who has worked in science education for the past 25 years. He is an instructor for the LA pedagogy course and PI for the Boston University Noyce Scholar Science Program.*

## Towson University Continues its Physics and Education Partnership to Prepare Future Teachers Effectively

*Cody Sandifer, Ronald S. Hermann, and David Vocke, Towson University*

At Towson University, there have been frequent, productive interactions between the Department of Physics, Astronomy and Geosciences (PAGS) and the College of Education (COE) for at least fifteen years. These interactions were driven by everyday program logistics, programmatic reforms, and concerns for specific students, all of which helped faculty from both colleges to form professional and personal relationships.

To provide a context for these interactions, it is important to note that Towson University is one of the few academic institutions nationwide to house a significant number of education faculty in its content departments. The PAGS department has twenty faculty, including six science educators: four specializing in elementary education, one specializing in the middle grades, and one specializing in high school. To effectively prepare undergraduate pre-service teachers, PAGS science educators work closely with faculty in various units within the COE: the Departments of Early Childhood Education, Elementary Education, and Secondary Education and the Center for Professional Practice. The director and staff of the Center for Professional Practice (CPP) are responsible for securing school placements for all educational field experiences, such as student teaching.

One hallmark of the collaboration between PAGS faculty and those of the Department of Secondary Education (SCED) is the co-advising of students. Undergraduate pre-service physics teachers are physics majors with a secondary education concentration, and they enroll in numerous education courses. The PAGS secondary education advisor (Ron Hermann) discusses the teaching of physics, physics coursework and related internships and research with his education advisees. The SCED advisors, like David Vocke, ensure that physics teacher candidates fulfill program requirements for attaining teacher licensure. This collaboration has resulted in a collegial relationship between PAGS and SCED.

A critical experience for the future teachers in our program is the capstone student teaching internship, in which interns teach half the semester at a middle school and half the semester at a high school. Working relationships between PAGS and SCED faculty ensure that student teachers receive the support they need during this challenging transition from pre-service to in-service teachers. For instance, PAGS and SCED faculty might discuss specific students prior to their field placements to share areas of strength or concern.

SCED faculty who serve as Professional Development School (PDS) liaisons are responsible for placing student teaching interns with qualified mentors in the local PDSs. However, PAGS is responsible for providing university supervisors for these interns. Secondary specialist Ron Hermann serves as one of these

supervisors, observing the interns a minimum of three times at each middle and high school placement. Interns also participate in a student teaching seminar and complete a project that is designed to provide evidence of student learning at their school site based on student learning outcomes (SLO) they develop with their mentor and a supervising SCED faculty member. The seminar is instrumental in assisting interns as they complete their Interstate Teacher Assessment and Support Consortium (InTASC)-anchored portfolio, a key requirement for graduation. SCED faculty are responsible for assessing the strength of the portfolio and reporting the quantitative scores.

The Teacher Education Executive Board (TEEB) is another body that meets regularly (once per month) to share information across departments. TEEB is a university-level committee that consists of the Dean, Associate Dean and Assistant Dean of the College of Education and one representative from every department on campus that is involved in teacher preparation. As with many formal meetings, TEEB is also a place where informal side discussions and water cooler talk happens between PAGS and SCED faculty.

The relationship between faculty in both departments has carried over to external grant submissions for programs that affect our shared students, and many of these jointly submitted grants have been funded. These programs, such as the Phys-TEC, Noyce Scholarship, and UTeach programs, involve senior personnel from both colleges and have helped maintain a true partnership.

An unexpected benefit of this partnership is that tenure-track faculty from PAGS feel comfortable enough with SCED faculty to discuss promotion and tenure issues. When deciding when to submit his promotion and tenure documents to the College of Science and Mathematics, for example, Ron Hermann wanted an “outside” perspective and sought the advice of the SCED department chair. The chair was able to draw upon his extensive knowledge of the evaluation process to provide candid information that helped Dr. Hermann decide when to go up for tenure.

The collaboration between the PAGS and SCED departments has also solved ongoing problems related to Towson’s secondary physics teacher education program. In the past, due to a lack of time and resources in the CPP, new mentor teachers were often not sufficiently oriented to the logistics and goals of student teaching supervision. Due to the positive relationship between the COE and the PAGS, however, PAGS faculty were able to step in to provide paid orientation workshops for new physics mentor teachers, with the funding provided by external grants.

An ongoing issue that still needs to be addressed is that interns

tend to be placed in physics classrooms that are traditionally taught, whereas Towson University faculty prefer interns to be placed in classrooms that encourage a greater degree of inquiry and/or active learning. We are optimistic that our strong ties with the SCED department and CPP can provide a collaborative solution to this issue. Although negotiations in this area are still continuing, PAGES faculty are hopeful that they will participate in the selection of mentor teachers that align philosophically with the pedagogical goals of the secondary education and physics programs.

In conclusion, we are happy to report that there has been a natural collaboration between the COE and the Fisher College of Science and Mathematics (FCSM) for many years. Faculty in both colleges have worked diligently to prepare the highest quality physics teachers possible by improving secondary education coursework, advising, and student teaching. PAGES faculty could not have implemented these programmatic changes on their own, and necessarily needed the expertise of COE faculty to be successful. In the future, PAGES will continue to provide future teachers the best possible education with our partners in the COE.



*Cody Sandifer (left) and Ron Hermann (center) of the Department of Physics, Astronomy and Geosciences partner with Dave Vocke (right) of the Department of Secondary Education to prepare physics teachers.*

*Cody Sandifer is a Professor of Science Education and Ronald S. Hermann is an Associate Professor of Science Education in the Department of Physics, Astronomy and Geoscience at Towson University.*

*David Vocke is a Professor of Education in the Department of Secondary Education at Towson University.*

## Establishing and Maintaining the Partnership with the School of Education

*Chuhe Kwon, California State University Long Beach*

While the number of high school students taking physics in the United States has been increasing rapidly, only 35% of high school physics teachers have a degree in physics or physics education [1]. Despite this severe, long-term shortage of qualified physics teachers, the Task Force on Teacher Education in Physics (T-TEP) reported that few physics departments and schools of education are engaged in the preparation of physics teachers, and physics teacher education programs in the U.S. produce few graduates [2]. Since 2001, the Physics Teacher Education Coalition (PhysTEC) has directly engaged physics departments in preparing physics teachers and provided funding to selected sites to develop national models to increase the number of highly qualified physics teachers. Unfortunately, building a robust partnership with the school of education is a challenge commonly faced by the PhysTEC sites. Because the California State University Long Beach (CSULB) PhysTEC project has built and maintained a very successful partnership, we hope to aid physics departments considering a partnership with the school of education by describing the key characteristics of our education faculty partner.

Secondary science teaching licensure is a post-baccalaureate program in California, and the science departments at California State University Long Beach (CSULB) have traditionally been detached from science teacher education. Prior to the PhysTEC grant, the Physics and Astronomy Department was no exception. Our physics BA degree designed for future sec-

ondary teachers graduated less than one student per year and the major advisors directed anyone interested in teaching to the single-subject credentialing advisor in the Science Education Department. CSULB is unique in that the Science Education Department, which is responsible for teaching science methods courses, resides in the College of Natural Sciences and Mathematics (CNSM). Since the Science Education and Physics departments are in the same college, we were able to quickly identify the perfect partner in the College of Education: Dr. Laura Henriques, the Chair of the Science Education Department. She brought practical knowledge of state licensure as well as experience working with pre- and in-service teachers, the College of Education, and the California State University system in science teacher education. A former high school physics teacher herself, she is a tireless advocate in making the CSULB PhysTEC activities relevant to pre- and in-service physics teachers.

By drawing upon our experiences, we have made a list of characteristics needed for a partner in the school of education. Firstly, the partner must have in-depth knowledge of state credentialing and have experience in implementing the licensure requirements at the university. Teaching licensure is governed strictly by the state, and the credentialing program in each institution has a history and tradition that need to be honored. An ideal candidate is an established faculty member respected both by the school of education and the physics department who



CSULB Physics Department mixer: Galen Pickett (Physics Co-PI), Laura Henriques, Kevin Dwyer (TIR) and Chuhee Kwon



California Science Teachers Association meeting. Katie Beck (TIR), Chuhee Kwon, and Laura Henriques.

can guide the PhysTEC project in the early years. At CSULB, PHYS 491 *Pedagogical Content Knowledge (PCK) in Physics* was developed and offered as an upper division elective in the physics department due to the difficulty of getting the course approved as a science methods course in the credentialing program. By not pursuing the credential curriculum process, we were able to design PHYS 491 as a true physics PCK course without credentialing restrictions. PHYS 491 was offered in the first semester of the grant (Fall 2010) and has now been taken by 37 students including future teachers, physics majors, physics and science education MS candidates, and in-service teachers. With Dr. Henriques' guidance, the CSULB PhysTEC project demonstrated an early commitment to improving physics teacher education.

Secondly, the partner in the school of education must have a passion for supporting high school physics teachers, preferably as a former high school physics teacher himself/herself. Because most high schools have a single physics teacher who teaches a mixture of physics, math, and other sciences, he/she is often professionally isolated, so having an education partner who understands the needs of those teachers is crucial.

In addition, a faculty member with an established connection to local high school science teachers is preferred. Dr. Henriques served as the secondary science credentialing coordinator for a decade and is still involved with some of the advising of prospective secondary teachers. She also keeps in touch with many alumni and teachers who participate in professional development opportunities, runs listservs for science teachers and the

Association of Future Science Educators club, and currently serves as the President of the California Science Teachers Association. By tapping into her personal connections with the local science teachers, we have gained a network of potential physics teachers to participate in our PhysTEC project.

Above all, a partner must share the common goals of the program. At CSULB, we wanted to improve our physics teacher education, to establish a robust pathway for physics majors to become teachers, and to build a physics teaching network involving in- and pre-service teachers, majors, and physics faculty. Our shared goals and mutual respect have helped the CSULB physics department establish and maintain a successful partnership with the school of education.

*Chuhee Kwon is Chair of the Department of Physics and Astronomy at California State University Long Beach. She was PI on the CSULB PhysTEC grant (2010 – 2013) and continues working to promote physics teacher education.*

1. Casey Langer Tesfaye and Susan White, High School Physics Teacher Preparation (American Institute of Physics, College Park, MD, 2012). Available at: <http://www.aip.org/statistics/reports/high-school-physics-teacher-preparation>.
2. Transforming the Preparation of Physics Teachers: A Call to Action. A Report by the Task Force on Teacher Education in Physics (T-TEP), (American Physical Society, 2012). <http://www.phystec.org/webdocs/2013TTEP.pdf>

## Browsing the Journals

Carl Mungan, *United States Naval Academy*, <mungan@usna.edu>

- The article “Birds on power lines” in the July 2014 issue of the *American Journal of Physics* (<http://scitation.aip.org/content/aapt/journal/ajp>) discusses three effects related to a bird contacting a single high-voltage power line: capacitive charge transfer to the “spherical” bird even if it stands on one foot, and currents in the bird between its two feet due to its finite resistance and to the ac phase difference along the wire. The August issue has a paper on page 764 that analyzes the path that a block takes when it is given a push at some angle (relative to the straight “down” direction) on a rough inclined plane. Particularly interesting is the case when the incline is small enough that the block eventually comes to rest. Finally, the September issue has a PER paper that shows that a group of South Korean high school physics students who solved an average of 2200 physics problems each did not perform significantly better on exams than those who solved comparatively few. It is not helpful to simply grind through a large number of problems, but instead some of the students’ time should be spent learning the bigger picture of physics concepts and frameworks.
- Page 349 of the September 2014 issue of *The Physics Teacher* (<http://scitation.aip.org/content/aapt/journal/tpt>) has a nice analysis (with convincing YouTube links) of why a heavy disk at the end of a rod is much easier to lift with one hand when the disk is spinning than when it is not. The October issue has one of my all-time favorite High School Photo Contest pictures on its cover. I only hope the young lady doing the “Orange Wave” did not choke on paint particles a few seconds after the camera snapped the portrayed shot. I thought the article about writing “Letters home as an alternative to lab reports” made a convincing case and I may try it in my own classes. William Layton surprised me on page 426 by showing that a light bulb on the input side of an isolation transformer will go out if a similar bulb on the output side is unscrewed from its socket. I was similarly amazed to read on page 428 that a tuning fork with one tine covered is louder than with it uncovered. Lastly, my whole family had a fun time constructing a closed loop from a single strip of paper that can lift a bucket of water when held by a single finger, purely by folding the strip in the manner explained on page 436.
- The July 2014 issue of *Physics Education* has an article that experimentally tests the Bernoulli equation for water flowing out of a jug on page 436. On page 390, the familiar problem of a ladder leaning against a wall is discussed, but this time with the floor smooth and the wall rough. Benacka has developed a new way to solve the Kepler problem without changing variables to  $u = 1/r$  in the July 2014 issue of the *European Journal of Physics* and presents an Excel spreadsheet to calculate the motion. Interesting articles in the September issue include measurement of the electric charge on a piece of Scotch tape pulled apart from another piece of tape, a simple derivation of the Boltzmann factor, and an analysis of a catenary without using the calculus of variations. Both journals are accessible at <http://iopscience.iop.org/journals>.
- Page 1455 of the September 2014 issue of the *Journal of Chemical Education* at <http://pubs.acs.org/toc/jceda8/91/9> has a simple derivation of shot noise in a photodiode or photomultiplier tube using the Poisson distribution.
- The March 2014 issue of the *Latin-American Journal of Physics Education* (<http://www.lajpe.org/>) presents a model fitted to experimental data for the eddy current damping of a magnet oscillating through a hole in a metal disk on page 109.
- Mazur’s group has published a study in *Physical Review Special Topics–Physics Education Research* at <http://journals.aps.org/prstper/pdf/10.1103/PhysRevSTPER.10.020113> about the times that students take to respond to clicker questions. Response times for correct answers are shorter than times for incorrect answers, suggesting that instructors should end the polling at around the 80% response rate to cut down on the number of random guesses biasing the overall histogram of results.
- Usually light pushes objects away due to the radiation pressure. Can it also attract them, creating an optical tractor beam? An article in *Physical Review Letters* suggests that it might, as a result of the ac Stark shifts, at <http://journals.aps.org/prl/abstract/10.1103/PhysRevLett.111.023601>.



## Web Watch

*Carl Mungan, United States Naval Academy, <mungan@usna.edu>*

- You may have heard about The Particle Adventure. Browse it on the web at <http://particleadventure.org/>.
- MathJax uses Javascript to enable you to display equations in webpages without installing anything. Learn about it at <http://www.mathjax.org/>.
- A collection of Flash animations illustrating physics concepts is at <http://faraday.physics.utoronto.ca/GeneralInterest/Harrison/Flash/>.
- The National High Magnetic Field Lab has educational resources devoted to E&M at <http://www.magnet.fsu.edu/education/tutorials/>.
- Slides is a site at <http://slides.com/> used to create, display, and share presentations online.
- The European Journal of Physics has started soliciting video abstracts from authors of selected papers as a novel way to increase their visibility. It remains to be seen whether the idea will catch on more broadly, but you can see the initial efforts at <http://iopscience.iop.org/0143-0807/videoabstracts>.
- Speaking of videos, the American Museum of Natural History has been preparing a new high-quality “science bulletin” once a month at <http://www.amnh.org/explore/science-bulletins> organized into the categories of astronomy, earth science, biology, and human medicine. Also see the Library of Congress materials about the solar system and beyond at <http://www.loc.gov/teachers/classroommaterials/primarysourcesets/understanding-the-cosmos/>.
- Periodically, we should all re-read Feynman. A transcript of his 1966 lecture “What is Science?” is at [http://www.fotuva.org/feynman/what\\_is\\_science.html](http://www.fotuva.org/feynman/what_is_science.html).
- Vanderbilt has an excellent overview of the flipped classroom at <http://cft.vanderbilt.edu/guides-sub-pages/flipping-the-classroom/>.
- Classical physics has lots of interesting topics for investigation. A few choice puzzles are reviewed at <http://arstechnica.com/science/2014/08/the-never-ending-conundrums-of-classical-physics/> with many reader comments.
- PhysPort at <https://www.physport.org/> is a new comPADRE website devoted to practical PER resources to support physics teaching and assessment.
- James Lincoln has been putting together a great set of video demonstrations and animations on YouTube at <https://www.youtube.com/channel/UCPFMJN19E7-ncgE9aBAIElg>. Another good collection of science videos is at <https://www.youtube.com/user/scishow>.
- Plus Magazine has some provocative math puzzles (some of which are based on physics) at <http://plus.maths.org/content/Puzzle>.
- ChemSpider at <http://www.chemspider.com/> is a useful site for providing properties, structure, images, and spectra of chemicals such as aspirin.
- EduTopia has an informative section devoted to integrating technology into the classroom at <http://www.edutopia.org/technology-integration>. Also see the recent newspaper article warning against the use of laptops to take notes in class at <http://www.washingtonpost.com/news/morning-mix/wp/2014/04/28/why-students-using-laptops-learn-less-in-class-even-when-they-really-are-taking-notes/>.
- Faculty Focus puts out excellent articles on higher ed teaching at <http://www.facultyfocus.com/> which you can sign up to receive by email.
- The pro-nuclear-energy camp makes a good case at <http://www.nuclearfaq.ca/>. The anti-nuclear position is also well articulated at <http://www.greenpeace.org/international/en/campaigns/nuclear/>.
- Finally, Open Science World has started writing some intriguing reports, with the current list of physics and math ones at [http://openscienceworld.com/category/math\\_physics/](http://openscienceworld.com/category/math_physics/).



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