



Forum on Education

American Physical Society

Summer 2010 Newsletter

Carl Mungan, 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

Larry Woolf

As the new chair, I am looking forward to an exciting year for the *Forum on Education* (FEEd). First and foremost, the success of the FEEd depends on the dedicated efforts of many talented individuals. I would like to acknowledge the hard work of the past Chair, Peter Collings, who did double duty by simultaneously chairing the APS *Committee on Education* during his tenure. I would also like to thank the members of the FEEd *Executive Committee* who recently completed their terms: Ernie Malamud, previous past chair, for 4 years of service in the chair line and a long history of service to the FEEd; G. Samuel Lightner, APS/AAPT Member at Large; and Olivia Castellini, APS Member-at-Large. I welcome the newly elected members: Vice-Chair Renee Diehl, APS/AAPT Member-at-Large Richard Peterson, and APS Member-at-Large Alice Churukian.

The FEEd continues to attract a large fraction of APS members. The only larger units are the *Forum on Industrial and Applied Physics*, the *Forum on Physics and Society*, and the *Division of Condensed Matter Physics*. Current FEEd membership is about 4700, nearly 10% of the APS.

At the March and April Meetings, the FEEd invited and focus sessions were very well attended. The FEEd organized or co-sponsored 14 invited sessions and 2 focus sessions on a wide range of educational topics. Thanks to all the session organizers and chairs for a fine job.

The FEEd website has seen numerous updates thanks to the efforts of our exemplary Secretary-Treasurer Bruce Mason. Bruce has recently updated the newsletter index (<http://www.aps.org/units/fed/newsletters/index.cfm>) and posted the *APS FEEd – AAPT Understanding on Joint Sessions*, as well as the *FEEd Executive Committee Calendar* (<http://www.aps.org/units/fed/governance/index.cfm>).

Initial planning is already underway for the 2011 March and April meetings. Chair-Elect Chandralekha Singh is the program chair, so if you have any suggestions for invited sessions, focus sessions, or workshops, please contact her at clsingh@pitt.edu.

As mentioned above, the FEEd depends on the efforts of many dedicated volunteers. Our newly elected Vice-Chair Renee Diehl is the chair of the nominating committee for the next slate of candidates. Please send suggestions for nominees, yourself included, to her at rdiehl@psu.edu. Next year, there will be open positions for the vice-chair, APS Member-at-Large, APS/AAPT Member-at-Large, and Secretary-Treasurer. For details about the responsibilities of each of these positions, see <http://www.aps.org/units/fed/governance/index.cfm>.

Another key role for the FEEd is the publication of 3 newsletters per year. Taking on the role of a newsletter editor is rewarding and interesting; members of the FEEd Executive Committee and former newsletter editors are available for assistance. A prime example of a dedicated volunteer is this issue's editor, Carl Mungan. This will be the second newsletter that Carl has either co-edited or edited. We are currently looking for an editor for the Spring 2011 issue as well as future newsletters. Contact me at Larry.Woolf@ga.com if you are interested.

Please consider writing an article or a letter to the editor for the newsletter. If you have an interesting program, experience, or strong opinion on any issue related to physics education, the newsletter is your outlet to communicate and possibly influence the physics education community. Contact a newsletter editor for further details at <http://www.aps.org/units/fed/newsletters/index.cfm>.

In my candidate statement, I discussed 3 areas that I wanted to focus on during my tenure in the chair line: (1) Providing an industrial physics perspective on undergraduate and graduate physics education; (2) Encouraging physicists to engage in the variety of roles that are available for improving science education; and (3) Publicizing and providing physics education research in a user friendly package to K–12 teachers. Some of these areas have been explored at recent meetings [1–2]. Please consider sharing your expertise in these areas, either via suggestions for invited or focus sessions, workshops, or newsletter articles.

References

[1] “Tutorial on Physics Careers in Industry and Government,” APS 2010 March Meeting, <<http://www.physics.oregonstate.edu/~tate/APS2010Tutorial>>.

[2] “Preparing Physics Students for Careers in Industry,” APS 2009 March Meeting, <<http://www.aps.org/units/fed/newsletters/summer2009/pittsburgh.cfm>>.

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Report from the Chair of the APS Committee on Education

Peter Collings

The *Committee on Education* (CoE) of the APS serves in an advisory role for the President, Executive Board, and APS Council regarding matters of physics education. It suggests and supervises initiatives that improve the cooperation between the educational community and other parts of the physics society. The *Committee on Education* and the *Forum on Education* work together, with the Committee directing its attention toward policy and the Forum concentrating on activities designed for APS members. The FEd Past Chair, Chair, and Chair-Elect are members of the Committee on Education.

One issue that CoE has been discussing is the preparation of and continuing support for physics teachers. The APS organizes Teachers' Days at some of its meetings, inviting local teachers to participate in a program that takes place at the meeting site. While there is good evidence that such a program is an effective one-time activity, it suffers from a lack of follow-through. CoE has recommended to APS that future Teachers' Days be organized by an educational institution with planning support from APS. The institution could then repeat these programs, hopefully establishing important connections to local physics teachers. Discussion is ongoing at APS about efforts to give this a try.

CoE has been following the work of the *Task Force on Teacher Education in Physics*, which will issue a report in the near future. The findings of this task force will address the

commitment to physics teacher preparation of physics departments, schools of education, academic institutions, professional societies, and funding agencies, as well as suggesting ways to increase the quality and capacity of programs for the professional development of physics teachers. CoE is working to ensure that this report will get widespread dissemination.

A successful *Conference for Directors of Graduate Studies* was held in 2008 and the findings of that conference can be downloaded from the graduate education page of the APS website at <http://www.aps.org/programs/education/graduate/conf2008/index.cfm>. CoE has endorsed these findings and has also decided to initiate planning for a second conference in 2012. CoE members Chandralekha Singh (at the University of Pittsburgh) and Marvin Marshak (at the University of Minnesota) are leading the process. Organizing and Steering Committees are being formed and NSF is being approached in hopes of securing funding. APS is already running a listserver for Directors of Graduate Studies.

Peter Collings (pcollin1@swarthmore.edu) is the Morris L. Clothier Professor of Physics in the Swarthmore College Department of Physics & Astronomy. His research specialties are liquid crystals, light scattering, self-assembly of biologically important molecules, and supramolecular chemistry. He is Past-Chair of the Forum on Education.

Using Web Videos as a Recruiting Tool

Robert Ehrlich

Currently there are an enormous number of free videos relating to physics on the web. One can, for example, find sites that feature physics lectures, as well as videos of physics demonstrations and simulations. The latter two collections are often useful for teaching, particularly if they involve simulations of systems for which live demos are not possible, or footage of live demos that are difficult or expensive to carry out. As one measure of the prevalence of physics videos on the popular site YouTube, a search for the keyword physics gave 14 300 hits—almost as many as a search on the keywords “Barak Obama” or “Lady Gaga,” for whom one video had 160 million views. It is difficult to know how reliable the physics figure is, since many of the most widely viewed videos with this keyword actually have little to do with physics, and conversely many videos that appear using other physics-related search terms, such as energy or astronomy, are perhaps not included in those 14 300. (The top-viewed physics video “Large Hadron Rap,” with nearly 6 million views, describes the physics being pursued at the Large Hadron Collider at CERN to the tune of an engaging rap song.) One useful resource for sorting through the videos most relevant to teaching is the monthly “YouTube Physics” column in *The Physics Teacher* journal which highlights different videos each month. Our narrower focus here, however, is on how web videos can serve as a recruiting tool, their value relative to other recruiting vehicles, how they can be made inexpensively, and some tips on getting maximum visibility for your video.

Well done physics-related videos can stimulate student interest in physics and be a recruiting tool in that sense, but what about their value as a recruiting tool for individual departments? Traditionally, many academic departments have relied on printed flyers, and many still do, judging from the number that continues to pour into my own department each week. Since we at George Mason have long ago run out of wall

space to post these expensively produced flyers, most of them wind up in a drawer somewhere, and may even get thrown out. Although virtually all departments now have their own web sites, a departmental video posted on YouTube can make a nice addition. Unlike flyers, for which departments have no idea how many eyeballs actually see them, with YouTube videos one not only can see the day-by-day numbers of viewers, but also the viewer’s demographics (age and sex) and their country of origin.

The most interesting data supplied is what YouTube calls “hot spots.” The hot spot data is a graph that shows the ups-and-downs of viewership at each moment in the video, compared to videos of similar length. Thus, the higher the graph, the “hotter” your video, i.e., fewer viewers are leaving your video and they may also be rewinding to watch that point in the video again. Audience attention is an overall measure of your video’s ability to retain its audience. While few physics recruiting videos are likely to “go viral,” they can receive considerable attention if done well, and they are entertaining and compelling enough for people to want to pass around. To “go viral” implies that word spreads exponentially like a virus because most viewers like it so much they each tell their friends about it. What are the properties for a video to have this potential? Humor certainly is a big plus, as is brevity, surprise, and avoidance of blatant advertising.

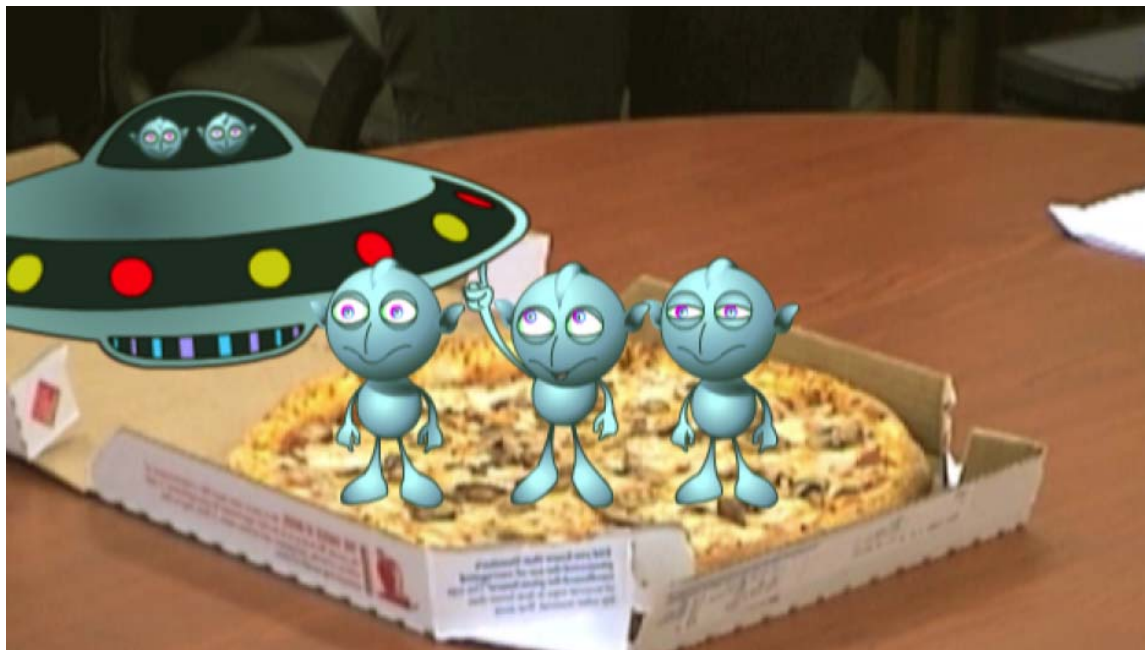
Given the relative advantages of using videos for recruiting, it is surprising that so few physics departments use them, which I attribute to lack of knowledge of how they can be made at very little expense, and perhaps academic stodginess. I was able to find only six of them on YouTube, with just three at U.S. schools: Utah Valley, West Virginia, and Northeastern Universities. Recently, I created the concept for a video for our department, and

contracted to have it made using the services of a professional narrator and a professional animation company (AFX Animation) based in India. Today this process can be very easily done by posting one's job on web sites such as E-lance, and allowing people and companies worldwide to bid on the project. In our case, the cost of the animation, the narration, and all the editing was well under \$500, which is less than we would have paid to produce 500 copies of an attractive flyer. The video starts out fairly conventionally, and the shocker comes about halfway through, when miniature aliens land on a pizza being served to a visiting group of students and their parents—see a still frame from the video below. It remains to be seen how much attention our video will ultimately receive, but it was viewed 200 times during its first three days on YouTube.

After analyzing YouTube's "hot spot" data for our video I learned that many viewers tuned out after 15–20 seconds of what seemed to be a fairly conventional sales pitch, and they never

got to the cute alien animation part about 2 minutes in! I therefore posted a second shorter version on YouTube so as to lure a greater number of viewers, in the hope that with the shocker coming early on, the video had the potential of "going viral." (Both versions can be easily found by searching YouTube for the keywords "George Mason" and "physics.") Just think—with 200 views in the first 3 days, if we can only manage to increase that by a factor of a million we will have exceeded the number of views of the top "Lady Gaga" video. Following Al Bartlett's well-known lesson about exponential growth (one of the top physics-related videos on YouTube), that's a "mere" 20 doublings—so if you tell two friends about it, and they tell two friends, that needs to happen only 18 more times!

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Modernizing the Physics Curriculum by Being Less Modern

Philip Gleckman

Introduction

I was invited to the 2010 APS March Meeting to offer suggestions from an industrial point of view on the development of new academic programs in renewable energy. As APS is a *physics* society, I took it as an opportunity to place the program we already have—the undergraduate physics curriculum—under the spotlight. The standard physics curriculum begins with an introduction to two pillars, mechanics and electricity & magnetism, and then, following an intermission when these are combined in vibrations & waves, veers off into quantum mechanics where it stays for the next two terms. Most, if not all, of the students' advanced laboratory consists of repeating famous experiments in modern physics such as Rutherford and Compton Scattering. Is there anything wrong with that? Yes. The critically important subjects of classical thermodynamics, heat transfer, and fluid mechanics (“THF” for short) have been hijacked by the Department of Mechanical Engineering. THF are the sciences that underlie not only renewable energy but also conventional electrical production as I will show through examples.

Energy's past and future

Most people have no idea that 90% of the electricity in the United States comes from steam. It is a triumph of elementary thermodynamics that we can calculate the efficiency of this process, known as the Rankine Cycle, just by applying the First and Second Laws of Thermodynamics and using steam tables for entropy and enthalpy. In the first step of the idealized four-step process, water is pumped adiabatically to a state of higher pressure and temperature represented by an increase in enthalpy. In the second step, heat generated by burning coal (or through a nuclear reaction) is added to convert the water to superheated steam at constant pressure

resulting in a further enthalpy increase. The steam expands through a turbine in the third, work-producing step. The final step that closes the cycle uses a cooling tower to condense the steam back into water. Cycle efficiency is calculated by writing the laws of thermodynamics for the control volumes in each step and solving for the net work [1].

Solar thermal plants are being built in the desert for utility-scale electric power (above 100 MW). These new Rankine Cycle plants replace the heat generated by burning fossil fuel with renewable concentrated sunlight and do not exhaust any greenhouse gases. SEGS1, the first solar thermal plant, was built in the Mojave Desert in 1984. Therminol oil is heated inside vacuum-insulated steel tubes at the focal line of parabolic mirrors and the heat is transferred to steam in a heat exchanger. By expressing the enthalpy increase in terms of a change in fluid temperature, the First Law can easily be used to determine the length of the oil piping needed to reach the desired outlet oil temperature of 400°C for a given flux, flow rate, and tube diameter. For example, in SEGS1 where the flow rate is about 400 lpm, if you assume a flux of 70 suns on a 70 mm-diameter tube, you can show that the tube must be 1/3 of a kilometer long! What if you wanted to know the outlet steel temperature to make sure it does not overheat? *You cannot calculate that from first principles!* The problem is that the flow is turbulent. Newton's Law of Cooling tells us that the known heat flux q into the fluid is related to the difference between the absorber and fluid temperatures by $q = h\Delta T$ where h is the heat transfer coefficient. All the physics of convection is captured in the non-dimensional heat transfer characteristic known as the Nusselt number which in turn is a function of the non-dimensional Reynolds and Prandtl numbers as well as the friction factor. The idea of using completely empirical correlations is foreign to most physics students.

The Rankine Cycle does have its shortcomings for solar power: water is obviously not abundant in the desert where the sun is bright, and steam plant equipment is expensive to build and maintain. There have been ongoing research efforts to instead use air as the working fluid in a Brayton Cycle. Rather than parabolic trough mirrors, an array of heliostats produces much higher fluxes (hundreds of suns) into a receiver atop a tower. Air flows through tubes in the receiver and is heated by convection to meet the conditions of gas turbines. The challenge of designing an air receiver can be appreciated by considering that the heat transfer coefficient is typically $1/3$ that of oil while the flux can be an order of magnitude higher.

My final example comes from the wind power industry. A director of a national lab has said that the “technologies needed for wind power aren’t rocket science.” The engineers at a company called FloDesign may disagree with this characterization since they have used an important part of rocket science— aerodynamics—to achieve a breakthrough in the efficiency of wind turbines through the use of a shrouded rotor. Interestingly, undergraduate-level fluid mechanics is all that is necessary to derive the maximum possible efficiency (59%) of a conventional wind turbine. It is only necessary to express familiar mechanical laws such as energy and momentum conservation in unfamiliar forms for fluids passing through control volumes [2].

Recommendations

While the preceding examples highlight the central role of THF in energy, these classical

disciplines are also critical to a scientific understanding of many natural phenomena that people experience. Physics students should be encouraged to take courses in these areas if they are offered in the mechanical engineering curriculum, and at liberal arts schools these subjects should be included in the physics curriculum. Heat transfer cannot be understood without fluid mechanics, so fluids should be taught first. Fluid mechanics can be used to introduce vector fields and can serve as a conceptual bridge between mechanics and E&M. New laboratory experiments should be designed so that students can experience the *science* of fluids and heat.

A physics graduate student approached me after my talk and told me that while he agreed that these were important subjects he had learned them well as an undergraduate. Impressed, I asked him where he studied. “China,” he replied.

References

- [1] For example see R. Sonntag and C. Borgnakke, “Fundamentals of Engineering Thermodynamics,” 2nd ed. (Wiley, Hoboken NJ, 2007).
- [2] M. Hansen, “Aerodynamics of Wind Turbines,” 2nd ed. (Earthscan, London UK, 2008).

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A Better Way to Increase Physics Majors: Greater Emphasis on Concepts

Art Hobson

I applaud Stewart Brekke's suggestion [1] that we increase the number of college physics majors by vigorously reaching out to the minorities, women, and inner city kids who have been insufficiently represented in professional physics. As Brekke says, the most important vehicle for accomplishing this is high school physics.

However, Brekke's solution is "the standard, mathematically-based high school course using drills and practice, especially in physics problem solving, with extra help from the high school physics teacher." Three lines of evidence suggest that such a course will not solve the problem posed by Brekke and that the best sequence for non-science students is conceptual physics first (no algebra, but quantitative nevertheless). Science students should begin with either an all-conceptual course or an algebra-based but still strongly conceptual course.

First, the recent successful growth areas for high school physics have been conceptual courses first, honors and AP courses second, and traditional math-based courses not at all; women and minorities, in particular, are enrolling in the rapidly growing conceptual course. According to data from *American Institute of Physics* Education Director Jack Hehn and AIP Senior Research Associate Michael Neuschatz, conceptual physics grew by 1000% during 1987–2005, honors and AP physics grew by 225%, while the standard math-based course remained about constant at 2% growth [2]. Neuschatz attributes the recent overall 76% surge in high school physics enrollments to the "wider variety of physics courses now available to students," adding that "a higher percentage of students than ever before is now taking conceptual, or non-computational, physics classes, as well as honors and AP physics classes" [3]. According

to Hehn and Neuschatz, "It was particularly the spread of the conceptual approach, aimed explicitly at non-science-oriented students who might not yet have the mathematical skills for a traditional course based on algebra and trigonometry, that spurred high-school physics to grow beyond its traditional confines.... From 1987 to 1997, more than two-thirds of the increase in physics enrollments was accounted for by the jump in the number of girls taking physics. And from 1997 to 2001, close to half of the absolute enrollment gain was due to increasing minority participation" [2].

Second, a leading finding of physics education research is that many students who are able to use formulas to solve standard math-based physics problems do not understand the conceptual physics behind these problems. Conventional problem-oriented physics instruction does little to change these misunderstandings [4–6]. Thus, effective teaching requires something more conceptual than the traditional problem-solving course. Inquiry-based teaching methods (another key recommendation of physics education research) clearly helps. Brekke's suggested "extra help from the ... teacher" is another good idea. But can these help enough to attract and keep large numbers of minorities, women, and other students who have not previously been attracted to physics, absent a change in course content toward a more conceptual approach?

Third, the *College Board*, which oversees the Advanced Placement courses and exams, has always urged that students headed for scientific careers complete a conceptual or "Category A" physics course in the ninth or tenth grade before enrolling in an AP Category B (algebra-based) or C (calculus-based) course: "A high school version of a Category A course that

concentrates on conceptual development and that provides an enriching laboratory experience may be taken by students in the ninth or tenth grade and should provide the first course in physics that prepares them for a more mathematically rigorous AP Physics B or C course” [7]. But students are unfortunately skipping the Category A course and going directly to the mathematical courses. According to a study of AP math and science courses, many students are poorly prepared before starting these courses, some having skipped intermediate preparatory courses so that they could squeeze more AP courses onto their high school transcripts. According to Haverford College physics professor Jerry Gollub, who co-chaired the study group, “They’ve gotten caught up by the success of a system that is being driven by a funny motivation: student efforts to get into college,” rather than knowledge [8].

Thus there is ample reason for nonscientists to enroll in a conceptual physics course first, before possibly proceeding to a more mathematical course. For future science students, there might be another viable path in the future, one that also emphasizes conceptual development. There are plans to introduce a revised AP Category B course, with a recommended two-year syllabus containing a much stronger conceptual component. The first semester of this course might then be a suitable first physics course for scientists. This course should also be suitable as the second physics course for those crossover students who, upon taking a conceptual course, find they are attracted to science.

An even more important reason for urging a more conceptual approach is that today’s typical high school and college curricula fail to provide the scientific literacy that all students so dearly need. The present math-based courses spend little time on modern (i.e., since 1900) or contemporary physics, such as the beautiful new cosmology that is beginning to answer questions that humankind has asked for thousands and probably millions of years. These courses thus fail to describe the physics of the real universe as scientists understand it

today. Furthermore, the math-based courses provide little connection to the many physics-related societal topics, such as global warming, that will determine humankind’s future. In this scientific age, all people surely need an enlightened view of the actual physical universe and science-related social issues. Because conceptual physics courses do not need to spend time on algebraic formulations and problems, it is possible for these courses to include contemporary physics and societal topics. It is my understanding (although I have not seen the syllabus) that contemporary physics and societal topics will also be addressed in the future in the recommended new two-year AP Category B course.

The minorities, women, and inner city kids about whom Brekke is rightly concerned will be mostly alienated by his recommended algebraic-problem-oriented course, although a few might be attracted by the one-on-one tutoring that he admirably suggests. These students are far more likely to be attracted to a socially relevant and scientifically up-to-date course that avoids algebra. The enrollment figures given above provide evidence for this. Although it is only anecdotal evidence, I have found that such students lose heart and interest right away when I introduce a little algebra into my university-level conceptual physics course, but that they perk up when the course presents, conceptually, the big ideas of classical and modern physics along with related societal topics. This is true not only of minorities, women, and inner city kids, but also of nearly every non-science student I have known in 35 years of developing and teaching physics literacy.

I conclude that non-science high school students should begin their study of physics with a broad, conceptual, scientific literacy course that covers the main classical principles, emphasizes modern and contemporary physics, and includes physics-related social issues. The important “second tier” of students that Brekke is interested in, namely students who do not initially plan to be scientists but who might be persuaded into physics with the right teaching, might then be sufficiently attracted to physics

to take an honors or AP high school course following the conceptual course, and/or they might choose physics or engineering once they get to college. This sequence should substantially increase the number of physics majors by attracting Brekke's "second tier," while boosting their scientific literacy. Science students should also begin with a first physics course that is grounded in concepts, either through an all-conceptual first course or through a more mathematical first course that highlights concepts while including societal and modern topics.

Acknowledgement

My friend and colleague Gay Stewart provided helpful comments.

References

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[3] Turner Brinton, "High school physics enrollment hits record high," American Institute of Physics, Jan. 10, 2007, available online at http://www.eurekaalert.org/pub_releases/2007-01/aiop-hsp011007.php.

[4] Eric Mazur, *Peer Instruction*, (Prentice Hall, Upper Saddle River, NJ, 1997), Chap. 1.

[5] Eunsook Kim and Sung-Jae Pak, "Students do not overcome conceptual difficulties after solving 1000 traditional problems," *Am. J. Phys.* **70**, 759–765 (2002).

[6] David Hestenes *et al.*, "Force concept inventory," *Phys. Teach.* **30**, 141–158.

[7] "College Board AP Physics, Course Description, May 2010–May 2011," p. 5. Online at <http://www.collegeboard.com/student/testing/ap/sub_physb.html?physicsb>. (Click on "Download the Course Description".)

[8] *Learning and Understanding: Improving Advanced Study of Mathematics and Science in U.S. High Schools*, National Academies Press (2002), http://www.nap.edu/catalog.php?record_id=10129. Also see Karen Arenson, "Study faults advanced-placement courses," *The New York Times*, Feb. 15, 2002.

Art Hobson (hobson@uark.edu) is Professor Emeritus of Physics at the University of Arkansas, Fayetteville. He is the author of *Physics: Concepts & Connections* (Pearson/Addison-Wesley, San Francisco, 5th edition, 2010), a conceptual physics literacy textbook for college students.

21st Century Physics For In-Service High School Physics Teachers

Bruce Sherwood

Introduction

Matter & Interactions [1] is a calculus-based introductory university physics curriculum for engineering and science students that features a contemporary perspective, with emphasis on parsimony (a small number of powerful physics principles rather than a large number of formulas) and on unification (for example, mechanics and thermal physics are treated as one integrated subject rather than two disjoint ones, and electrostatic and circuit phenomena are analyzed in terms of the same fundamental principles rather than completely different methods). The atomic nature of matter is emphasized throughout. Computational modeling is an important component of the course; students write programs to model physical systems and to visualize fields using VPython (<http://vpython.org>).

A version of this curriculum consisting of a semester of mechanics and a semester of electricity and magnetism is now offered through the distance education division of NCSU to in-service high school physics teachers in a technologically advanced distance education format, including innovative interactive lectures on DVD. The goal is not to train teachers to teach this university curriculum in high school (although a few teachers are now using it with students who take a second year of physics) but rather to give teachers a contemporary perspective on introductory-level physics, which they did not experience when they were in college. During the distance education course, teachers write reflections on their own learning, which are quite illuminating.

Components of the course

Here is a list of the major components of the distance education course, many of them

technological in nature:

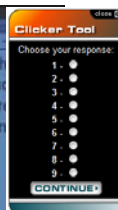
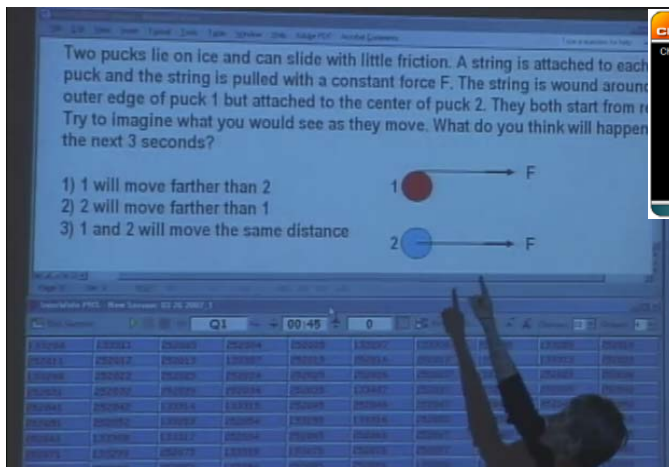
- Textbook (Matter & Interactions)
- Interactive video lectures
- WebAssign computer homework system
- Course web site
- Experiments (may involve video of data acquisition)
- For E&M, a desktop experiment kit
- Computational physics (in VPython)
- Course forum (including reflections)
- Email
- Scan/Fax/PDF submissions of reports/tests/etc
- Weekly teleconference (Elluminate)

Interactive video lectures

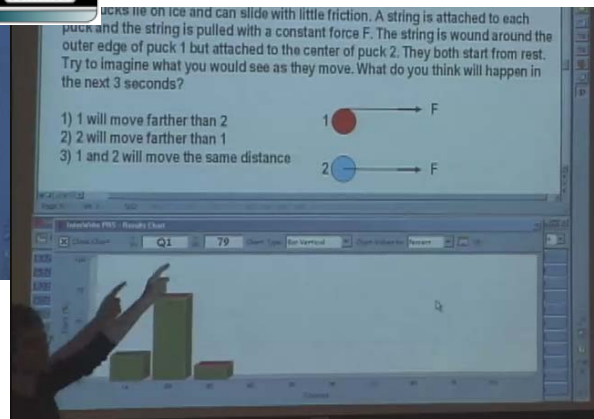
A novel component is the interactive video lectures, which have the following properties (see Fig. 1). Lectures with interactive clicker questions given by Ruth Chabay were filmed. The video was edited and compressed with one semester of 40 lectures per DVD. The video segments end with a clicker question on the screen. A simulated clicker appears for the distance learner to respond. After the response, the next segment begins with a display of the histogram of the student responses in the original classroom, with discussion. The effect is to provide much of the interactivity of the original lectures.

Many teachers have commented that they found the interactive videos particularly engaging, although a minority said that they would prefer that the videos not stop on a question. In Spring 2010, lectures accompanying the new 3rd edition of the textbook were filmed, and the plan is to edit them to fit into a format in which the halts are optional.

Fig. 1. A clicker question is posed...



the teacher answers, using a simulated clicker...



and after answering, the high school teacher sees the histogram of student responses from the original classroom.

Computational modeling

In the mechanics course, teachers write computer programs using VPython to model physical systems and to see the Newtonian synthesis in action: starting from initial conditions, repetitive updates of momentum and position can predict the future. In the E&M course, teachers write programs to calculate and visualize electric and magnetic fields in 3D (see Fig. 2). One problem is that it is easy to get stuck when writing a program in isolation, so teachers are encouraged to send drafts of programs by email for critique.

Other components of the course

One of the problems in distance education physics courses is the difficulty of including useful activities beyond textbook study and homework. Because the participants are high school physics teachers, in many cases they have access to equipment upon which experiments in the course are based. For an experiment on Young's modulus which involves measuring the stretch of a long thin wire under load, using equipment most teachers do not have, a video is provided which

shows a person taking data, and the teachers must write up an analysis of that data. For E&M, the teachers buy a kit that enables them to do desktop experiments on electrostatics, circuits, and magnetism.

The isolation inherent in a distance education course is partially addressed by the existence of a course forum and by optional weekly teleconferences using Elluminate, a system which includes audio, chat, and a whiteboard upon which all can draw.

Homework is turned in using a computer homework system, WebAssign, for which a large suite of Matter & Interactions problems has been developed by the textbook authors.

Teacher reflections

A recurring assignment for the teachers is to write reflections on what they are learning, and how the new ideas might affect their own teaching. The single most significant element in their reflections has been their reaction to the emphasis on starting analyses from a small number of fundamental principles rather than from a large number of secondary formulas.

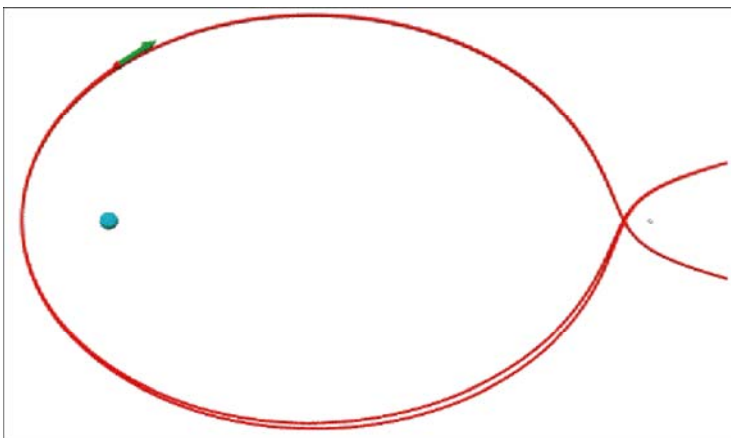
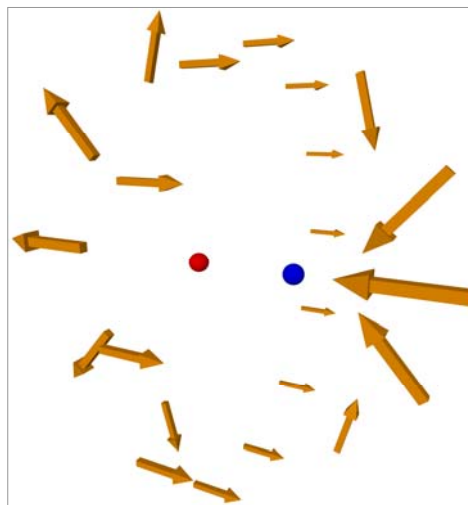


Fig. 2. A program written by a high school teacher to model a spacecraft moving near a fixed Earth and Moon (i.e., a restricted three-body orbit)...



and a program to compute and visualize in 3D the electric field of a dipole.

Parsimony and unification

Newton introduced the notion of reductionism into physics, that a small number of fundamental principles (parsimony) can explain a wide range of seemingly disparate phenomena (unification). The Momentum Principle (Newton's second law) plus a universal law of gravitation made it possible to explain the motion of the planets and comets, the tides, and much else.

Reductionism was greatly strengthened in the twentieth century. Quantum mechanics seemed to change everything, yet it turned out that momentum, energy, and angular momentum were still central, giving added weight to parsimony. The discovery that the large number of "fundamental particles" could be explained in terms of a small number of quarks and leptons was another powerful demonstration of parsimony. The identification of just four fundamental interactions (gravitational, electromagnetic, strong, and weak), which then collapsed to just two

(gravitational and the Standard Model), was the result of a drive for unification.

However, the twentieth century perspective on the power of parsimony and unification, which is at the core of contemporary physics, was scarcely represented in the physics courses these high school teachers took in college. As a result, they found a reductionist approach to introductory physics an eye-opener and often commented in their written reflections on how this approach had made a big impact on their view of physics, and that it was triggering significant changes in their own teaching.

Reference

- [1] Ruth Chabay and Bruce Sherwood, *Matter & Interactions* (3rd edition, 2010), John Wiley & Sons, Hoboken NJ. See the webpage <http://matterandinteractions.org>.

Bruce Sherwood (Bruce_Sherwood@ncsu.edu) is Professor Emeritus from North Carolina State University and now lives in Santa Fe, NM.

An Interview with Boris Korsunsky

Carl Mungan

Tell me about your educational and career trajectory.

I grew up in Moscow, Russia. My last two years of high school were spent at one of the most selective Moscow math and science schools. I was a good student (although always a bit of a clown) and I especially enjoyed physics. My physics teacher was a part-timer; her main job was being a physics editor at *Kvant*, a magazine very similar to and the predecessor of the now defunct *Quantum*. By the time I graduated from high school, I knew I wanted to be a high-school physics teacher. At the insistence of my parents, I got an engineering degree but went straight into teaching afterward. I taught for a few years at the same school where I had been a student while getting another degree in Physics Education. I emigrated to the United States in 1992. I remember that I told all my friends and colleagues that I was going to remain a teacher in the US and everybody thought that I would switch to computer programming. That's what most immigrants with math/physics background did, but I wanted to keep doing what I really loved. After some part-time gigs, I finally got a full-time job at a boarding school in Western Massachusetts and then moved near Boston where I still live. In 2003, I completed my doctoral dissertation at Harvard School of Education and, unlike most of my fellow students, chose to remain a high-school teacher (although having a Harvard degree does help in finding consulting jobs). I have been at Weston High School for ten years now and I couldn't be happier with the community, the colleagues and the administration—truly, an enlightened and exciting place to work.

In addition to classroom teaching, I have always tried to be professionally active in as many ways as possible: I have written many articles for *Quantum* and *The Physics Teacher*, led workshops for teachers both in the US and abroad, served as a coach for the US Physics

team, have been involved with the AP Physics program in different capacities and have done a lot of freelance writing for various publishing companies.

What are some differences between Russian and American high schools?

First of all, let me stress that the educational system in any country is part and parcel of the national culture, its political and economic system. In other words, one has to be careful about making “value comparisons.” Second, the high-school system in Russia nowadays is in many ways different from the Soviet system of my time. (I graduated from high school in 1982.) However, I can still comment on some differences.

In Russia, like in many European countries, most academic subjects (including math and science) are studied over several years. For instance, I had five years of physics and four years of chemistry (starting in middle school). Also, in my days, there was a single national curriculum for all schools. These days, Russian schools are freer to choose their curriculum but every high-school graduate must pass a series of national exams in various subjects, including math, physics, chemistry, language, and history. The results of these exams, along with the student's GPA, are used for college admissions. No letters of recommendations, and no accomplishments in arts, athletics, or community service play a role in college admissions (at least not officially, although it still helps to have the right parents, know the right people, or be an international-level athlete).

Mathematics and science teachers in Russia get much more thorough “content training” than their American counterparts (perhaps, at the expense of pedagogy and psychology classes). A typical physics teacher graduates with training similar to that of a physics major.

(Considering that a Russian college degree usually takes five years to obtain and the course load is very high, that would be the equivalent of getting both a B.S. and M.S.) In the classroom, teachers expect a no-nonsense atmosphere, with little patience for what here in the US would be considered “learning disabilities,” “athletic commitments,” and so on. If the students enjoy their classes, great, but that is not a teacher’s primary concern. Overall, schoolwork in Russia is considered “the civic duty of the young generation” from a very early age. In the US, the pressure to perform academically often does not begin in earnest until high school. (The relatively recent proliferation of state-level competency testing is changing things, however.) In Russia, from the very first day of school, students are given homework and grades, and are scolded by both their parents and their teachers for poor performance. Every kid knows that, if their grades are bad, they’ll be in trouble. The fear of punishment is definitely a factor in the overall academic achievement. In most families there is huge parental pressure to do well at school. From what I know, such pressure on students is also prevalent in many other countries. I believe that it is the culture of high expectations and of making education the highest priority—as opposed to some mysterious “innate ability”—that makes Asian and Eastern European immigrant children so academically successful here in the US.

Another factor that puts tremendous pressure on Russian male students is the possibility of being drafted. The Russian military, for many young men and their parents, is a nightmare: poor living conditions, rampant hazing, and many training accidents, often resulting in serious injuries and even death. Many colleges offer deferment from the service, and many male students work extra hard to earn a spot at one of those colleges.

Discuss some of the books you have written.

You are kind to call them “books”—they are all “supplements” of sorts. When I began my teaching career here in the US, I was surprised and frustrated by the lack of resources for

interesting physics problems. There have always been plenty of such books in Russia, so I decided to write one to use with my AP Physics students. I had always enjoyed elegant physics problems, participated in physics and math competitions myself, and trained my students, some of whom made it to the Russian and the US national physics teams. The book, written two years after my arriving in the US, was published as a supplement of challenging, Olympiad-style problems for one of Raymond Serway’s physics textbooks. Almost fifteen years later, that book has not been a huge commercial success. I am pretty sure it’s out of print by now. Maybe, there is no market for such books in the US? Most of my own students find these problems too hard so I rarely use them in class, but some of them have been used in the column of *Challenges* that I have been editing for eight years for *The Physics Teacher*.

My second book was also a collection of problems. That was a “fun” project: each problem was based on a fact from the *Guinness Book of Records* or a similar source. My students do enjoy these problems and I use them in my classes on a regular basis.

I have also written (or, rather, reworked) an AP-preparatory book, which has since been updated again. Also, at the end of last year, I published a completely different, “un-serious” book: a collection of funny student quotes, named *Trophy Wives Don’t Need Advanced Physics*. (The title is an actual quote from a student’s test.) I had been collecting quotes for a number of years, from my own classroom and from other sources, and I was nudged to finally put together a book by several really funny (or sad?) lab reports collected from my freshman physics class last year. First, I wrote a short article for *The Physics Teacher* and then I decided to go a little further. The article and the book came out at about the same time. You can find out more about this effort at <http://funstudentquotes.com>.

I am still planning to write a book on the subject I have always been passionate about: The art of teaching problem-solving skills in

the physics classroom. It was the topic of my dissertation, it has been one of the primary goals of my teaching, and the book on that subject remains a very important goal in my professional plans. Some day I'll get to it....

What else can you tell us about your *Physics Challenges* column in *The Physics Teacher*?

Well, as I mentioned, I have always been interested in competition-style physics problems—the ones that put to shame the artificial distinction between “conceptual” and “computational” problems. These problems can be called challenges, brainteasers, or puzzles. The point is that they require deep understanding and creative thinking, but no knowledge beyond a rigorous high-school physics course. I proposed the column twice. When Karl Mamola became the editor of *The Physics Teacher*, he kindly agreed to give the column a pilot run and it's now been eight years, I think. I get quite a few solutions each

month, and many more teachers and students solve these problems without submitting, judging from the informal feedback I get and from the number of downloads the column gets each month. Teachers use them as “bonus” problems in class; some discuss these problems as part of the teaching process, to demonstrate the interplay of different concepts and ideas in the same situation. Many colleagues have thanked me for the column over the years and I am honored to provide this service to the community. I am pleased to see that solutions have been coming from all over the world but I am a little sad that the vast majority of *student* contributions tend to be from abroad. I would encourage my colleagues in the US to recommend these problems to their best students and to help them stretch themselves.

Boris Korsunsky is a physics teacher at Weston High School (korsunskyb@mail.weston.org) in MA.

Report on the Minority Bridge Program

Theodore Hodapp

Physics education provides a unique look at the world, the capability to solve a wide range of problems, and the tools for success in diverse careers. Unfortunately, we as a community do a rather poor job at providing this opportunity to large segments of the population of the United States. Progress has been made in encouraging women to study physics, and the number of women pursuing advanced degrees in physics continues to climb linearly (increasing steadily over the past 4 decades at about 0.4% per year, although still far short of parity) but our progress with underrepresented minorities (URMs) remains poor. For our purposes we include as URMs African-, Hispanic-, and Native-Americans. African-Americans as a group have, in fact, lost ground in the past decade in both absolute numbers and in their representation as a proportion of the US population. To continue to advance the field of physics, to take advantage of the benefits of diversity in solving problems, and to provide everyone the opportunity for a 21st century caliber education, we must address this issue.

Underrepresented minorities make up about a quarter of students entering college in the US, but only about 10% of physics bachelor's degree recipients (a drop of a factor of 2.5), and the leak continues by another factor of almost two when we look at doctoral degrees in physics. Figure 1 indicates the percentage along with typical annual numbers at each stage.

One positive indicator is that at least in the transition to academia, the fraction of URMs relative to the overall population remains roughly equivalent to the production of new PhDs, with about 10 individuals each year choosing this route.

Additionally, the number of PhDs granted to minorities in physics has not seen any appreciable increase in nearly three decades.

Figure 2 indicates the percentage of physics PhDs granted to US citizens who are African-, Hispanic-, or Native-American. The number is normalized to the population fraction of 18 year olds (as the Hispanic population of the US has been growing dramatically during this period). Consequently, 100% on this scale would represent a third of all degrees granted to minorities, since that is the representation of URMs in the US population.

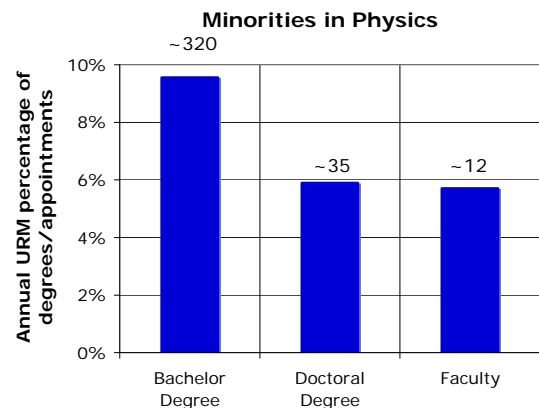


Fig. 1. Percentage of undergraduate degrees, doctoral degrees, and new academic appointments in physics each year given to under-represented minorities. All degree numbers are for US citizens or permanent residents only. Data are from the Department of Education's IPEDS Completion Survey, and from the American Institute of Physics Statistical Research Center.

To address these issues, the APS Education and Diversity Department convened a series of roundtable discussion in 2008 and 2009 between the APS, the National Society of Hispanic Physicists (NSHP), the National Society of Black Physicists (NSBP), and the American Association of Physics Teachers to identify the most pressing issues facing the physics community in minority education, and what specific actions might be taken to address them.

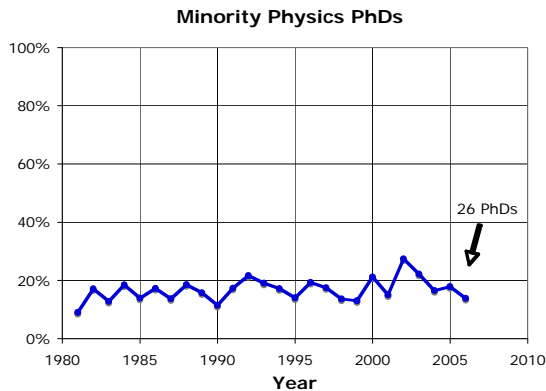


Fig. 2. The fraction of doctoral degrees given to under-represented minorities normalized to the age-18 US minority population fraction. To reach parity, we must increase minority physics PhDs by about a factor of 5. Sources of this data include the US Census Bureau and the Department of Education's IPEDS Completion Survey.

The first result was the development of a joint diversity statement (see sidebar), endorsed by the APS, NSHP, and NSBP, which calls for action on these issues and serves as a starting point to direct our activities. Wendell Hill from the University of Maryland, a member of the APS Executive Board at the time and a former board member of NSBP, charged the APS with developing proactive strategies to address the lack of diversity in physics. The American Physical Society already has a number of programs designed to increase diversity in physics such as the Minority Scholars Program (www.aps.org/programs/minorities/honors/scholarship) which provides merit-based scholarships to promising minority high school students and beginning physics majors, minority speaker travel grants (www.aps.org/programs/minorities/speakers/travel-grants.cfm) and an active database of minority speakers (www.aps.org/programs/minorities/speakers). To build on these efforts, and to answer the charge, APS entered into a number of discussions throughout 2008 and 2009 to determine an appropriate set of actions. The result of these conversations has led us to initiate the APS Minority Bridge Program (www.aps.org/mbp).

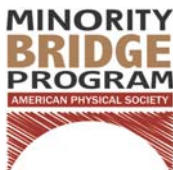
08.2 JOINT DIVERSITY STATEMENT

(Adopted by the APS Council on November 16, 2008)

To ensure a productive future for science and technology in the United States, we must make physics more inclusive. The health of physics requires talent from the broadest demographic pool. Underrepresented groups constitute a largely untapped intellectual resource and a growing segment of the U.S. population.

Therefore, we charge our membership with increasing the numbers of underrepresented minorities in physics in the pipeline and in all professional ranks, with becoming aware of barriers to implementing this change, and with taking an active role in organizational and institutional efforts to bring about such change. We call upon legislators, administrators, and managers at all levels to enact policies and promote budgets that will foster greater diversity in physics. We call upon employers to pursue recruitment, retention, and promotion of underrepresented minority physicists at all ranks and to create a work environment that encourages inclusion. We call upon the physics community as a whole to work collectively to bring greater diversity wherever physicists are educated or employed.

The Minority Bridge Program (MBP) has an ambitious goal of bringing the fraction of physics PhDs granted to minorities into parity with the fraction of bachelor degrees (~10%). This will require us to roughly double the rate at which these PhDs are educated (an additional 30 PhDs each year). We think this is both challenging and possible.



To get the program started, the National Science Foundation awarded the APS in August 2009 a pilot grant of roughly \$130,000 to bring together many key players in the community to formulate a plan for addressing the disparity. The result has been a productive year engaged in discussions with minority students, faculty from minority serving institutions, leaders of existing bridge programs, and representatives from research universities. We have visited about a dozen minority serving institutions, made direct contact with many of their students and faculty, and brought together some of the top research universities that are eager to commit their own resources to addressing the problem.

We have seen a number of successful potential models including the Fisk-Vanderbilt bridge

program (www.vanderbilt.edu/gradschool/bridge) the Columbia Bridge to the PhD (www.columbia.edu/cu/vpdi/bridge_students.htm) and a number of efforts funded by the NSF's Alliances for Graduate Education and the Professoriate (www.agep.us). We hope to build on the successes of APS' role in managing the PhysTEC project, in organizing discussions between Directors of Graduate Studies, and in gathering leaders of REU programs to build a program, raise funds, and actually resolve the gap between bachelor and doctoral degrees in physics for under-represented groups.

In the summer of 2010 we will hold a gathering of these groups to solidify plans and commitments and formulate an action plan. APS staff, including Michelle Iacoletti who was hired by the project, and Arlene Modeste Knowles of the Education and Diversity Department, have been working with a Steering Committee led by Cherry Murray (2009 APS President) to develop and carry out the project.

Stay tuned!

Theodore Hodapp (hodapp@aps.org) is the APS Director of Education and Diversity.

Writing to Learn: A Circuits Laboratory Report Without Numbers

Michael Faleski

As a new instructor trying to put together physics courses for a residential high school of motivated students, I was scrambling late into the night almost every day. Inspiration at 2 o'clock in the morning would lead to a class activity performed only a few hours later. Much of the time, there was not enough proper equipment for the experiment so we would improvise with whatever was in the room to make things work. Students actually commented that they enjoyed these "MacGyver" experiments which seemed to be put together with bubblegum and paper clips! Out of these inspired nights came a few experiments that I continue to use ten years later in a well equipped lab.

One late night while trying to prepare an experiment with resistance, I was reading an *American Journal of Physics* article about student understanding of simple electric circuits [1]. The set of circuit questions used by the authors for their study was provided in the text and I had enough equipment for my classes to construct these circuits in the laboratory. To turn this into an experiment requiring a report, I needed something more than having students simply choose the answer to the multiple choice questions. In addition, I did not have time to perform almost fifty one-on-one interviews with students each semester like those documented in the article. After some more thought, I realized that students could write a paragraph about the physics of each of the circuits and thus began what they affectionately came to call "The Essay Lab."

The design of "The Essay Lab" is this: After completing the introductory material about circuits and Kirchhoff's rules, students are given a set of multiple choice questions related to simple circuits (batteries, light bulbs, wires, and switches) that they answer in their lab groups. A sample question with the data table of the required measurements students need to

make from the activity is provided in Fig. 1. Each of the questions is written so that there is a change in the circuit (a switch opens or closes, a light bulb is unscrewed from its socket, and so on) and the answers are related to how quantities associated with the circuit (current, voltage, bulb brightness, power) do or do not change. After debating all of the questions, lab groups construct each of the circuits, record a set of prescribed voltage and current measurements, and then record the same set of measurements after making the required change in the circuit. Once data is collected, the groups debate the questions again. Based on casual observation of responses, the groups answer only 20–30% of the questions correctly before conducting experiments. When there is not enough time for groups to make all of the required measurements (during a 2-hour class), data is provided to them.

Now that they have data for each circuit, students write fully-formed *essays* explaining the physics of the circuit... but the data cannot be used in the essays! The data provide a "safety net" to check arguments before they are committed to paper. If someone reasons that the current in the circuit increases, the data allow for a determination of whether or not that statement is true; in the essay, it cannot be argued that the current increased because "we measured that." For each essay, there must be correct physical reasoning not only justifying the correct choice, but also explaining why the other choices are incorrect. In this way, students need to make qualitative arguments describing the physics of all aspects of the circuits. A sample essay is provided to classes as a way to help students understand what is expected in the write-up.

Typically, the activity consists of 8–10 circuits with the essays due in stages over the course of five weeks. This allows me time to provide

feedback to students about their work before the next set of essays is due. Especially after the first essays are returned (and grades are not that great!) there is an increase in attendance at office hours before the next set of essays. This actually reduces the amount of time spent grading because after several revisions, many essays need no corrections and receive full marks. Also, as students recognize their own misconceptions and address them, the quality of writing improves over the course of the five weeks.

Grading a large number of essays can be time-intensive, but having students write about physics gives me insight into how they think through problems. This information allows me to adjust classroom presentations and activities in order to address misconceptions that appear commonly in their writings. Over the past 7 years while teaching at Delta College, more than 200 students have completed “The Essay Lab” from sections of my calculus-based E&M course. As a check of their understanding, the DIRECT exam on basic circuits is given during the final week of the class [2]. The average score by my sections on this assessment is 68% (52% is the national average for university students). These results show that even though there is extra effort to read many essays, it is worth the extra time since misconceptions are being dealt with directly. Though I cannot compare scores on DIRECT from students that

have not written essays (because all of my classes do so), students have told me that they felt this was a worthwhile experiment because they learned a lot. Also, when students return to visit after taking subsequent courses in electricity or circuits at other colleges, they tell me that they were extremely well prepared for these courses.

To increase student understanding and to learn what they are thinking, essays are a great pedagogical tool. While it is more work to read and grade multiple essays from a single experiment report over the course of several weeks, what is gained from the experience makes it worthwhile for both the student and their instructor. At least it does for me!

References

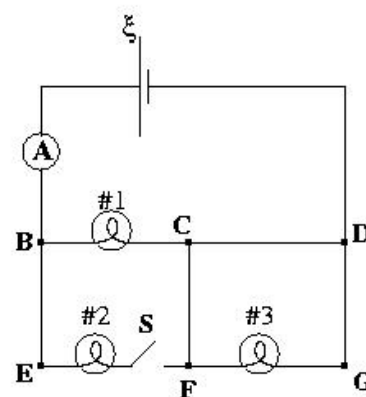
[1] R. Cohen, B. Eylon, and U. Ganiel, “Potential difference and current in simple electric circuits: A study of students’ concepts,” *Am. J. Phys.* **51**, 407–412 (1983).
 [2] P.V. Engelhardt and R.J. Beichner, “Students’ understanding of direct current resistive electrical circuits,” *Am. J. Phys.* **72**, 98–115 (2004).

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Fig. 1. For the circuit at right, the ammeter reading is initially I . The switch S in the circuit is initially closed. It is then opened. Consequently:

- (A) The ammeter reading increases.
- (B) The potential difference between B and C stays the same.
- (C) Bulb #3 lights up more brightly.
- (D) The potential difference between E and F decreases.
- (E) The power supplied by the battery stays the same.

Before Change	After Change
Current through ammeter	Current through ammeter
Voltage from B to C	Voltage from B to C
Voltage from E to F	Voltage from E to F
Voltage from F to G	Voltage from F to G



The Application Of Play Theory to Pedagogical Design

Juan Burciaga

At one time course preparation (metaphorically speaking) was simply dividing up the textbook into 39 daily chunks and then inserting timely tests. But as our understanding of the complex learning environment, and of our responsibility for that environment, have grown, faculty are increasingly called upon to attend to social construction within the course, maintain a constructivist learning environment, address affective objectives, and secure the engagement and motivation of a diverse student population. Play theory offers a framework to inform, balance, and interpret these new, and frequently conflicting, pedagogical demands.

Why play?

But by “applying play theory to curriculum development” I do not mean using games to make aspects of instruction more palatable, nor even that learning can be a form of play. Instead my main argument is:

Playing can be part of the learning process because the subject to be learnt is, at least in some respects, essentially playful. [1]

We should not think of a game as a way to make physics more fun, but instead focus on showing how much of physics is play. In order to incorporate this insight we need to rethink physics in order to understand, illuminate, and engage the fundamentally playful nature of physics. A second factor that helps explain how play theory can be useful to curriculum developers is that the core aim of play is the organization of experience. In other words, the purpose of a game is not really the solution of a task but the ordering and shaping of the experience of the game by the players, i.e., *it's not if you win but how you play the game*. Or, from our expectations, it's not the answer but how you ask questions, get the answer, and check to see if you have it right.

Too often we focus our assessment on the before and after, and not on the day-to-day experience of the learners (or in this paradigm, of the players). Even when we assess on a daily basis, the emphasis of the assessment is frequently on what have they learned and rarely on how they are experiencing the course. When we are able to re-imagine a course in this paradigm then a course is imbued with the fundamental values of exploratory learning, curiosity, and risk-taking, since the course is partially developed in response to the active design and execution of the actions of the learners.

Properties of play

In this paradigm, each course can be thought of as a game and the teacher a game designer. In many ways this perspective is a familiar one for those teachers who think that as teachers all we can do is to set the learning environment. For curriculum development a useful definition of play summarized from Johann Huizinga's seminal work is:

Play is a free and meaningful activity, carried out for its own sake, spatially and temporally segregated from the requirements of practical life, and bound by a self-contained set of rules that hold absolutely. [2]

Several properties of play determine how curriculum developers may effectively apply play theory to curricular design. Play takes place in a “magic circle” (chessboard, baseball field, backyard, etc) separated from daily life in space and time where the rules of the game hold true. In the magic circle, players are tested (strength, speed, reasoning, etc) against “something else” according to the rules [1]. This magic circle informs the players (students) that the rules of the game are in force and demands that they engage the learning under the rules developed by the game designer (the teacher).

The magic circle for a lab course is well-defined but for a lecture course the magic circle may be somewhat ambiguous since the learning environment extends beyond the classroom and encompasses many environments. Generally, in a game the “something else” or “other” that players are tested against may be another person or team, an idealized performance, or an inanimate challenge. In physics, “the other” that physicists are measured against is the physical universe, or more precisely their understanding of the physical universe.

The rules are developed from the objectives of the course. But these rules have specific constraints and most of these constraints are centered on the concept of “fair play.” In addition, the rules help focus the actions of the game in a way that the play makes sense and carries meaning for the players. If players do something right there is a reward and if they do something wrong they are penalized. Although the rules may be explained, how they fit into particular situations is not readily determined. Thus there should be room and time to explore. This ambiguity opens the game to rhythm.

In play there is risk, the chance to get it wrong. So there is always dynamic interplay of action and reaction between players and the other. This pattern establishes a rhythm to the play experience. To capture the intensity of the experience we need to focus on the feeling of risk, anticipation, effort, rhythm, and sense of fair play. Under the play paradigm, assessment of a learning situation must incorporate monitoring the experience of the players (students) during the game (learning).

An example: The physics laboratory

We can make these ideas a little more concrete by looking at an example—the physics laboratory for an introductory course. Let us take a course that is populated by students of diverse majors and is the first physics course at the college level. In the interests of total disclosure, the lab I am discussing was not actually designed within the paradigm of play theory. The design of the lab experience grew

organically as do much of our courses. But several years ago, as I was reflecting on why the course design was so effective, I came across the potential application of play theory to curricular design. The lab manual, the TA manual, and the faculty handbook for the lab experience are available from a pedagogical archive maintained by the *American Association of Medical Colleges* [3].

Objectives

- Students develop an ability to pose questions, pursue answers to those questions, evaluate the answers, modify their inquiry, and develop new questions.
- Students make an extended inquiry, i.e., students repeatedly trace the development of phenomena from observations, through conceptual understanding, to a rough mathematical model, to developing predictive criteria, and finally to a refined model of the physical world.
- Students learn how to work effectively in a group both in their lab groups and as part of a community of researchers, scholars, and explorers with responsibilities to that community.
- Students also have the opportunity to see themselves as effective and valued members of that community of scholars.

These objectives can be summarized in three general rules:

Work as a Team.

Learn to Ask Questions.

Pursue Extended Inquiry.

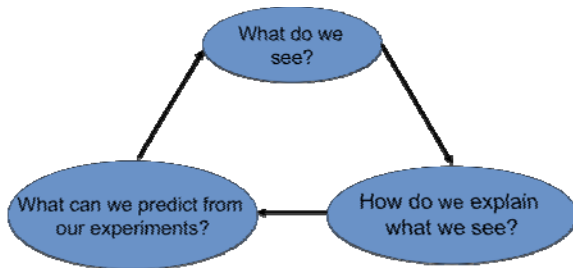
Work as a team

Much of the social interaction we are promoting was developed and assessed in group work. We modified the Cooperative Group roles developed for problem solving in physics [4] for the laboratory environment. Thus students were educated in cooperative group work. In order to demonstrate the benefits of the approach, the Lab Questions

were designed to be complex enough that the students needed other group members to successfully engage the lab experience. In addition, we communicated to the students (repeatedly) that the emphasis of the lab assessment is in how well the group is pursuing their assigned roles and developing their inquiry. The assessment rubrics used to measure the level and quality of the social engagement depended on monitoring the conversation of the students as they interacted with one another and generated their investigation. But by monitoring the level of engagement we were also paying close attention to the experience of the lab environment from the perspective of the “players”.

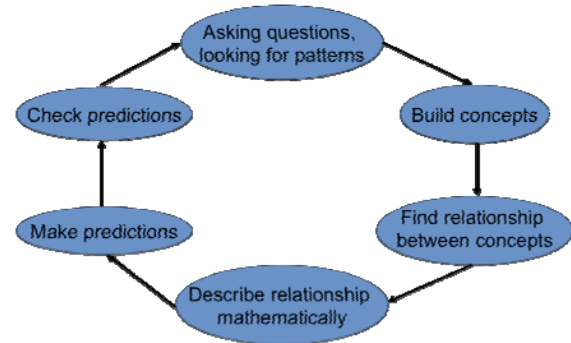
Learn to ask questions

From the perspective of a student, one of the most daunting demands of an inquiry-based lab is how to ask questions that lead to a useful investigation. In order to educate students in this aspect of the lab experience three separate learning cycles were incorporated. The first day of the lab began with a Lab Question that required students to generate an investigation to answer. Students were thus asked to generate an inquiry including most of the procedure and data recording, analysis, and interpretation. The student groups were guided in their inquiry and every 1–3 weeks encountered another Lab Question that seemed to arise naturally from the inquiry they had generated. In order to start their discussion of how to begin thinking of generating their inquiry Students were instructed to ask the three questions of Learning Cycle 1.



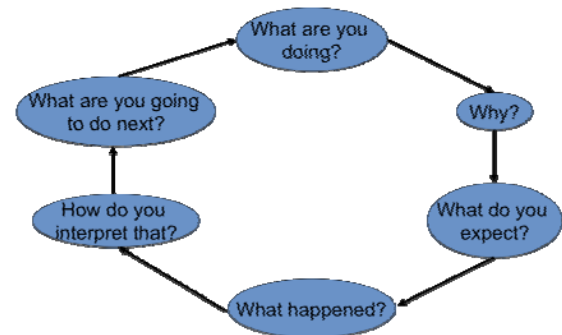
Learning Cycle 1: Cycle used by students to start generating their inquiry.

Although students were explicitly asked to pursue this set of questions for their inquiry, a successful pursuit involved a second learning cycle that students needed to apply.



Learning Cycle 2: Lab questions were designed on this pattern of inquiry.

Finally, the lab instructors guided the inquiry of the students by using a third set of questions to capture where the students were in their investigation, how they were thinking of their inquiry, and which allowed us to guide them to the next step of the inquiry. This pattern was used in both visits from the lab instructors and also in written comments in their lab journals.



Learning Cycle 3: Learning cycle used by lab instructors to give feedback to the students both orally and through written comments.

The guidance offered by the lab instructors was very sparse at the beginning of the semester and was progressively reduced as the semester continued. By the end of the semester, the lab groups were able to pursue Projects, a 3-week-long inquiry into a system they had not encountered and successfully generate an

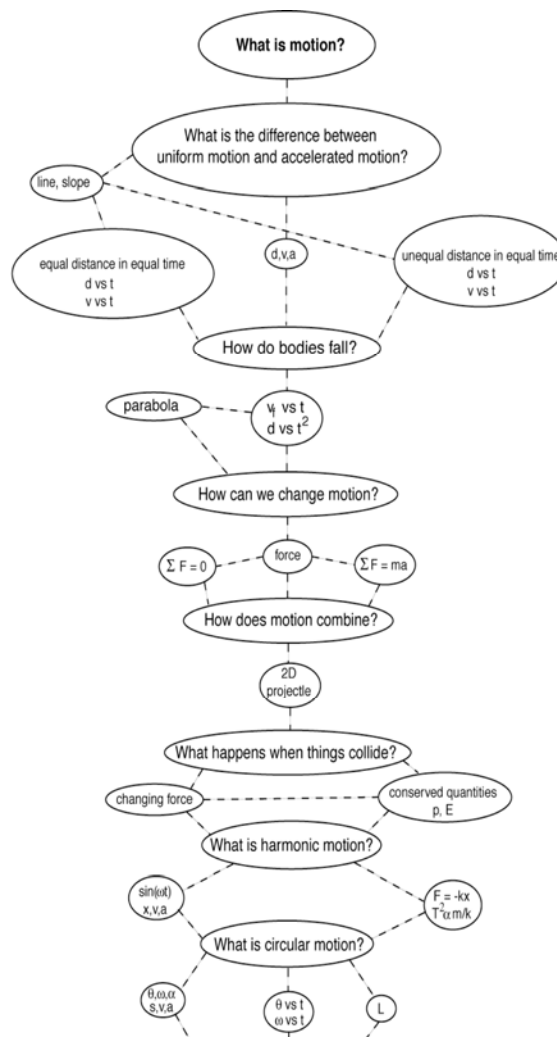
extended investigation with virtually no input from the lab faculty.

The use of these learning cycles led to an unintended but beneficial development. By constructing the experience about these learning cycles, we imposed a rhythm of thought, action, and experience. Play theory sheds light on the importance of this aspect to better engage the attention of the students and enhance the level of meaning to the lab tasks. Rubrics based on the discussions among the students were used to assess the quality of the critical inquiry. By monitoring the level of critical inquiry, we were also paying close attention to the experience of the lab environment from the perspective of the “players.”

Pursue extended inquiry

The idea that all experiments have a known answer and can be verified in 3 hours is a common perception among students at the introductory level. A key element of the lab experience was to emphasize that an inquiry may continue indefinitely as the questions being asked are answered, redefined, and extended. This is possible since the Lab Questions are linked by a storyline allowing students to pursue and discover extended patterns as a result of their investigation. The assessment rubrics (used to monitor the students ability to pursue an extended inquiry) allowed us to pay close attention to the experience of the lab environment from the perspective of the “players”.

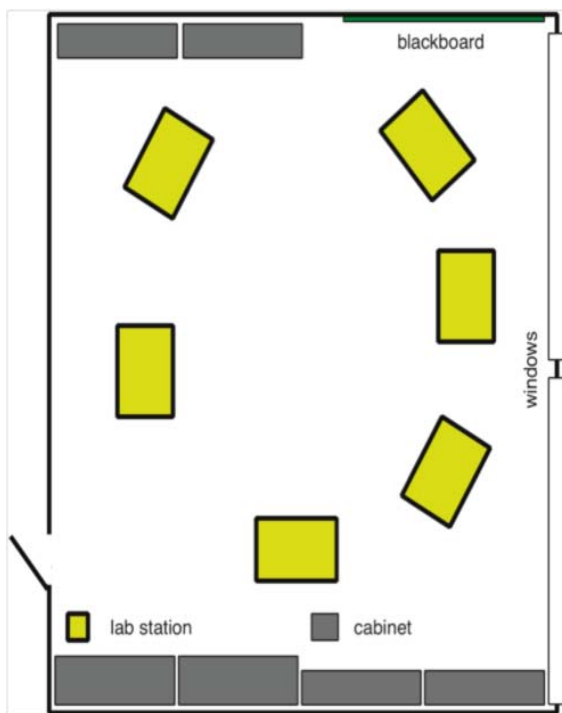
In addition, a “magic circle” of the lab room reflected the design of the curriculum. There is no center of authority and each lab station has equal status. Each lab station was separate and relatively private so that each group could develop their own investigation but stations faced one another across a common environment to encourage interaction and sharing. Each lab station had a complete set of equipment so the students have the ability to pursue and modify their inquiry independent of other groups or of the faculty.



Storyline: *An example linking the Lab Questions.*

Further explorations

Applying the paradigm of play theory to the lab course (particularly the introductory lab) is straightforward. However applying it to a lecture course is more problematic. Identifying the play elements in a theory/problem-based course needs additional work. Developing those activities that bring out the play elements of a theory course and assessment protocols that can assess learning in the extended environment of non-lab courses are other aspects that need attention.



The magic circle: Room setup for the introductory lab.

In addition to the works already cited, faculty may wish to examine the comments on play theory in physics pedagogy in *College Teaching and the Development of Reasoning* [5] and the abridged reprints in the *Game Design Reader* [6].

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Encouraging the Next Generation of Scientific Leaders

Joann DiGennaro

What are your students doing this summer?

The *Center for Excellence in Education* (CEE) offers two summer programs, the Research Science Institute and the USA Biology Olympiad, cost-free to high achieving students in science, technology, engineering, and mathematics (STEM).

From June 20 to July 31, 46 of this nation's top achieving students in STEM studies, three of whom are *Department of Defense Education Activity* (DoDEA) scholars, along with 27 students from abroad, will gather at the *Massachusetts Institute of Technology* for the annual *Research Science Institute* (RSI). Twenty of this nation's top biology scholars will gather at *Purdue University* for the *USA Biology Olympiad* (USABO) from June 6–18.

The *Research Science Institute*, jointly sponsored by the *Massachusetts Institute of Technology* and CEE, provides a unique opportunity for young scholars who are rising seniors or the equivalent to engage in cutting-edge graduate-level research and connect with like-minded peers. RSI Students, fondly referred to as "Rickoids" after the late Admiral H.G. Rickover, Father of the Nuclear Navy and Founder of the Center with CEE's President, Joann DiGennaro, participate in one week of academic courses at MIT and then spend four weeks in research internships under the mentorship of leading scientists and researchers in the Boston area. The program culminates with each student completing an academic paper and presenting their findings to their peers and a panel of judges.

RSI alumni have included 432 *Intel Science Talent Search* (STS) semifinalists, of whom eight have been first-place winners. In 2010, 60% of the top 10 awardees were alumni of RSI. Alumni are also predominately recognized in the *Siemens Competition in Math, Science & Technology* (awarded the first

place prize in 2007), and as Rhodes and Marshall Scholars and Fields Medalists.

Please contact Maite Ballestero, Vice President of Programs for CEE at maite@cee.org for more information about the RSI.

The USABO program, jointly sponsored by *Purdue University* and CEE, trains future leaders in the biological sciences. The USABO is a four-tier competition which consists of an open exam, a semifinal exam, the National Finals program culminating in a final exam, and Team USA's participation in the *International Biology Olympiad* (IBO). National finalists spend two weeks on Purdue's campus studying with leading U.S. biology professors in the subjects of cellular biology, microbiology, biotechnology, plant anatomy & physiology, animal anatomy & physiology, ethology, genetics & evolution, ecology, and biosystematics.

In 2004, Team USA won an unprecedented four gold medals in Brisbane, Australia, a feat accomplished for the first time in Biology Olympiad history. In 2009, for the third consecutive year, Team USA took home four gold medals at the *International Biology Olympiad*.

Please contact Kathy Frame, USABO Director, at kframe@cee.org for more information about the USABO competition.

What are you doing this summer?

The *Center for Excellence in Education* has just launched the *National Lab Skills Initiative* to address the challenges of instruction and learning in our nation's high school laboratories, particularly in rural and urban communities. The mission of the Initiative is to assure a future talented and diverse U.S. workforce in STEM. CEE plans to roll out the *National Lab Skills Initiative* in Virginia and

Indiana this fall. Based on the findings in these states, the program will then be inaugurated in 8–11 states before national replication.

As part of the Initiative, CEE will develop an online mentor program for Master Teachers of science education to connect with less experienced teachers, many from rural and urban areas. The Center will create a clearinghouse of laboratory experiments and lesson plans as a resource for these teachers as a component of CEE's *Teachers Resource Center*. Master Teachers of science education are encouraged to take an integral role in this exciting endeavor by submitting one or more laboratory experiences. They may be hands-on or virtual and exhibit aspects of sustainability, cost effectiveness, assessment, and replicability. It is also encouraged that activities involve public/private partnerships.

Please contact Gillian Goldmark, the National Lab Skills Initiative Manager at ggoldmark@cee.org, for more information and to become involved with this project. Visit

CEE's Web site, www.cee.org, to learn more about the Center and its programs and initiatives.

About CEE

The mission of the *Center for Excellence in Education* is to nurture high school and university scholars to careers of excellence and leadership in science, technology, engineering, and mathematics, and to encourage international collaboration among leaders in the global community. CEE has contributed to the scientific leadership of this country since its founding in 1983 by recruiting intellectually gifted and talented students and nurturing them through exceptionally designed programs to new academic heights to become tomorrow's leaders in science, technology, engineering and mathematics.

Joann DiGennaro (joann@cee.org) is the president of the Center for Excellence in Education.

Recruiting Physics Students in High School

Gabriel Popkin

What would you think if your child came home from school and told you that he or she had been advised not to take physics? You would probably be shocked, but the unfortunate fact is that such advice is frequently dispensed by well-meaning guidance counselors and others who are involved in helping high school students make academic decisions. These advisors often fear physics might hurt students' GPAs, and therefore their college prospects. They may have had a negative experience with physics—perhaps during their own high school career—or they may know nothing about physics at all beyond what is in the popular media, which is largely that physics is an impossibly complex subject reserved for geniuses (see the TV show *The Big Bang Theory* for ample evidence of this).

About a year ago, a group of us at APS and AAPT met to discuss the issue and begin developing an information campaign that would counteract the negative publicity that we know physics often gets. Although we did not have hard data on the prevalence of students being dissuaded from taking physics in high school, we had received an alarming number of independent reports of this phenomenon occurring in different parts of the country, and felt compelled to take action on behalf of the physics education community. One of our initial decisions was to enlist physics teachers to provide information to students and guidance counselors. Many teachers are members of AAPT and APS, read our organizations' publications, and attend their meetings; in addition, they are our natural allies in this campaign.

Our efforts were also informed by focus groups conducted among high school students by John Rice of *CommonSense Communications*, a marketing consulting firm. This initiative, though in its early stages, has yielded some clues into how high school students think about physics, and why more of them do not take it.

Rice thinks the fundamental problem is a dire lack of knowledge among high school students about how physics can help them in their careers and their everyday lives. He says, "High school students who take physics usually like it—especially if it is hands-on—however, almost all of them plan on majoring in engineering, because they know what they can do with engineering. They have no idea what they can do with physics. They do not know that they can use physics to treat cancer, design an electric guitar, or develop new sources of energy. There is a near-complete lack of connection between the physics taught in high school and any possible applications." As for those who choose not to study physics, Rice says that he thinks "They know what chemistry and biology are, but they do not know what physics is, or how it could be useful in their lives. All they know is that it is hard, and they are afraid it will kill their GPA."

Data from the *American Institute of Physics* (<http://www.aip.org/statistics/trends/highlite/hs2/hshigh.pdf>) show that about a third of US high school graduates take physics at some point. By comparison, over 90% take biology and over 60% take chemistry, according to the *National Center for Education Statistics* (http://nces.ed.gov/programs/digest/d09/tables/dt09_151.asp). The fraction taking physics represents a major gain over two decades ago, when it was around a fifth, but it still indicates that two-thirds of our high school graduates have not taken physics—not to mention all those who do not graduate from high school. If these students hope to compete in the high-tech 21st-century economy, they will be at a major disadvantage.

It also hurts their chances of getting into a good university. According to Vikki Otero, Senior Assistant Director of Admissions at the University of Colorado at Boulder, "College admissions is never just about the GPA. We are interested in seeing that students have

maintained an excellent college prep curriculum. A transcript with physics is better than one without it.” This sentiment is echoed by Greg Pyke, Senior Associate Dean of Admissions at Wesleyan University, a liberal arts university in Middletown, Connecticut. Pyke says, “Highly selective colleges and universities look for students who have taken a very demanding program in high school, which includes courses such as physics. The rigor of the program is often more important than the final grades they get.” Over three-quarters of incoming Wesleyan freshmen have taken physics in high school; at Caltech, physics is a requirement for admission.

With all this in mind, we have developed a multi-pronged approach to recruiting high school students, which began with a survey of physics teachers to gather best practices for increasing course enrollments. This yielded a number of interesting and clever strategies that included making sure the chemistry and math teachers in their school promote physics to their students (since these courses typically come before physics in the curriculum); inviting guidance counselors into their classroom to observe hands-on activities; and doing fun labs and activities in high-visibility places around the time that students enroll in courses for the following year. Much of this wisdom was distilled in an article [1] in *The Physics Teacher* by Earl Barrett, a high school teacher with many years’ experience in recruiting students to his program.

Our next effort was to develop a poster entitled “Top 10 Reasons Why You Should Take Physics.” This poster uses humor and colorful graphics to communicate the many benefits of studying physics, which range from broad incentives such as “Physics teaches you how to think,” to specific careers and technologies that

rely on physics. We have distributed this poster to thousands of physics teachers by inserting it into an issue of *The Physics Teacher* as well as by handing it out at APS, AAPT, and *National Science Teachers Association* (NSTA) meetings. The poster can also be downloaded or ordered at <<http://www.aps.org/programs/education/posters.cfm>>.

These are the first steps we have taken toward filling the physics information vacuum, but there will need to be many more if we are going to ensure that every student has the opportunity to enjoy the benefits that physics has to offer. Some future efforts we have in mind are:

- Publishing an op-ed piece in *The Science Teacher* about the importance of physics in the high school curriculum.
- Designing a brochure for teachers to give to guidance counselors explaining the benefits their students will get from taking physics.
- Creating an online “toolkit” for teachers to recruit more students into physics classes. This will have a home on the web at <http://www.compadre.org/careers/>.
- Engaging *Society of Physics Students* chapters in recruiting high school students to study physics.

Finally, we want your help. If you have ideas on how to recruit high school students into physics, please email us at popkin@aps.org.

Reference

- [1] E. Barrett, “Increasing physics enrollment in your school,” *Phys. Teach.* **47**, 399–400 (2009).

Gabriel Popkin (popkin@aps.org) is an *Education Projects Manager at APS*.

Physics Class Field Trips to the Local Science Museum

Helen Briggs

A little over 25 years ago, my algebra-based physics class begged for a field trip. The biology classes got to go lots of places but we did not. They suggested a trip to Discovery Place in Charlotte. It is a 20 000 square foot interactive science museum about 90 minutes away from our campus. I got a van and away we went for a day of fun, or so I thought. The problem was that the students looked at the exhibits but did not touch anything. They really did not have any concept of what to do and were a little afraid that they might do it wrong or worse yet, break something. It was an educational failure for them and a big disappointment for me.

The next year we went back but this time I came prepared with a rough map of where to locate 10 specific exhibits and a series of required activities for each student to do at the selected stations. We were going to make it a “real” physics lab, complete with data acquisition and calculations. They came away excited about what they had learned and amazed at all the different places we managed to find physics.

The following year I could not afford the time or money necessary to take my class to Charlotte. They were disappointed because this had been viewed as the reward for surviving an entire year of physics class. One of my students suggested we go to the local science museum, the Catawba Science Center. I agreed and went on my fact finding mission the next week. They had a lot of “standard” physics

exhibits: whisper dishes, giant kaleidoscope, flow tunnel, and so on. I drew a map and wrote out required activities for our visit. I was amazed at how much fun and excitement the students had. Using simple measuring devices I provided (a stopwatch and a measuring tape) and the 12 exhibits I picked out, they saw connections for the physics we talked about the entire year. There were activities related to mechanics, optics, thermodynamics, and even acoustics. Two students subsequently became volunteers for the science center and several wanted to know what the regular hours of operations were so that they could bring their friends!

This was the start of a tradition for my physics classes. Every year they look forward to their “fun” lab and the science at the museum. I mention the lab activity all year long to build anticipation. I have managed to keep this field trip fresh because the science center changes its exhibits and brings in new ones on a temporary basis. The downside is that I sometimes cannot do a favorite activity because it is no longer on the floor and I have to go every year to review the exhibits and write up new instructions for the ones I pick. I am always glad we go. The students thank me and often branch out to try things I did not require. It opens their eyes to see science in the world around them.

Helen Briggs (Helen.Briggs@lr.edu) is an Associate Professor of Physics at Lenoir-Rhyne University in Hickory, NC.

2009 Topical Conference on Advanced Laboratories

Randolph Peterson and Gabe Spalding

Physics laboratory instruction after the introductory course sequence was the focus of last summer's advanced lab topical conference, held at the University of Michigan on July 23–25, 2009. One hundred and fifty participants from one hundred universities and colleges came to explore the meaning and purpose of advanced undergraduate laboratories and research experiences in the physics curriculum. Broadly the conference goals were that attendees should have come away with:

- An understanding of the wide variety of *curricula* used for laboratory instruction;
- Techniques for programmatic preparation for undergraduate research and for integration of undergraduate research with the instructional laboratory curriculum;
- Methods for assessing student understanding in laboratory instruction, including in particular assessment of writing;
- A broader view of teaching strategies and pedagogy for the laboratory;
- A knowledge of, and *hands-on* experience with, new or improved experiments and techniques; and
- Knowledge of commercially available equipment appropriate for advanced labs.

Ten invited speakers addressed these issues by reflecting on their own experiences and lab programs. There were three panel discussions to explore these issues, followed by breakout discussion sections related to more specific subfields of research or laboratory instruction, such as teaching electronics, programming and interfacing of computers with laboratory equipment, and new experiments in fields such as biophysics and condensed matter physics.

In addition to the discussion and presentations, there were 54 workshops on advanced lab experiments and interfacing languages in the afternoons, allowing everyone to “walk-the-walk” of the hands-on experiential education that advanced labs represent. Faculty from the University of Michigan presented 10 of their

advanced lab experiments as part of these workshops. Participants from other universities also brought complete experiments, and 12 vendors brought commercially produced instructional experiments, greatly extending the number of available workshops. While workshops using the *LabVIEW* and *MATLAB* programming languages for interfacing experiments were held for larger groups of up to 16 people, we were able to limit enrollment for the other “hands-on” workshops to 5 people at once, by repeating those workshops multiple times.



Conferences focused on this portion of the curriculum have been rare, with the last one, *LabFocus*, run in 1993. Last summer's conference was also unusual in the amount and level of equipment brought by participants and vendors for hands-on, extended demonstrations and interactions. In addition, PIRA (*Physics Resource Teaching Agents*) provided a wide array of lab demonstrations in an evening presentation specifically tailored for advanced physics courses.

There are many reasons to suggest that it should not be another 15 years before the next focused conference on advanced labs occurs. Interest in this conference was clearly very strong, as registration had to be capped due to space limitations at 150 participants. Moreover, preliminary results of a survey

regarding the status of laboratory instruction beyond the first-year courses, conducted by ALPhA (the *Advanced Laboratory Physics Association*), along with the input of a number of presenters, combined to make a clear case for revisiting this portion of the curriculum. At many institutions, advanced lab instruction is often very far from being a “shared” responsibility, in many cases with only one person (even at some very large institutions) bearing the load of the traditional Junior/Senior Advanced Lab over decades, often with minimal (less than \$1000 per year) financial investment. The consequences of this “ghetto-ization” of the Advanced Labs are often a stagnant curriculum, with almost no content that could not have been taught 40 years ago. At the same time, based on the conference presentations, there are a number of programs that are vibrant sources of inspiration and innovation. The situation is clearly one where shared opportunities for faculty and curricular development become especially important, particularly for those institutions where the relevant instructors lack the time and supporting cohort that might be desired.



Not your typical poster session.

Dissemination and discussion of individual experiments and larger curricular models should help participants’ programs to create a more cohesive, integrated four-year arc of laboratory instruction that builds and reinforces concepts across the undergraduate curriculum. In many cases, it may also result in a move towards “co-valuing” experiment with theory and simulation in the physics major, making

more room in the curriculum for new labs. That said, assessing such long-term consequences is challenging and, at this stage, a principal outcome of the conference is a set of questions facing departments. What formats work for implementation and for assessment? What new research problems have found their way into the advanced lab, and what are the advantages of injecting such “currency” into undergraduate programs? Whether discussing individual experiments, particular laboratory courses, or broader pedagogical approaches, a great deal of interaction on these questions among the participants evolved out of the invited presentations, contributed posters, panel discussions, and the wide range of engaging examples from the workshops.

The high value placed upon capstone experiences, which in many cases is dominated by experimental undergraduate research projects, was clear from many of the participants’ programs. A thrust toward more open-ended projects (and interactions with undergraduate research) within the advanced lab curricula is also motivated by progress in work on inquiry-based labs for the introductory first-year courses.

Notably, it really was by having a large gathering focused on laboratory instruction that attention was given to large curricular questions dealing, for example, with the range of goals associated with courses like the traditional Junior/Senior Advanced Lab, and the relative merit of offering laboratory instruction in focused courses that are “attached” to courses dealing with particular topics in depth *versus* those factors that lead programs to offer a range of “stand alone” laboratory courses. It is clear that there is a wide variety of approaches that have been adopted for the laboratory. While the formal, non-laboratory part of the physics course sequence for majors has often been described as a “spiral curriculum,” which revisits, reinforces, and refines key concepts, the cohesion of laboratory curricula over the four-year experience of a typical major requires much more intentional planning than just selecting interesting or challenging

experiments, because no standard cannon currently exists.

In retrospect, from the evaluations of the conference, it was a valuable experience for those involved in advanced laboratories, and needs to occur more often than the previously established window of 10–20 years between conferences with this focus. The support of the FEd (along with ALPhA, NSF, APS, AAPT, PIRA, the Physics Department of the University of Michigan, and the participating vendors) was very important to the success of this conference.

Considerable material from the presentations and breakout sessions is **available online** at <http://advlabs.aapt.org/events/event.cfm?ID=2>.

Randolph Peterson (rpeterso@sewanee.edu) at The University of the South and Gabe Spalding (gspalding@iwu.edu) at Illinois Wesleyan University, among many others, helped organize the 2009 Topical Conference on Advanced Laboratories.



Waiting for the PIRA advanced labs demo show to start on Friday evening.

Undergraduate Perspectives from the APS/AAPT Meeting

Gary White and Kendra Rand

Have you ever considered what an APS meeting looks like from an undergraduate's point of view? I find their perspectives on physics meetings refreshing, often giving me a new appreciation for such events. That's one reason why the *Society of Physics Students* (SPS) often enlists students to attend and report from national physics meetings, such as the recent "Apruary" meeting in Washington DC held February 13–17, 2010.

Following are excerpts from four student articles and from one of our SPS advisors who attended the meeting. To read the stories in their entirety, and to see other reports and highlights from the meeting, visit the webpage <http://www.spsnational.org/meetings/reports/>.

Particle Physics, Climate Change, and Dinner with Vera Rubin by Leigha Dickens, University of North Carolina at Asheville

For students like me, the opportunities to meet and mingle with the larger physics community were priceless. Sunday afternoon, after a quick trip to the National Zoo to see the famous pandas Mei Xiang and Tian Tian, I hit the presentation room to see what my peers were doing. I was very impressed with the quality of



Former SPS intern Mary Mills (left) and SPS reporter Leigha Dickens (center) enjoy dinner with Vera Rubin at the APS/AAPT Joint Meeting. At the meeting, Vera Rubin was inducted into Sigma Pi Sigma, the Physics Honors Society, as an honorary member. (Photo by Luke Heselden.)

undergraduate students have our hands in all kinds of groundbreaking work: developing better methods to manufacture super capacitors, examining the electrical properties of impurities in a two-dimensional crystal called graphene, working with quantum dots and nonlinear optics, probing the physics of amorphous semiconductors, and examining particle suspension in specially designed nano-fluids.

Where Ideas Meet by Katie Foote, Providence College

In addition to attending sessions, networking with faculty, and visiting with graduate students, I had the pleasure of interviewing Ronald Thornton of Tufts University who received the 2010 Excellence in Physics Education Award. I ended up talking to him for over an hour, listening to his adventures overseas, and hearing his advice. Originally a particle physicist, Dr. Thornton emphasized how his physics background fine-tuned his ability to calculate and model. He attributes many successes, ranging from his world-renowned educational resources to his award-winning solar house designs, to the strong critical thinking and problem-solving skills that he developed studying broadly based science.

Highlights from Washington by Erin Lease, Kutztown University

The poster session and reception was a great chance to meet with students from all over the United States and the world. Meeting and talking to so many students gave me new ideas about the kinds of physics I could study and the research positions available at different universities. I had the opportunity to speak with a graduate student who is working at CERN in Switzerland. There was a very intriguing poster on sensing ground motion with triangular lasers. I also spoke with a student who utilizes two-dimensional analysis,

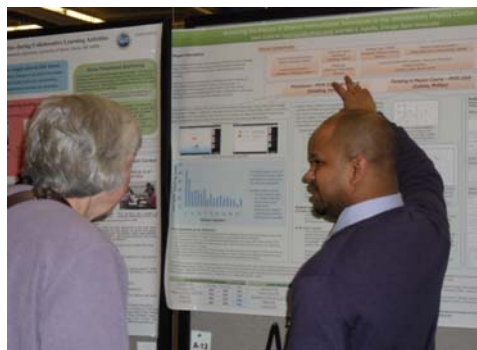
stereo imaging, and airglow tomography for measurements of upper atmospheric phenomena, including lightning-induced transients called “sprites” and “elves.” I was intrigued, having never heard a physicist talk about elves in a serious fashion.

One Neutrino’s Trip to Washington DC by David Neto, Rhode Island College

Dr. Douglas Finkbeiner gave a talk on methods for the indirect observation of dark matter. Although dark matter is not visible, there are ways that it can be indirectly detected, for instance by the photons created when a dark matter particle decays. Dr. Finkbeiner outlined a process by which data from several telescopes, including the Fermi Gamma-Ray Space Telescope, can be used to form a composite map. Then, one by one, known processes can be modeled and subtracted from the map. The excess left over could be the result of dark matter annihilations. A map was indeed made using this process and it did contain additional signals that may have been caused by dark matter!

Chicago State Physics goes to DC by Mel Sabella, Co-SPS Advisor, Chicago State University

In February, a group from Chicago State University (CSU) made the trip from the snow and cold of Chicago to the snow and cold of Washington DC to attend the joint meeting. Two faculty members, Edmundo Garcia and Mel Sabella, and six students from CSU attended and presented their work in SPS outreach (Erica), nuclear high-energy physics (Neli and Macario), and physics education research (Virginia, Sean, and Geraldine). Having students attend professional conferences is a crucial part of their educational background and is an integral part of the Chicago State science programs. Since so many of our science majors are involved in grant-funded research, our students have been able to travel throughout the country to present and discuss their work. Often the important role of presentation, explanation, and



Sean Gallardo from CSU presents his research during a poster session on Tuesday night.

discussion in science is missing from academic coursework since there is rarely enough time to explicitly address these issues. Going to conferences gives our students a better sense of the social aspect of science and the importance of discourse. Support for CSU students to attend the meeting was provided by NASA and NSF (grants 0632563 and 0833251).

Looking for a little extra support for your students to attend a physics meeting?

The *Society of Physics Students* (SPS) offers travel support at a level of \$200 for SPS chapters or individual students who report on a national physics meeting for SPS. Interested? See details at <http://www.spsnational.org/programs/awards/reporter.htm>.

To learn more about SPS and its affiliated honor society, *Sigma Pi Sigma*, go to <http://www.spsnational.org>. Forms to install a chapter are at http://www.spsnational.org/governance/handbook/sps_petition_form.pdf. There is no charge to the institution to install a new chapter.

Gary White (gwhite@aip.org) is the Director of both the Society of Physics Students and Sigma Pi Sigma, and is the Associate Director of Education at the American Institute of Physics. Kendra Rand maintains the SPS Reporter Program and helped compile this collection of excerpts.

Physicists, Philharmonics, and Youth Symphonies

Dwight Neuenschwander

Many metropolitan philharmonic orchestras maintain a Youth Orchestra. There may be a variety of attitudes with which the professional members of a Philharmonic regard the members of its Youth Orchestra. Two extremes are (1) with condescension, and (2) as colleagues. The difference is substantial for all parties, and for the state of music itself. When Youth Orchestra members are treated as colleagues by the Philharmonic members, that does not mean the differences in experience and musical maturity are irrelevant. To become Philharmonic members, the Youth Orchestra members will have to audition and earn their chairs. However, genuine expressions of collegiality nurture mutual respect. The youth respect their elders for the latter's experience, aspiring to learn from them and take their place among them. The elders respect the youth for their enthusiasm and passion. They are in this together, the art of making music. Their love of music, and their desire to excel at it, makes them colleagues. The music itself is better because of the mutual respect.

Likewise, the physics community has its professional physicists, with their PhDs, research programs, and publications. The physics community also has the *Society of Physics Students* (SPS), supported by the *American Institute of Physics*, a consortium of ten physics societies, including APS. At any moment, the SPS has between four and five thousand members, most of whom are undergraduates. How established professional physicists regard SPS members says much about who we are as a community. I would argue that the larger physics community should acknowledge the SPS members as colleagues. Both groups share a love of physics, which draws them together in shared interest and make colleagues of them already. The young are inspired and challenged by their seniors, and the seniors are challenged and invigorated by the young. Physics is the better for it.

One does not have to major in physics to belong to SPS, although most SPS members are physics majors. The physics and non-physics majors who identify with SPS deserve the respect of societies such as APS, but for different reasons. The physics majors are not merely undergraduates who happen to be taking physics courses; rather, with the proper encouragement, they quickly come to see themselves as physicists who happen to be undergraduates. The difference in emphasis is transformative. I could tell you some stories here, such as about a young man named Mike whose homework habits were originally rather haphazard. But after presenting at a regional meeting some experimental results that sampled his spectrum of skills better than homework problems, an experience which included a conversation with a distinguished leader of the topic in which he was interested, he became a serious physics major. Today he manages an industrial laboratory.

Some of the non-physics major SPS members will decide to convert to physics, but those who have committed to other majors also deserve the respect of the physics community. They are as important as the physics majors, for another reason. Just as it takes not only musicians, but also an appreciative audience for music to be meaningful, likewise the health of physics in general depends on the larger society having a substantial number of physics appreciators. Here I could tell you about a young lady named Joy who, as an undergraduate, published a paper in a physics journal and then after graduation became an insurance actuary. As an actuary she has given numerous talks at local colloquia and at national physics meetings, describing how a physics degree prepares one well, with highly transferable skills, for any career that requires evidence-based reasoning and mathematical modeling.

The education of a physicist resembles a Gothic arch with two sides. One side is the physics curriculum. The other side is extracurricular professional development. Without both sides, the arch will not stand. The professional development side of the arch, in the development of professional physicists and physics appreciators alike, is found in the

Society of Physics Students. The SPS has a crucial role for the well-being of physics.

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AAAS Project 2061: Developing Standards-Based Science Assessment Resources

Mary Koppal and Jo Ellen Roseman

Calling for the development of assessments that are “valid, support and inform instruction, provide accurate information about what students know and can do, and measure student achievement against standards,” the U.S. Department of Education’s *Race to the Top* program clearly recognizes the important role that high-quality assessment plays in education reform [1]. *Project 2061*, the long-term science literacy initiative of the *American Association for the Advancement of Science* (AAAS), shares this view and has been engaged in assessment-related research and development for more than a decade. This effort takes advantage of *Project 2061*’s foundational work in standards-based reform in science education that aims to help every student graduate from high school with the knowledge and skills needed to make well-informed personal and civic decisions and to pursue science learning over a lifetime. *Project 2061*’s seminal publications include *Science for All Americans* [2], a description of what it is that everyone should know in science, mathematics, and technology; *Benchmarks for Science Literacy* [3], a set of K-12 learning goals for all students; and *Atlas of Science Literacy* [4], a collection of knowledge maps that display connections among science ideas—conceptual, cognitive, and thematic—that contribute to a coherent understanding of the natural and designed worlds.

With funding from the National Science Foundation, the *Project 2061* assessment research team is nearing completion of a bank of items for middle and early high school science [5]. Covering 16 topics that are essential to literacy in life, earth, and physical science—including force and motion and energy transformations—the items expect students to make use of a variety of cognitive skills such as recognizing the truth of scientific facts and principles and using targeted ideas to explain, predict, and analyze phenomena. The

item bank will be supported by a set of related assessment resources, including detailed clarification of the knowledge students are expected to have for each targeted idea, descriptions of the relevant misconceptions that have been identified and documented, and student response data gathered during national field tests of the items.

Content-aligned assessments

Project 2061’s approach to science assessment emphasizes the precise alignment of items to the science ideas being tested and the identification of students’ misconceptions about those ideas. The item development process involves both qualitative alignments and the use of quantitative psychometric methods to ensure the overall effectiveness of the items as accurate measures of what students do and do not know and as indicators of the specific difficulties students may have in forming scientifically accurate understanding. After first “unpacking” and defining the boundaries of the ideas to be tested, the research team then reviews the research literature to identify potential misconceptions or alternative ideas that students may have. If the literature is inadequate, the researchers conduct their own interviews with students to supplement the existing data.

During the pilot testing phase of the process, students provide feedback on the items and their reasons for selecting or rejecting each of the answer choices. This feedback helps *Project 2061* researchers incorporate the identified misconceptions as distractors (wrong answer choices) and resolve any other problems with the vocabulary, task context, or graphics used in the item that may be confusing to students. Each item is then reviewed by scientists and science education experts using a set of review criteria to ensure content alignment and construct validity. After

revisions are made based on the reviews and student feedback, the items are field tested on a large national sample to determine the psychometric properties of the items and clusters of items. Field tests have involved more than 1000 schools and 5900 classrooms, and each item is taken by approximately 1500 students.

Undergraduate implications

Although *Project 2061*'s assessment items are designed for use in middle and early high school, the work also has implications for science teaching and learning at the college level. The research team has begun to use student response data gathered during national field tests to investigate the progression of students' understanding between middle and high school and to examine the differences and similarities in the misconceptions that students at each level hold.

To get a sense of the full range of student responses and how they might change over time, *Project 2061* researchers have also administered selected items to college students. As an example, students at two universities were tested for their understanding of a set of ideas about chemistry [6]. The undergraduates included students who had taken high school chemistry and were enrolled in a college-level introductory chemistry course but had not yet had any instruction at the college level and students who had had at least one semester of college-level chemistry instruction. By comparing the performance of the college students with students in middle and high school, the *Project 2061* researchers found that students had the most difficulty with ideas about atomic motion, changes of state, conservation of mass, and thermal expansion and were most successful with items testing the ideas that all matter is made up of atoms and that atoms are extremely small. Although the data showed a steady increase in understanding of chemistry from sixth grade to college and suggested a hierarchy of misconceptions that appear with less frequency as students become more familiar with the topic over time, the findings also pointed to the surprising

persistence of certain misconceptions even at higher grade levels. For a full discussion of these and other findings, go to <<http://www.project2061.org/publications/2061Connections/2009/media/DRK-12 Paper.pdf>>.

Online assessment resources

Scheduled to launch later this year, *Project 2061*'s science assessment web site will provide free access to the items that have been developed, along with information on the specific ideas and misconceptions that are targeted by each item, the correct answer choice, and the difficulty of the item. The site will also include national field test data—reported by gender, grade level, and primary language of the students—to provide a snapshot of what middle and high schoolers know about this set of important science ideas.

To find out more about *Project 2061*'s assessment research and development and for updates on the status of the assessment web site, visit the *Project 2061* home page at www.project2061.org and navigate to <http://www.project2061.org/cgi-bin/signup.asp> to sign up for a free electronic newsletter.

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the National Science Foundation DR-K12 principal investigators (Washington DC, Nov. 2009).

Mary Koppal is the communications director of Project 2061. The assessment research team is led by principal investigator George DeBoer who serves as deputy director of Project 2061, and by co-principal investigator Jo Ellen Roseman who directs Project 2061. The research team also includes Cari Herrmann Abell, Jill Wertheim, Jean Flanagan, David Pollock, and Abby Burrows. Contact us at 202-326-6666 or project2061@aaas.org.



John Stewart, Editor

This issue features two articles on the *Noyce Scholarship Program*. The Noyce solicitation was discussed by NSF Program Officer Joan Prival in the Spring 2009 issue of this Newsletter. The full solicitation is available at http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5733. The Noyce program offers scholarships to STEM students who commit to teaching in high-need schools. The scholarship recipients are required to teach for two years in a school district with at least one high-need school for every year of scholarship support. Gay Stewart of the University of Arkansas discusses the implementation and evolution of the Noyce Program at the U of A. Gabe Popkin of the *American Physical Society* discusses the PhysTEC project's Noyce program. This is the only Noyce program held by a professional society and may form a model for future programs in other STEM disciplines. Both programs have demonstrated success at encouraging STEM majors to join the teaching profession, increasing the pool of highly qualified science teachers. The programs both support undergraduate students and graduate students in *Master of Arts in Teaching* (MAT) programs.

The interactions between college and university STEM departments, colleges of education, and school districts are extremely complex and change from state to state and from institution to institution. As such, it makes sense to offer these scholarships as grants to university faculty who understand and have worked with the complexities. There is one element of the Noyce program at the University of Arkansas that has been so successful that I feel it could be removed from the grant model and offered as a general national program. A student graduating with a STEM degree and committing to teaching for three years in a high-need school district could be given a Noyce scholarship to pay for an accredited *Masters of Arts in Teaching* program. If offered as a general scholarship program and administered nationally, this would greatly lower the barrier to teaching for many students and go a long way to alleviating the shortage of STEM teachers.

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University of Arkansas Noyce Scholarship Program

Gay Stewart and John Stewart

The *University of Arkansas* received a *Noyce Scholarship Grant* in September 2007. It has since received two supplements to the original funding. The original goal of this UArk-Noyce program was to produce 36 new STEM teachers by granting Noyce Scholarships dedicated to improving the quality and diversity of future teachers in the state of Arkansas. The scholarship provides support for

STEM undergraduate students and STEM graduates who wish to enter the *University of Arkansas* (UA) *Master of Arts in Teaching* (MAT) program. The first supplement is supporting three career-changing physics teachers to extend their commitment to teaching in high needs schools to four years, although they only required one year of Noyce scholarship support. The second supplement

will allow five additional MAT students to be supported in 2011–2012, supporting a further increase in the number of STEM students entering teaching that the additional recruiting activities proposed in the supplement should produce. In 2001, the UA's MAT program was recognized as one of the leading teacher preparation programs in the United States. The *American Association of Teacher Educators*, the premier professional organization related to teacher preparation, awarded the MAT program with its annual *Excellence in Teacher Preparation Program Award*. This award is given to only one university each year.

Many students that initially express an interest in teaching later decide not to pursue it as a career due to the financial incentive to choose a better-paying STEM career. This barrier is substantially reduced by the scholarship program. In the first partial year and two full years of the program, students entering their senior year in a STEM discipline who wished to pursue a career in K–12 teaching were identified. The students with the best qualifications and highest need received support for both their senior year and the MAT year. A \$10,000 scholarship was awarded for the senior year and \$14,500 for the MAT year scholarship. Students receiving the senior-year scholarship were required to apply for the MAT. The UArk-Noyce program only provided two undergraduate scholarships in the first year, due to the lateness of the award date. In 2008–2009 three undergraduates and 12 new one-year MAT scholarships were awarded. The incoming 2010–2011 cohort has 16 MAT Noyce Fellows. With this cohort, UArk-Noyce will have supported 39 new teachers across the STEM fields of mathematics, physics, chemistry, biology, geology, and engineering. This represents more than a 40% increase over pre-grant production of STEM teachers.

The key to both funding and implementing the program has been a strong, well-planned, multi-faceted recruitment effort and building on capabilities and partnerships developed in other funded projects.

Recruitment

Activities that predate the UArk-Noyce program in STEM departments and the *College of Education and Health Professions* (CoEHP) initiatives provided a foundation for recruitment activities. The UA *College of Engineering* (CoE) is dedicated to the recruitment, retention, and graduation of underrepresented groups in engineering. They are also committed to improving education in the state and realize that a key component of this is more qualified STEM teachers. The physics department is part of the retention plan for the new engineering students. The new first-year engineering curriculum is built around students taking physics, calculus, and a pre-engineering problems course to help them build the skills and connections necessary to succeed. The physics courses chosen for this are PhysTEC courses, since the CoE recognizes that the methods we wish to prepare our future teachers to use are the best methods to help most students to learn. Thus, all engineering students will be exposed to the idea of teaching as a career, why it is so important and can be so rewarding.

Unlike recruitment activities in the *College of Arts and Sciences*, every student recruited by the CoE is a potential STEM teacher. Currently the underrepresented groups (African American, Hispanic/Latino, and Native American) comprise approximately 9% of the total *College of Engineering* enrollment. The College's goal is to recruit and retain underrepresented students to reflect at least 30% of the engineering student enrollment. Through such programs as *Diversity Impact Day*, *Engineering Highlights*, and *Scholar's Day*, the *Office of Recruitment* in the CoE, with the help of the *University Admissions Office*, identifies and aggressively recruits underrepresented students to attend UA. The *Office of Engineering Recruitment* employs undergraduate students who travel the state to recruit and also houses the telemarketing efforts for undergraduate recruiting. Engineering undergraduates call prospective engineering students several nights a week to increase matriculation to the UA.

Physics and CoE are also partners in the *MicroElectronics-Photonics* (MicroEP) program that has partnered since 2000 with the UA Graduate Recruitment Office in the existing UA/HBCU institutional partnership *George Washington Carver Project*, dedicating 25% of the MicroEP REU site positions to these students. As a result of these and other efforts, the REU participant population of 61 students over four years has been 34% minority and 34% female.

Efforts have been made on the UA campus to market the Noyce Scholarships to the minority fraternities and sororities beyond the CoE minority organizations, and to the Hispanic organizations on campus and in the community at large through informational meetings.

Integration with other projects

The UArk-Noyce program builds on infrastructure, experience, and partnerships formed during previous funded educational projects. The University of Arkansas Fayetteville became a primary PhysTEC site in 2001. For the first few years of the PhysTEC program, the MAT prerequisites were such that students deciding late on a career in teaching could not enter the program without an extra year in school, so they pursued nontraditional licensure. Our first PhysTEC teacher graduated in 2002. Five physics and one mechanical engineering graduates successfully completed the alternative licensure program, as well as two graduate students who had been heavily involved in teaching in the PhysTEC courses that decided they wished to teach high school by 2005.

While the number of physics majors pursuing a career in teaching increased, the 2006 MAT class was the first to have physics majors that decade. The MAT provides a much better preparation for these teachers than alternative licensure; however, the primary barrier to students getting this preparation has been financial. The UArk-Noyce scholarships help us encourage more of our students to enter the teaching profession with this optimal

preparation. This ensures a chance at a longer and more successful teaching career.

Unfortunately, graduate teaching assistantships in mathematics and science are often reserved for students pursuing a MS or PhD in the field. The UArk-Noyce Scholarships not only greatly lower the financial barrier to obtaining the MAT, but the physics department and the graduate dean have agreed to pay for more students to pursue the MAT at the close of the funding period. This will be done by giving up support for one MS or PhD student in order to fund two reduced teaching assistantships that still cover full tuition for MAT students while they carry greatly reduced teaching loads.

With the MAT program providing all majors with an excellent teaching preparation, the need is to identify science, engineering, and mathematics majors interested in and enthusiastic about teaching science. At the undergraduate level, a significant effort to produce more and better-prepared physics teachers is already underway through PhysTEC. The *American Physical Society* recognized that it is the responsibility of content departments to make sure there are adequately prepared teachers, and all recognize that there must be well prepared teachers if we are ever to achieve "Science for All Americans." The *National Council of Teachers of Mathematics* and the *Mathematical Association of America* have also recognized this need, as well as the other science disciplines. The five fundamental crucial elements of the PhysTEC project at the U of A, which allow us to serve all future STEM teachers are:

- A long-term, active collaboration among the content departments, the *College of Education and Health Professions*, and the local schools. The Department of Mathematics and the *College of Engineering* are strongly involved in this effort.
- A *Teacher-in-Residence* (TIR), a local K–12 master teacher, is a full-time participant in assisting education faculty in course revisions and team-teaching.
- The redesign of physics courses based on results from physics education research and

appropriate interactive technologies.

- The redesign of elementary and secondary science methods courses with an emphasis on inquiry-based teaching and learning. Mathematics and physics offer courses that combine methods and content for elementary majors. The mentoring program conducted by former TIRs and other master teachers provides a valuable induction experience for novice teachers.
- The participation of content-department faculty in the improvement and expansion of school experiences for their students.

The redesign of physics courses has not only constructed a model learning environment in the introductory content courses, but has also created a supporting upper-division course to guide students through a teaching internship experience. This class can be taken by advanced STEM undergraduates interested in teaching a physics lab/practicum. It can also be taken by graduate students wishing to do a better job teaching, and/or to enter into the *Preparing Future Physics Faculty* program on our campus. The course pays attention not only to teaching techniques, but how these techniques are tied to the topic being taught, helping these future teachers develop pedagogical content knowledge. While most of the students taking the course are physics majors, some mathematics, chemistry, and engineering majors considering teaching have asked to participate.

First supplement request

As with any education project, additional opportunities are identified as the project moves forward. Our first supplement request provided fellowships for career changers. We requested funding for three fellowships to be awarded to students who take a one-year Noyce scholarship for their MAT year, to allow them to switch careers to teaching physics and mathematics. Several of the Noyce recipients were not thinking of teaching as a lifelong career, but as a way to give back to the community for their education before going onto a more lucrative STEM career, or as something to do of value while they consider

for what new career they wish to prepare. In these cases, they were considering a high-needs school for only a few years, with a move into a district that can afford to pay them more as soon as possible. With an additional salary supplement of \$10,000 per year, three of these candidates, one with masters level physics research, and two with significant work experience, identified as of high potential to be effective in high-needs schools, were recruited to extend their stays in high-needs schools for a full four years. The fellowship requires a commitment that they spend a minimum of four years in a high-needs school and are committed to teaching in such a program. It is a \$10,000 stipend per year for four years. All three scholarships have now been awarded, placing exceptionally qualified teachers in high-need classrooms in Arkansas and Arizona.

Second supplement request

The project seeks to expand the pool of applicants for mathematics and physics teaching more broadly. A recruiting tool with great promise would be the involvement of students as early as following their sophomore year in teaching experiences in the summer, carrying a summer stipend. The UArk-Noyce project is uniquely positioned to offer an excellent experience dovetailing with the efforts of our recently funded NSF MSP, the *College Ready In Mathematics and Physics Partnership*. Sophomores identified through the introductory reformed classes in mathematics and physics that have strong teaching potential are being asked to join the in-service summer workshops, and are paid a stipend to assist the workshop leaders. They will be placed in positions to form bonds with in-service teachers and to see what the career entails. This will provide exceptional additional preparation for the existing learning assistant program in physics, and will form a basis for the new learning assistant program being established in mathematics. Some stipends will be used to help establish the *Mathematics Learning Assistant* program, until the structure is established so that it can be a course taken for credit by interested students,

as it is in physics, making it possible to sustain with no external funding.



PhysTEC-Noyce future teacher Tiffany Redding (center) and UArk-Noyce future teacher Marshall Scott (front).

The Noyce Scholarship program at the University of Arkansas has allowed many highly qualified candidates to enter the teaching profession and encouraged teachers already in the classroom to continue in high-need situations.

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PhysTEC Scholarship Program for Future Physics Teachers

Gabriel Popkin

The *Physics Teacher Education Coalition* (PhysTEC) *Noyce Scholarship Program* recently awarded its second round of scholarships to fourteen students at five universities, bringing the total number of scholarships awarded under the program to nineteen. Four scholars from the first round were awarded a second year of support, and ten new scholars joined the program this year. The *PhysTEC Noyce Scholarship Program* is led jointly by APS and the *American Association of Physics Teachers* (AAPT) as part of the larger PhysTEC project, which funds selected universities to develop their physics teacher preparation programs and increase the number of qualified physics teachers they graduate.

The 2010–2011 scholars attend Ball State University, Cornell University, Seattle Pacific University, the University of Arkansas, and Western Michigan University, all of which have received funding under the PhysTEC project. Six scholars will be seniors in 2010–2011, and eight will be post-baccalaureate students. Each will receive a \$15,000 scholarship to pursue his or her goal of becoming a physics teacher, and in turn has made a commitment to teach in a high-need school after graduation. Now that the PhysTEC Noyce Scholarship Program is in its second year, we can reflect on what we have learned, and where we believe the project is headed. This article will discuss the general outlines of the program, our strategies for recruiting teachers, and our vision for the future.

Program overview

In 2008, the APS and AAPT won a \$750k award from the *National Science Foundation* (NSF) to provide *Robert Noyce Teacher Scholarships* to around thirty future physics teachers at PhysTEC-funded institutions over the next five years. Six institutions—the five listed above as well as the University of North Carolina-Chapel Hill—signed on to be PhysTEC Noyce sites. Typically the *National Science Foundation*, which runs the *Robert Noyce Teacher Scholarship Program*, gives grants to faculty members at universities, who then grant scholarships to applicants from all science, technology, engineering, and mathematics (STEM) majors. The PhysTEC Noyce award is the first given to a professional society, as well as the first to focus on a single science discipline. According to NSF Program Officer Joan Prival, “The PhysTEC Noyce project is providing a unique implementation of the Noyce program, and we are very interested to see how the project will benefit from the involvement of a professional society working with a consortium of institutions.”

For APS and AAPT, the project has two major benefits. One, it allows us to award these scholarships entirely to future physics teachers, which are among the hardest teachers for schools to hire in any math and science field. And two, it ensures that PhysTEC graduates who take the Noyce scholarship will be teaching in the underserved communities where they are needed the most. Specifically, recipients commit to teach for two years in a high-need school district for every year of scholarship support, where “high-need” is defined as any district in which at least one school has a high proportion of low-income students or out-of-field teachers, or a high teacher turnover rate. This is actually a very broad category that includes a significant fraction of US districts, and Noyce teachers typically have little problem finding a position where they can fulfill their commitment.

The Noyce program began in 2002, and received a major boost from Congress in the form of a 2008 supplemental appropriations

bill that dramatically increased its budget. The increase was a direct response to the call for increased preparation of more STEM teachers in the National Academies’ influential *Rising Above the Gathering Storm* report. As of 2009, the program had made 249 awards that supported 2587 future teachers. The philosophy of the program is to provide an incentive for STEM majors to go into teaching, a field typically offering lower salaries than many other career options available to those with a technical background.

We have found that the financial support does indeed make a big difference to students who are considering whether they can afford to go to school to become teachers. According to Gay Stewart, a University of Arkansas physics professor and PhysTEC Noyce site leader who also administers an independent Noyce project, “The Noyce scholarships allow my students to spend their time learning to teach instead of working or worrying about loans. We have an award-winning *Master of Arts in Teaching* program, but it is full-time and students don’t get support or have time to work. We should not ask our students to choose teaching over higher-paying professions, and then tell them they need to go into debt to become a teacher.” Vera Lyman, a Noyce Scholar and graduate of the *University of Colorado* at Boulder, echoes this, saying, “Student teaching is a particularly hard time financially for teachers who are just going into education, so to have that scholarship when I was student teaching was really helpful.”

Recruiting teachers through Noyce

The success of the PhysTEC Noyce Program depends on effective recruiting of talented students who may be interested in teaching. To this end, we have designed posters and brochures to advertise the program, and sent them to the six project sites each fall to be put up around the physics department and science building. In addition, we have a website (www.PhysTEC.org/noyce) and we recently produced a video promoting physics teaching careers, which can be viewed at www.PhysTEC.org/video. We are in the

process of producing a version of the video specifically aimed at potential Noyce applicants, which will be ready by the 2010 NSF Noyce Conference. Posters and brochures may pique students' initial interest, but that is just the beginning of the process. In fact, the most important thing we have learned about recruiting physics teachers is that it is individualized encouragement, advising, and mentorship that makes the real difference. There is no substitute for hearing from a respected professor, "You know, I think you would make a great physics teacher." Becoming a teacher is a commitment of many years if not a lifetime—first to an educational track that leads to teaching certification, and second to service in the classroom and ongoing professional growth to become an expert teacher. Some people are on the teaching track from an early age, but as we see over and over again in the data, very few of these people get physics degrees. Likewise, many students discover and pursue a passion for physics, but not nearly enough of them are drawn into teaching the subject they love.

Several of our scholars were inspired to pursue physics teaching by the experience of having a bad physics teacher in high school. This experience gave them the opportunity to help

their peers understand the subject (since the teacher had failed to do so) and thus discover the joys of teaching. Thus it is not surprising that one of the most effective strategies we have seen for developing interest in teaching is an early teaching experience called the Learning Assistant program, which most PhysTEC sites now implement in some form (<http://www.phystec.org/components/learning-assistants>). Learning Assistants are talented undergraduates who work with faculty members to make large-enrollment courses more collaborative, student-centered, and interactive. Such programs provide potential future teachers with strongly supported and low-stress early teaching experiences. In some cases, students in the Learning Assistants (LA) program first discover an interest in teaching through their experiences as an LA. The specific roles that Learning Assistants take on can vary between courses, but the common elements that distinguish them from conventional teaching assistantships are that Learning Assistants are typically recruited from among the top students in their class; they participate in a pedagogy course that introduces them to interactive teaching techniques and education research; and they are actively encouraged to enter a teacher certification program, often as a requirement for continuing in the program in future semesters.

Seattle Pacific University (SPU) has made its Learning Assistant program the cornerstone of its recruitment strategy. Site leader Lane Seeley describes his department's efforts to create an environment that emphasizes teaching and learning, "From their first day in a physics class at SPU, students are expected to fully participate in a community of physics learners, taking responsibility for their own learning as well as the learning of their peers. Students who were drawn to the intellectual challenge of science begin to recognize science teaching as a uniquely complex intellectual pursuit. The SPU Learning Assistant program consistently recruits some of the university's most accomplished students, who are drawn to the challenge of helping others construct physics understanding. For them, the Noyce

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Scholarship represents both an affordable plan and call to conviction. The decision to apply for a Noyce Scholarship is also an opportunity to transform their interest in physics teaching into a firm plan. One lesson we have learned at SPU is the importance of paying personal attention to individual students. A strategic teacher recruitment and preparation program is important, but there is no substitute for one-on-one mentorship. When we sit down with our students and tell them why we think they would be a great physics teacher they really take it to heart.” The success of Seattle Pacific’s efforts to engender in their students a desire to teach is evident in the fact that seven SPU students were awarded scholarships this year.

Another master of the personal touch is Gay Stewart, whose success in advising and mentoring prospective teachers have led to national recognition for Arkansas’ physics teacher preparation program. Stewart says, “Even when you have gotten a student interested in a career teaching physics, there are many roadblocks and distractions that can easily divert them from the teaching track. I work with all my future teachers every semester to make sure they are taking the right courses, getting the right experiences, and staying on track to graduate with the preparation they need to be successful. The Noyce scholarship is a huge help in that it removes the major distraction of how to pay for school, and the expectation of teaching in a high-need school also helps solidify my students’ commitment to the teaching career.”

What comes next

It is abundantly clear by now that mentoring and professional development for beginning teachers is as important to their professional success as is their undergraduate preparation. Because the first cohort of PhysTEC Noyce Scholars are only just now completing their scholarship term, the project does not yet have any teachers in the field. But as these teachers begin to graduate and enter the classroom, we plan to support them through a variety of

measures. After each of their first two years of teaching, all PhysTEC Noyce teachers will receive funding to attend a one-day professional development program before the AAPT Summer Meeting, as well as the meeting itself. The project also plans to provide opportunities for teachers to attend longer professional development workshops, such as those offered by the *Modeling Instruction Program*. In addition, the project has offered funding to its sites to hire part-time Teachers-in-Residence to help mentor recent graduates as well as current scholarship recipients. Beyond their cohort in the PhysTEC Noyce program, we expect our graduates to become part of the growing network of Noyce Scholars from around the country. Noyce scholars who are now teaching cite this network as one of the principle benefits of participating in the program. As Shelly Stachurski, a Noyce Scholar and graduate of the University of Colorado at Boulder, says, “I can attend a conference and inevitably I will run into a Noyce scholar. We will have that connection and immediately we can start talking about how having the Noyce scholarship and this network influences our teaching practice. We share resources, we share stories, and we share email addresses and stay in touch.”

Ultimately, the PhysTEC Noyce project hopes to support around 30 teachers over the next five years. But the larger goal of the project is to create not just teachers, but teacher leaders, who will have an impact that stretches beyond their classroom to their fellow teachers, as they take on leadership roles within their districts and professional organizations. As Valerie Otero, PhysTEC site leader and Noyce program administrator at the University of Colorado at Boulder, says, “Noyce Scholars are the future teacher leaders of this country. They are going to be the ones who figure what the education of tomorrow looks like.”

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The Real Meaning of Common Teaching Phrases

Carl Mungan

<i>peer instruction</i>	What is happening when 5 workers are at a construction site and only 1 has a shovel.
<i>structured reflection</i>	Student complaints about your course policies.
<i>inquiry-based activity</i>	What instructors have the students do when they didn't have time to fully prepare their notes.
<i>constructivism</i>	Attempting to construct sense out of student nonsense.
<i>assessment</i>	Retroactively making up explanations for why you did what you did in the course.
<i>curving the grades</i>	Rewarding students who didn't learn the material.
<i>problem-solving sessions</i>	Doing the homework for the students.
<i>physics education research</i>	Double-counting teaching as research on your annual faculty activity report.
<i>conceptual understanding</i>	Attribute of students who cannot solve problems.
<i>student-centered teaching</i>	Any classroom technique that is effective in the instructor's opinion.
<i>extra credit</i>	Benefitting students who didn't make time for homework.
<i>modeling method</i>	Working through all the steps of an example problem.
<i>interactive engagement</i>	What happens when the instructor is present in class, as opposed to "inactive engagement" when the instructor is absent.
<i>mastery learning</i>	Allowing students to repeat a test until they have memorized all possible permutations of it.
<i>course objectives/standards</i>	A list of everything students probably know about the subject before they take the course.
<i>collaborative environment</i>	The result of randomly rearranging desks in your classroom.

(In the spirit of a similar list entitled "Useful Research Phrases" which you can find by googling it.)

Browsing the Journals

Carl Mungan

• The May 2010 issue of *The Physics Teacher* (<http://scitation.aip.org/tpt/>) has a short but insightful article by Elisha Huggins about weighing a hollow cube whose walls are coated with mirrors between which a photon is bouncing. Does it matter whether the photon is bouncing vertically or horizontally? Also check out Boris Korsunsky's Physics Challenge entitled "Be There *and* Be Square" in the same issue. But beware because this problem is *much* harder than some of the ones in preceding issues!



• I enjoyed the interesting variety of Notes and Discussions in the June 2010 issue of the *American Journal of Physics* (<http://scitation.aip.org/ajp/>).

• The May 2010 issue of the *Latin-American Journal of Physics Education* (<http://www.journal.lapen.org.mx/>) has a lengthy article entitled the "Sliding rope paradox" which discusses a rope suspended over a frictionless peg off of which it is sliding. The connection with the well-known falling chain problem is also considered.

• There have been plenty of arguments about how airplane wings create lift. The most recent article on this topic is by Silva and Soares in the May 2010 issue of *Physics Education*. Another well-discussed problem is that of crossing a river in a boat. O'Shea considers some complications involved in that task in an article in the July 2010 issue of the *European Journal of Physics*. Look for both journals at <http://iopscience.iop.org/journals>.

• The *Journal of Chemical Education* has finally implemented a fully electronic submission procedure and a spiffy new webpage for accessing their journal at <http://pubs.acs.org/journal/jceda8>. You might be interested in one chemistry educator's heuristic interpretation of quantum mechanics on page 559 of the May 2010 issue.

• Some interesting letters to the editor appeared in the May 2010 issue of *Physics Today* (<http://www.physicstoday.org/>), stimulated (excuse the pun) by the January 2010 article about the discovery of the ruby laser in 1960.

• Finally, Art Hobson of the University of Arkansas passed along the following. The Jan–Feb 2010 issue of *Environment* has an article entitled "Now is the time for action" authored by 16 members of the National Science Foundation's *Advisory Committee for Environmental Research and Education*. They argue that "environmental issues must become a priority for the security of citizens and governments around the world," that "the world is at a crossroads" with "little time to act," and that "conducting research and education via a model of business-as-usual will not be sufficient." The Committee makes five recommendations: (1) increased support for interdisciplinary environmental research; (2) NSF must become a more interdisciplinary organization that attracts integrative research and education; (3) NSF must lead in implementing an integrated system of observational sensor networks that measure environmental variables and related human activities; (4) new approaches are needed for environmental education and public engagement; and (5) scientists must help policymakers develop a better understanding of environmental systems, including tipping points and the socio-economic effects of environmental change.

Web Watch

Carl Mungan



- AAPT has started a webpage dedicated to Advanced Undergraduate Physics Laboratory Experiments at <http://advlabs.aapt.org/>. Arbor Scientific has collected together a great set of demos and newsletters relevant both to high school and college-level physics at <http://www.arborsci.com/CoolStuff/>.
- SPIE has a web portal devoted to photonics resources at <http://optics.org/>. You can also sign up for weekly email alerts. AIP has a timeline with historical photographs leading up to the discovery of the laser at <http://www.aip.org/history/exhibits/laser/>. Another nice history lesson of the laser is available from Science News at http://www.sciencenews.org/view/feature/id/58499/title/Inventing_the_Light_Fantastic. Finally, Cochin University of Science and Technology in India has a photonics portal at [http://www.photonics.cusat.edu/Knowledge Portal.htm](http://www.photonics.cusat.edu/Knowledge_Portal.htm).
- Another web portal offering email alerts is Science360 supported by NSF. It covers all fields of science at <http://news.science360.gov/>. A well-known portal devoted to educational resources in general is at <http://www.merlot.org/>.
- The Institute of Physics (essentially the European counterpart of the AIP) has unveiled a new web platform for its journals at <http://iopscience.iop.org/>.
- Harvard's Department of Physics has started a Video Archive of lectures (both recent and historical) by well-known physicists at <http://www.physics.harvard.edu/about/video.html>. A mathematician has also collected a lengthy set of movie clips at <http://www.math.harvard.edu/~knill/mathmovies/>. For example, check out "A Serious Man" for a hilarious snapshot of a blackboard explaining the Uncertainty Principle. (Did you catch the mistake he made in the derivation?)
- Some well-designed Flash animations for physics are organized topically at http://www.sciences.univ-nantes.fr/physique/perso/gtulloue/index_a.html.
- There are many Periodic Tables on the web with different special features. Someone had the cute idea of constructing a periodic table of periodic tables at <http://www.keaggy.com/periodictable/>. Another useful resource is NIST's digital library of mathematical functions at <http://dlmf.nist.gov/>.
- Edwin Taylor and Slavomir Tuleja have an interactive explanation of the Principle of Least Action at <http://www.eftaylor.com/software/ActionApplets/LeastAction.html>.
- I suppose you know that to get a partial derivative of f with respect to x in HTML you would write $\frac{\partial f}{\partial x}$. If not, consult say http://comers.citadel.edu/math_sym2005.htm.
- Have you ever thought about going abroad for a year as a Fulbright Scholar? Learn about qualifications and how to apply at http://www.cies.org/us_scholars/us_awards/.
- A colleague sent me a link to a video at http://www.lsu.edu/pa/mediacenter/tipsheets/oilspill_hydrates_video.shtml of the growth of a white hydrate plug inside a capped tube lowered into escaping gas bubbles from the sea floor, demonstrating why BP's "top hat" approach failed.

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