

Forum on Education

American Physical Society

Spring 2014 Newsletter

Beth Lindsey, Editor

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

From the Chair

Paul Cottle, Florida State University

If you want to know what educational policy-makers and thought leaders think is hot in physics education, start with this lead from the December 5 issue of the *New York Times*:

To ease the way for students grappling with certain key concepts, professors at Davidson College in North Carolina will design online lessons for high school students in Advanced Placement courses in calculus, physics and macroeconomics and make them widely available through the College Board and edX, a nonprofit online education venture.

Given the tremendous work that the Davidson Physics faculty has done over the years in using technology to improve physics learning, we can all have confidence that the product of this initiative will be cutting-edge and will benefit the high school students who use it. But as this issue of the Forum on Education newsletter illustrates, the Davidson faculty has plenty of company in making important advances in the uses of technology for improving student learning, both in physical classroom and virtual environments.

There are particularly important challenges for the developers of virtual learning environments to overcome. Those of us who work in SCALE-UP classrooms and similar environments understand the power of interactions among students and between students and faculty for promoting learning. It is difficult to imagine an effective virtual environment that doesn't somehow replace those in-person social interactions with equivalently intense interactions between real human students and faculty over some medium like the internet. If you accept that, then you also realize that virtual learning environments will not replace highly qualified physics instructors. But they will allow students in remote locations like small rural communities

to have access to high quality physics instruction.

All of which is to say that virtual physics courses will never "solve" the high school physics teacher shortage, as some policy-makers hope they will. Last year, one state legislator in Florida repeatedly talked about allowing students to earn their physics credits by watching Walter Lewin's entertaining lectures. If only it were that easy to learn physics! But of course, MIT doesn't teach physics to its own students that way (the subject of another *New York Times* article, this one from January 12, 2009). Lewin himself emphasized the importance of other aspects of learning (like labs!) in a comment on the *New York Times* "Room for Debate" feature in May of 2012.

Nevertheless, I've been told over and over again by my own state's policy-makers (giving a list here would only get me into more trouble) that virtual physics will solve the state's physics teacher shortage. This is fueled in part by the standard desire for a cheap and easy solution to an instructional problem in what is generally considered to be a low-priority subject. But the certainty that virtual learning will solve the physics teaching problem is also the result of a deep-seated ignorance about how students learn science. One of the difficult tasks the community of physics educators has before it is leading our leaders to an understanding of how students learn science. Reading a textbook doesn't do it. Watching a video of an entertaining lecturer doesn't do it (even if it's Walter Lewin). Learning happens when a group of students and a passionate instructor invest in the hard work of making measurements (physical or virtual) and use the results of those measurements to help each other along the rocky road to understanding a new concept. For most of us, there are no shortcuts.

From the Editor

Beth Lindsey

This issue of the Forum on Education newsletter has the theme “Online Physics Education.” Many of us have observed the trend toward increased online course offerings at our universities. Last summer, the APS offered a workshop on Distance Education and Online Learning in Physics. The workshop report is available on the APS Website. At that workshop, participants discussed available resources, the evidence for what works and what doesn’t, and many of the challenges and opportunities facing educators in the online environment.

This newsletter includes five articles in which educators (many of whom participated in the APS workshop) share their experiences with online physics courses or resources. First, Gerd Kortmeyer describes how online courses are delivered at Michigan State University, and the impact that findings from online courses have had on their more traditional counterparts. Andy Rundquist describes how the availability of online materials resulted in his “flipping” the entire physics classroom experience, including more recent work with general education courses in which he is once again rethinking what a “flipped classroom” could mean. Tim Stelzer and Mats Selen provide a thoughtful discussion of their develop-

ment of online prelectures and reflect on the ways in which higher education and its goals are changing. Mike Schatz describes his experiences developing a Massive Open Online Course (MOOC) in physics.

Although many of us may remain skeptical that the essence of a physics course – incorporating interactive engagement elements and appropriate lab work, and maintaining a strong foundation in inquiry – can be conveyed in an online format, the articles in this newsletter demonstrate that some of our peers have found ways of successfully moving physics courses online, or integrating online and in-class course components. A common thread throughout all of these articles, however, is the effect that experiences with online materials have on instruction in more traditional environments, and the many open questions that remain regarding the most effective way of delivering online materials. Hopefully these articles will give you some insights into what works well in online physics education, what resources are out there, and what questions are currently open for investigation regarding the effectiveness and impact of online physics course resources.

Forum on Education Invited Sessions – March 2014 Meeting

Bringing Newcomers into the Physics Community - The Importance of Growth and Community Support

(A38, Monday 8:00 AM, Chair: Angela Little, University of California, Berkeley)

- Developing mindful, collaborative, and resilient physics students through regular reflection and empathetic feedback, Dimitri Dounas-Frazer, California Polytechnic State University
- Building Bridges to Belonging: Mindsets that Reduce Stereotype Threat and Increase Participation, Achievement, and Learning in STEM, Catherine Good, Baruch College, CUNY
- Enlightened Searches for Talent are Needed to Bring Newcomers into Physics, Casey W. Miller, University of South Florida
- Title TBA, Kathleen Hinko, NIST – Boulder
- Panel Discussion: Common Themes Across “Bringing Newcomers Into The Physics Community”, Angela Little, University of California, Berkeley

Graduate Education: Sustaining Thriving Programs by Embracing Challenges and Opportunities in the 21st Century

(G 38, Tuesday 11:15 AM, Chair: Theodore Hodapp, APS)

- Highlights From the Second Conference on Graduate Education in Physics, Renee Diehl, Pennsylvania State University
- Increasing Diversity in Physics at the PhD Level and Beyond, Keivan Stassun, Vanderbilt University (Winner of the Nicholson Medal for Outreach; Prize talk)
- The Landscape of Graduate Admissions: Surveying Physics Programs about Doctoral Admissions Practices, Geoff Potvin, Florida International University
- The future of the graduate physics curriculum and exam structure, Michael Thoennessen, Michigan State University
- Preparing Graduate Students for Non-Academic Careers,

Lawrence Woolf, General Atomics Aeronautical Systems, Inc.

Assessment Issues in Physics Education

(S38, Thursday 8 AM, Chair: Eric Brewster, Florida International University)

- Research-based assessment instruments: Design, validation and interpretation, Wendy Adams, Wendy Adams, University of Northern Colorado
- Colorado Learning about Science Survey for Experimental Physics (E-CLASS), Heather Lewandowski, University of Colorado – Boulder
- Using research-based assessment to improve teaching in your classroom and department: New resources on the PER User’s Guide, Adrian Madsen, American Association of Physics Teachers
- Title TBA, Melissa Dancy, University of Colorado
- Title TBA, Eugenia Etkina, Rutgers University

Reichert Award Session: Preparing Students for the Transition from Instructional to Research Lab

(T38, Thursday 11:15 AM, Chair: Heather Lewandowski, University of Colorado - Boulder)

- Jonathan Reichert and Barbara Wolff-Reichert Award: Updating Lab Curricula via the Tom Sawyer method of painting a fence, Gabriel Spalding, Illinois Wesleyan University
- Building Scholars One Mistake at a Time, Marty Johnston, University of St. Thomas
- Results from a model of course-based undergraduate research in the first- and second-year chemistry curriculum, Gabriela Weaver, Purdue University
- Capitalizing on Community: the Small College Environment and the Development of Researchers, M.R. Stoneking, Lawrence University
- Using instructional laboratories and research experiences in physics to build better people, Sean Robinson, MIT

Forum on Education Invited Sessions – April 2014 Meeting

Impacts and experiences with MOOCs

(C10, Saturday 1:30 PM, Chair: James Brown, Wabash College)

- A MOOC for Introductory Physics, Michael Schatz, Georgia Inst of Tech
- Massive Open Online Courses (MOOCs) for Physics – and for You?, David Pritchard, Massachusetts Institute of Technology
- Riding the MOOC Tsunami, Wolfgang Bauer, Michigan State Univ

AAPT: Physics in the life sciences

(H10, Sunday, 08:30 AM, Chair: Randall Knight, Cal Poly - San Luis Obispo)

- From Random Walks to Brownian Motion, from Diffusion to Entropy: Statistical Principles in Introductory Physics, Mark Reeves, George Washington Univ
- Optimizing Introductory Physics for the Life Sciences: Placing Physics in Biological Context, Catherine Crouch, Department of Physics and Astronomy, Swarthmore College

- Coordinating an IPLS class with a biology curriculum: NEXUS/Physics, Edward Redish, Univ of Maryland-College Park

Excellence in Physics Education Award: American Modeling Teachers Association

(J11, Sunday, 10:45 AM, Chair: Michael Fauerbach, Florida Gulf Coast Univ)

- Excellence in Physics Education Award: Modeling Theory for Physics Instruction, David Hestenes, Arizona State Univ
- Excellence in Physics Education Award: Graduate Programs for Professional Development of Physics Teachers, Jane Jackson, Arizona State University
- Modeling Instruction: The Next Generation \rightarrow building and sustaining a community of practice, Colleen Megowan-Romanowicz, American Modeling Teachers Association

AAPT: Readyng Physics Departments to Engage in Teacher Preparation and Course Transformation

(M10, Sunday, 3:30 PM, Chair: Monica Plisch, APS)

- It starts with one: Leading change and forming partnerships

for teacher preparation and pedagogical change, Laurie McNeil, Univ of NC - Chapel Hill

- Sustained programs in physics teacher education, Rachel Scherr, Seattle Pacific Univ
- Research on U.S. physics teacher education, David Meltzer, Arizona State Univ

Open Innovation Labs for Physics Undergraduate Independent Research

(X10, Tuesday, 10:45 AM, Chair: Duncan Carlsmith, Univ of Wisconsin, Madison)

- Open Innovation Labs for Physics Undergraduate Independent Research, Duncan Carlsmith, Univ of Wisconsin, Madison
- Physics as a Platform for Teaching Innovation, John Brandenberger, Lawrence Univ
- The Innovation Hyperlab: a Physical and Curriculum Framework for Fostering Innovation From Grade School to Grad School, Randall Tagg, Univ of Colorado - Denver

Call for Nominations for Awards and Fellowship

Call for Nominations: APS Fellowship

Application deadline: April 1, 2014.

APS members are eligible for nomination and election to Fellowship. Each FEd nomination is evaluated by the FEd Fellowship committee. Please consider nominating outstanding candidates. Full details can be found on the nomination instructions page.

Call for Nominations: Excellence in Physics Education Award

Application deadline: July 1, 2014.

This award recognizes and honors a team or group of individuals (such as a collaboration), or exceptionally a single individual, who have exhibited a sustained commitment to excellence in physics education. Please consider nominating outstanding candidates. See full details.

The APS Reichert Award for Excellence in Advanced Laboratory Instruction

recognizes and honors outstanding achievement in teaching, sustaining (for at least four years), and enhancing an advanced undergraduate laboratory course or courses. The award will be given to an individual or a team of individuals who have taught, developed, and sustained an excellent advanced undergraduate physics laboratory course or courses for at least four years. Some or all of this activity should have occurred within the five years prior to the nomination. The course(s) will lead upper-division students to experience a broad selection of experiments in the various interest areas of physics. This may include the development of experiment(s) reflecting current research.

Nominations are due July 15. Full details can be found at <http://www.aps.org/programs/honors/awards/lab.cfm>

The APS Award for Improving Undergraduate Physics Education

recognizes best practices in undergraduate physics education. This award was initiated in 2011 by COE in order to recognize physics departments and/or undergraduate-serving programs in physics that support best practices in education at the undergraduate level. Programs are recognized for 3 years, acknowledged on the APS website, awarded a plaque, announced in *APS News*, and recognized at an APS national meeting. These awards are intended to acknowledge commitment to inclusive, high-quality physics education for undergraduate students, and to catalyze departments and programs to make significant improvements.

The annual deadline for departments to apply for the award is July 15. Full details can be found on the [undergraduate faculty award page](#).

Additional Awards of Interest to FEd members

Paul Dolan, Northeastern Illinois University; Tarren Shaw, University of Oklahoma

While these are not APS-FEd awards, you should be aware of these, and you (or someone with whom you work) may be a good candidate:

Outstanding Undergraduate Science Teacher Award (OUSTA)

Nominations are being accepted now for the Outstanding Undergraduate Science Teacher Award (OUSTA). Presented by the Society for College Science Teachers (SCST), the award recognizes the efforts and achievements of an outstanding science teacher based upon teaching, scholarship, and service. The award includes a cash prize and support to attend the 2015 and 2016 SCST national conferences. Nominations for this award can be made by students or faculty, and self-nominations are encouraged. For more information see <http://www.scst.org/grants/ousta>, or contact the awards chair Tarren Shaw at tjshaw@ou.edu

AAPT/ALPhA Award for Undergraduate Physics Students

The AAPT-ALPhA Award would be given to a student or several

students, who have built (and possibly developed) an advanced laboratory experiment that will become a new part of their school's advanced laboratory program. This work would be carried out as a senior project, senior thesis or its equivalent. A project developed over several years by a succession of students could also be eligible. In such cases, the Prize would be shared among the several students involved.

The faculty supervisor will also share in the recognition.

This award will only be given for students in colleges and universities within the greater United States.

We anticipate that this award will first be awarded for after the 2014-15 school year. More information may be obtained from David Van Baak (dvanbaak@calvin.edu) or Jeremiah Williams (jwilliams@wittenburg.edu), or at <http://www.advlab.org>.

New APS Fellows Nominated from the Forum on Education

This year there are four new APS fellows, as nominated from the FEd. Their "citations" are below.

Paul J. Dolan, Jr., Northeastern Illinois University

Citation: For contributions to education in physics, including the physics of granular materials; and especially for leadership and service to organizations involved in physics education.

Randall D. Knight, Cal Poly

Citation: For the improvement of instruction in introductory physics by the writing of textbooks, student workbooks, and instructor guides that are grounded in physics education research.

Gabriel C. Spalding, Illinois Wesleyan University

Citation: For his work to create a community of physics educators focused on physics laboratory instruction beyond the first year; for creative efforts that have made photon-quantum mechanics affordable and accessible in the undergraduate laboratory; for curricular innovations that enhance the role of laboratory in undergraduate physics education.

Stamatis Vokos, Seattle Pacific University

Citation: For using physics education research to help improve the learning of physics in Washington State, for leading the multi-year efforts of the Task Force on Teacher Education in Physics, and for serving as a nexus of multiple productive collaborations.

News from APS

Ted Hodapp, APS Director of Education and Diversity

The APS Education and Diversity Department has been working in a number of issues over the past six months. In 2012 the APS began to assume a significant role in promoting the Conferences for Undergraduate Women in Physics. These locally organized and run conferences attract over a thousand undergraduate women to come together for a weekend in January to network, share and learn about physics research, visit laboratories, and attend sessions on applying for jobs and graduate programs in physics. In 2014 there will be eight sites spread across the country from New York to Florida to California. The APS has also helped the organizers raise external funds for these conferences from the US Department of Energy and the National Science Foundation. These funds help offset travel and meeting costs, and include funds to help evaluate conference impact. Deanna Ratnikova, APS Women and Education Program Administrator, is spearheading support for the conferences including registration, advertising, and logistics (www.aps.org/link/cuwip).

The Department is also pleased to announce that the APS Bridge Program, an effort launched in 2012 was able to help 13 underrepresented minority students gain entrance into graduate programs – all of who would not have been able to advance to graduate education without the program. We are monitoring their progress and working with APS-funded bridge sites (Ohio State and South Florida) to help these students succeed in their studies. We are currently selecting additional sites, and considering how we can facilitate a national campaign to help underrepresented students attain their educational goals through improved mentoring. For more information, consult www.apsbridgeprogram.org – stay tuned.

Finally, the Physics Teacher Education Coalition (PhysTEC) will be soliciting proposals for additional sites to help universities increase the number of high school physics teachers they educate. PhysTEC has had significant success at building ongoing programs and will be releasing a study commissioned to evaluate sustainability this spring on www.phystec.org.

16 years of online physics courses at Michigan State University

Gerd Kortemeyer, Michigan State University

In Fall 1997, our first physics course went online with 32 students: algebra-based introductory physics, first semester. Sixteen years later, we have seven physics courses online, spanning the whole range of introductory course offerings, with a total of over 1600 students in 2013. What have we learned?

Early beginnings

The use of online technology in physics teaching at MSU goes back to 1992, when CAPA came online as a homework tool. CAPA is built around the idea of immediate feedback and mastery-based formative assessment. It allows for a wide range of problem randomization, such that students cannot simply copy each other's answers. The system was used as an online component of otherwise traditional physics courses, however, this being 1992, "online" meant Telnet and X-Windows. Online homework eventually replaced traditional recitations in our department, and exam performance increased as a result, particularly among female students [1]. Around the same time, a group of faculty started developing a "hyper-textbook" for introductory physics, which replaced traditional textbooks and was distributed on a CD using a system called Supercard. Prior to the launch of the first fully online course, both homework and material moved to a web-based format, which eventually became the LON-CAPA platform [1].

Content and content maintenance

We clearly had a head start in launching the first online course, as

we could port existing materials from CAPA and Supercard: we already had all the homework we needed (developed over the past five years) and all the textual material (which is significantly less than what is included in a standard two-kilogram physics textbook – seriously, who actually reads this?). At launch time, we added some Java applets with simulations and several movies with lecture demonstrations, which, like the original materials, were produced by physics faculty.

Over the years, the material underwent several iterations, and it was forked for different courses and instructors. This process has been facilitated and encouraged by the underlying learning content management system of LON-CAPA, which allows for versioning and sharing of materials across courses and even institutions. Online content clearly needs maintenance: Java is prone to fail and needs to be replaced by HTML5, video codecs become obsolete (and anyway, old 320x240 pixel videos are substandard today), new technologies and toolsets become available (Camtasia [2] currently being one of our favorites), etc. The continual renewal and expansion is supported by fine-granular asset management, which allows for modular replacement of course assets. Today, LON-CAPA hosts about 110,000 online assets for physics courses [3].

These very same assets are also used for on-campus instruction, where they form the online component of the courses, at a minimum the online homework. Recently, in a residential college on

our campus, which is offering its own version of the calculus-based sequence, a flipped design has been adopted, where students use these online materials with embedded online assessment (“reading questions”) prior to the in-class sessions on the topics. Thus, faculty time spent on the online materials also benefits the on-campus instruction.

Logistics

We essentially run our online courses as separate sections of the same physics courses, so we technically or de-facto have one course in a given semester, of which some sections are on-campus and some online. Online courses are not on autopilot. The role of their faculty instructor is not so different from traditional courses, apart from not getting to be the sage-on-the-stage. Instructors still need to answer student questions, which in both online and on-campus courses mostly takes place in the online forums. Faculty also still needs to write the exams, but frequently, the instructors of the online and on-campus sections use the same exam.

Serving materials and homework online does not pose a large logistics problem, either: faculty generally need a little more support than students (who even in 1997 were just fine using the web), somebody needs to run the servers, and links to the administrative systems need to keep class lists and authentication up-to-date.

Exams in the online sections are a different topic: how do you guarantee their integrity? Short of using “Big Brother” systems like ProctorU [4] or working with a network of testing centers, we are taking a hybrid approach. Students who live within 30 miles of campus need to take the exam on-site in a standard setting, students who live further away need to identify a proctor (typically faculty at another college or university, librarians, or commanding military officers), and faculty need to approve the proctor and deal with the logistics of getting the exam materials back and forth. Most students are within the 30-mile radius (and most of these on-campus anyway), so they take the exams like everybody else.

What have we learned?

Our first question of course was: what have they learned? Using the same exams for the traditional and the online courses, we found a disconcerting result: the students in the online course had better scores – not by much, but statistically significant. Granted, the online students were self-selected and possibly a slightly different population, but what we learned from that: our traditional lectures were useless. Whether or not students sit in a lecture hall and attend a traditional lecture makes no positive difference in their learning, as measured by standard exams. It also did not matter who lectured, the faculty assignment of these classes rotates. The result underlined the need to reform our traditional courses, incorporate problem-solving and peer-instruction, and in some case eliminate traditional content coverage. We found that increasing the rate of in-class assessment and feedback increased use of the online resources [5] and led to better course performance [6]. We could have guessed that from analyzing the online courses, since it reflects the preferred learning path of the students. Based

on access log analysis, we found that almost invariably, students first gravitated to the online assessment and only if they could not solve the problems actually read the materials [7]. We also found that particularly among female students, formative assessment was used as an opportunity for peer-teaching [8]. We thus now do not have a single introductory physics class on campus anymore that does not use clickers, peer-teaching, and in-class active problem solving – anything else would be malpractice.

In both online and on-campus scenarios, assessment that is directly embedded into the online reading materials (not in a separate compartment of the learning management system) is particularly effective. Somewhat disappointingly, we also found that students do not use simulations or movies unless they are coupled with assessment. While we as faculty enjoy physics, like to play with online toys, and enjoy our bragging rights for writing a particularly nice simulation, access logs show that the vast majority of students do not bother even considering them – students are on a time budget and do not want to “waste their time” unless the toys are coupled with graded assessment problems. We have thus moved to making the simulations and other free-form answers themselves graded assessments, which based on HTML5/JavaScript can be integrated into LON-CAPA (e.g., [9]).

Technological innovation in online and on-campus classes are moving in parallel, since these are essentially sections of the same course run by the same department with the same standards. For a while, before reforming our classrooms, the only difference between online and on-campus sections was the absence of traditional lectures in the former. We have yet to analyze if we were able to reverse the significantly negative effect of lectures.

Where do we go from here?

In the foreseeable future, there are no plans to stop offering lectures; instead, we aim to continue moving them toward more reformed curricula and methods of teaching. If the students are spending face-to-face time with us, we need to make sure this time is better spent than lecturing to them, since we have proven that that is indeed a complete waste of time.

At the same time, we plan to expand our online offerings, both in terms of number of courses and frequency of offering them (already now, if students are willing to sacrifice their whole summer, they can get all of the algebra-based sequence “out of the way” over one summer [10]). Particularly students from other universities and colleges bring additional revenue on campus, which by now makes up a sizeable component of the department budget. In terms of platform, we are working on replacing the aging LON-CAPA platform by a more modern and modular system named CourseWeaver, which we are developing as a next generation learning content management and assessment system. We will hopefully be able to transition to this system three years from now.

[1] Gerd Kortemeyer, Edwin Kashy, Walter Benenson, and Wolfgang Bauer, Experiences using the open-source learning con-

tent management and assessment system LON-CAPA in introductory physics courses, *The American Journal of Physics*, Volume 76, Issue 4&5, 438-444 (2008)

[2] <http://www.techsmith.com/camtasia.html>

[3] Gerd Kortemeyer, Stefan Dröschler, and Dave Pritchard, Harvesting Latent and Usage-based Metadata in a Course Management System to Enrich the Underlying Educational Digital Library, *International Journal on Digital Libraries*, 10.1007/s00799-013-0107-6 (2013)

[4] <http://www.proctoru.com>

[5] Daniel Seaton, Gerd Kortemeyer, Yoav Bergner, Saif Rayyan, and Dave Pritchard, Analyzing the Impact of Course Structure on eText Use in Blended Introductory Physics Courses, *American Journal of Physics* (submitted)

[6] James T. Laverty, Wolfgang Bauer, Gerd Kortemeyer, and Gary Westfall, Want to Reduce Guessing and Cheating While Making Students Happier? Give More Exams!, *The Physics Teacher* 50, 540-543 (2012)

[7] Behrouz Minaei-Bidgoli, Data Mining for a Web-Based Educational System, Doctoral Thesis, Michigan State University, 2005

[8] Gerd Kortemeyer, Gender differences in the use of an online homework system in an introductory physics course, *Phys. Rev. ST Phys. Educ. Res.* 5, 010107 [8 pages], (2009)

[9] James T. Laverty and Gerd Kortemeyer, Function Plot Response: A Scalable System for Teaching Kinematics Graphs, *American Journal of Physics*, 80, Issue 8, 724-733 (2012)

[10] <http://www.pa.msu.edu/academics/online-courses>

Gerd Kortemeyer is an Associate Professor of Physics at Michigan State University. He is the director of the LON-CAPA project and has published numerous papers on teaching physics, particularly on his research into the development of effective tools for online learning.

My flipped journey

Andy Rundquist, Hamline University

I was at a physics chairs conference several years ago, and we were discussing how to deal with students cheating on homework. It was where I first heard of Cramster.com and I came away pretty depressed. One suggestion that I laughed at when it was mentioned, was to just do quizzes instead of collecting homework. I laughed because I did not see how I could cough up that much class time for assessment, especially since I tended to collect homework on a daily basis. It is funny to think about it now, but that experience is what led to one of the biggest changes to my approach to teaching. These days people would call my response “flipped learning,” but at the time, I called it “stopping cheating.” This past summer I went to another chairs’ conference and the subsequent conference on online learning and I got a chance to share some of what I have learned since jumping on this flipped bandwagon.

I am constantly tweaking my teaching. Often what makes me crabby in one class is what is addressed in the next. A lot of the changes I have made have been centered around the preciousness of class time. In class students have nearly unfettered access to me, so I figured I should prioritize the things that we do in class so that I could help them the most. The thing that dropped to the bottom of the list was reading the text to them, which was a very cynical description my chair gave of my lecture style after he visited my classroom in my first year.

So what does my class time look like now? My students are engaging with each other and the material, using physical whiteboards to draw up potential solutions to challenging problems, and talking with each other and me trying to place the new material in the con-

text of the old. I encourage my students to come prepared with 1) an understanding of why we are studying the daily topic in the first place, 2) an initial knowledge of the vocabulary we will be using, and 3) experience with where and what their resources are. They do this by reading the text, watching the videos I provide, and talking with each other through our class backchannel.

I am constantly prioritizing what should be done in class versus out. The list is long, but includes derivations, history, examples, lab planning, assessment, and tying ideas together. I make choices about that list on a daily basis, with very few things always being in or out of class. I do my prioritization based on how I feel class is going, what questions students are asking, what I have done in the past, and what logistics are needed.

Making this change has made teaching harder for me. In class I have to have an overall plan, but otherwise I need to be flexible to meet students’ needs. If I ask them to do a problem that is too hard, I need to figure out where they are stuck and make quick decisions about whether to “teach” them at that moment or let them develop their own models as they struggle. I have learned a lot talking to friends and colleagues who are high school teachers, especially those who use the modeling curriculum.

I have had to give up a few things. In the past, I was usually present when they learned (or at least heard about) some cool thing. Now, they have almost certainly read about it or studied a video about it before class, so I do not get to witness that “ah-ha” moment. I console myself by taking that cool thing and having the students

really dig deep with it in class, but I would be lying if I said I did not miss that sage-on-the-stage feeling every once in a while.

One thing I will not miss, though, is looking at my watch whenever a student asks me a tangential question. You know that feeling, when a student has demonstrated an interest in the topic, but is tying it to something that would take too much time away from your lecture to cover in today's class. In the past I had always look at my watch before answering. Not anymore. I have already "covered" what I wanted to with my reading assignments and videos and other resources that I have provided. If a student wants to dig deep right now in class, let's do it! Better to honor their passion than to be a slave to your calendar, I say.

Probably the coolest thing to come out of all of this, for me, is putting some of the tools I use to create resources into my students' hands. When I started to realize how much more useful my solution set screencasts were (to save time going over them in class) compared with just the paper copies, I started to look into having students turn in their work the same way. My solution screencasts do not just show the work, they discuss the steps in detail, mostly because I talk a lot faster than I can write. Turning that around and having students explain their thinking is much more valuable than looking at a sheet of their (you hope) handwriting. That sort of thing is also useful when groups are trying to bring you up to speed on their progress. Forcing groups to wait around until their turn at the end of lab is not nearly as efficient as having them make a screencast/video of their progress that they can email you and you can watch before the next lab.

My most recent experiment with "flipping" is what I have dubbed "flipping the flip." In a non-science-major physics of sound and music course this past fall I had the students only come prepared by having them think about a simple question. One example was "what actually makes the sound of a snap?" I did not ask them

to read or watch videos or anything leading up to class. I did it because one of the biggest problems with a flipped pedagogy is student buy-in and preparedness. I wanted to see what I could do in a class where I did not expect much (if anything) from them before class. Once in class, I would throw out a problem like "what's going on in this simulation" or "could you snap in outer space" and slowly they would start working together to figure out what was important/hard/weird/exciting about the topic. At the end of the class we would gather and they would put in their requests for resources. They would ask for pages in the text to read that might explain what confused them, or they would ask for an explanation from me about why we would use one equation and not another. I would dutifully go provide those resources and they would use them to prepare for the various assessments we had in class. It was a fun class to teach, but I felt that it put even more pressure on me to be flexible while trying to get them from A to B.

There has been a lot of research about flipped class teaching, but I think more could be done. Determining the best mix of at-home versus in-class work would save me a lot of time, though I do think there is a lot that will always be case-by-case. Research into the best ways for students to make use of out-of-class resources, including static content, dynamic content (where they can interact with the material somehow), and peer/instructor-based connections (like backchannels), is vitally needed by this physics research engineer. At the end of the day we are all trying to help students learn in the best ways possible. I will keep looking at what makes me crabby about the last course I taught to figure out what to try in the next course, and I will continue to keep tabs on the research that you and others are doing to help me do that.

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Navigating the Challenges and Opportunities of Online Education

Mats Selen and Tim Stelzer, University of Illinois at Urbana-Champaign

Students' unprecedented access to content on line is dramatically and irreversibly changing higher education. The opportunities are fantastic, but so are the risks. Similar to white water rafting, standing still is not an option, and simply letting the current dictate our path would be disastrous. In this article, we will argue that physics has a special role to play in navigating these changes, describe steps we have taken at the University of Illinois, and begin a discussion about the much larger challenges we face moving forward to ensure that our efforts at efficiency don't come at the price of turning higher education into online training programs.

The physics community can be proud of the impact it has had on higher education. The development and dissemination of ideas to improve student learning in lecture, recitation and labs have certainly improved the quality of education in physics,¹ and many other disciplines are not only adopting educational strategies developed in physics but are also gaining appreciation for the type of discipline-based education research we have established. Our past accomplishments give us the opportunity, and responsibility, to help navigate at this exciting time in education.

The changes we have made to our introductory courses at the University of Illinois provide a nice illustration of the opportunities and challenges technology is providing. Fifteen years ago our colleagues contributed an article, "Parallel Parking an Aircraft Carrier,"² describing what turned out to be the first phase in transforming our introductory courses. This transformation included adding Peer Instruction³ to our lectures, group problem solving of context rich problems⁴ to our recitation sections, and "predict-observe-explain" labs⁵. These course enhancements measurably improved our students' experience. Perhaps even more important was the change in infrastructure, which both institutionalized the changes and provided an environment for continued evolution. Indeed, the success of our course transformation did not result in our taking a break from innovation, but inspired our faculty to continue improving the courses.

One challenge we faced in implementing Peer Instruction was designing "clicker questions" that probe conceptual understanding at the appropriate level of difficulty. Fortunately, Just In Time Teaching (JiTT)⁶ provided an elegant solution. Having the students answer questions online before lecture allowed us to tailor the lecture and clicker questions based on their responses. One unanticipated benefit was that students really liked having their responses to the JiTT question incorporated into the lecture. Indeed, it became a badge of honor for students to have their response displayed in class.

One clear and somewhat disappointing result from examining the JiTT responses was that the students were learning very little from

the textbook prior to lecture. Hence, a large amount of lecture time was devoted to delivering content rather than addressing student misconceptions and promoting deep conceptual understanding using Peer Instruction, frustrating both students and instructors.

Our solution was to replace the textbook with online multimedia content, and to require that students view this before coming to class. In this way we could spend class time discussing the material they just viewed rather than delivering the material itself. Placing the content online had the benefit of making it easy to deliver and gave us the ability to give credit to students for participating.

Using multimedia techniques that combine carefully designed audio and visual elements to deliver content is not a new idea. Indeed, we were inspired by significant existing research indicating that multimedia can be a very effective method for people to learn complex ideas.⁷ Guided by that research, we designed web-based "prelectures" for our introductory Mechanics and E&M courses. Our own clinical studies confirmed results in the literature.⁸ Figure 1 shows that students using the multimedia prelectures scored 13% higher on standard exam problems both immediately after seeing the material (Units 1-4) and two weeks later (Retention) than students reading from the book.

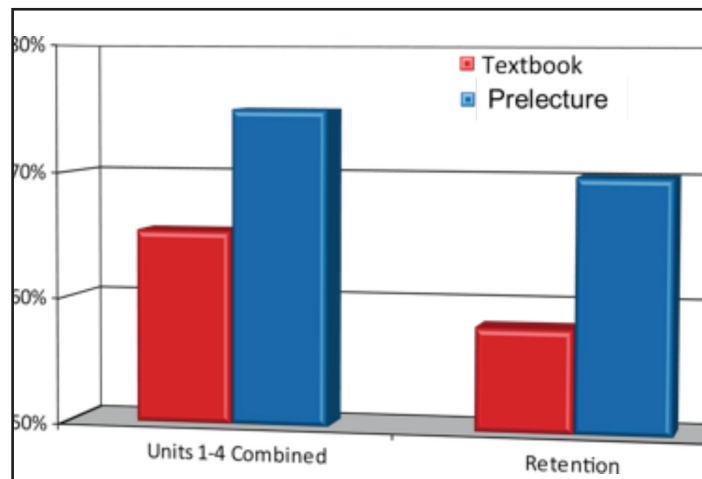


Figure 1. Results from a clinical study at the University of Illinois, showing that students using the multimedia prelectures scored 13% higher on standard exam problems both immediately after seeing the material (Units 1-4) and two weeks later (Retention) than students reading from the book

Introducing prelectures into our physics course qualitatively changed the lecture experience. Although we didn't use the phrase, we had effectively "flipped" the course. Students came to lecture better prepared, and we essentially doubled the class time devoted to Peer Instruction activities. The positive impact of these changes is best illustrated in Figure 2. It shows that students find the course easier, have a more positive attitude toward physics, and find lec-

ture more valuable in helping them learn the material than before we made these changes.⁹

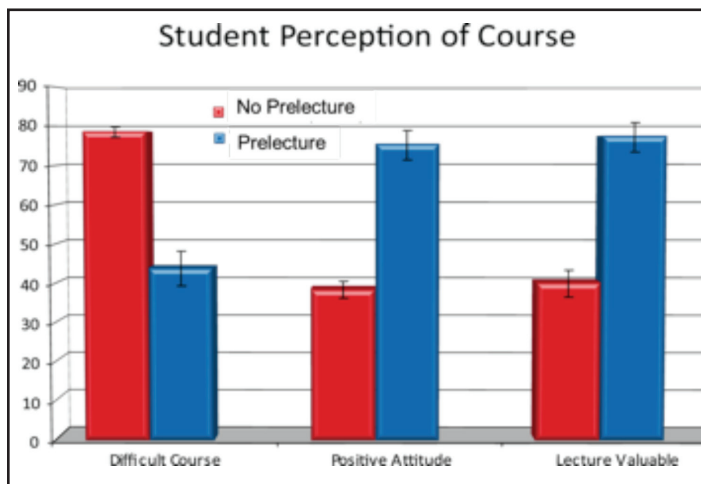


Figure 2. Results from surveys of students taking introductory Electricity and Magnetism courses at the University of Illinois. Adding prelectures and devoting more lecture time to Peer Instruction resulted in students finding the course less difficult, having a more positive attitude toward physics, and finding lecture more valuable in helping them learn the material.

Our results on the positive impact of adding online prelectures to an introductory physics course may appear to support the case for developing effective fully on-line courses. As compelling as this may seem on the surface, there are important risks and challenges to consider.

At the heart of these challenges is our ability to validate the impact of transformations as massive as moving a course completely online. Our research on the impact of prelectures is similar to most physics education research in that the intervention is aimed at improving, not replacing, the student interactions and experiences that have defined the physics courses for generations. These relatively modest changes give one confidence in evaluating the impact of the changes using traditional instruments used to assess student performance in the course (e.g. Exams, Surveys). It is important to note that although these instruments are often validated, they are necessarily incomplete. The Force Concept Inventory¹⁰ provides an excellent illustration.

Prior to the introduction of the FCI, many physics professors assumed that a student's ability to solve difficult problems in mechanics implied that they understood the concepts behind Newton's laws. The FCI demonstrated that we had become so efficient at teaching students to solve problems they could now do so without understanding some very fundamental principles. The ability of the FCI to quantify the lack of understanding of agreed upon learning objectives inspired and validated many important reforms to physics education.^{3,11} Indeed, most of these reforms engaged students in "high order" reasoning activities to help them develop this conceptual understanding. The result was that, in addition to showing larger gains on the FCI, our students were developing critical thinking skills that transcend the course. In hindsight, the

importance of directly testing conceptual understanding seems clear, however, one should not underestimate the extraordinary efforts of the physicists who championed the reforms to explicitly teach and assess students' conceptual understanding.

Advances in online technology, combined with social and economic pressures, present us with a new opportunity and an even greater challenge. Soon there will be "efficient" online activities that can train students to perform well on FCI-like exams as well as traditional exam calculations. If our learning objectives for our introductory courses are limited to mastering the FCI and solving a set of "difficult" mechanics problems, then the path forward is clear. However, if we also want our courses to help students develop higher-level critical thinking skills, then it is important that we identify and clearly articulate these goals, and that, in the context of our courses, we use assessments that accurately reflect the student's progress toward those goals. Relying solely on traditional exam problems and FCI-like assessments to guide the development of fully online courses will inevitably prune the critical thinking aspects from these courses, transforming them from educational experiences into training programs.

Higher education is undergoing dramatic and irreversible changes. We have a unique opportunity and responsibility to guide these changes so that they enhance the quality of our students' educational journey, and preserve the learning experiences that enable our graduates to meet the challenges facing society. Using technology to develop new educational activities is an important and exciting component of this journey and will undoubtedly move forward quickly, so it is critical that our ability to assess the impact of these developments advance at the same rate. Our challenge is to engage in active discussion, clearly articulating the goals of our courses, and to develop and implement accurate and reliable assessments to guide our journey.

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Your World is Your Lab: A MOOC for Introductory Physics

Michael Schatz, Georgia Institute of Technology



Most colleges and universities consider an instructional laboratory to be an essential component of an introductory science course. At first glance, offering a lab science **MOOC** – a lab that is **M**assive (potential student enrollments in the tens of thousands) and **O**pen (anyone may sign up and participate without paying tuition or fees) and is integrated into an **O**nline **C**ourse – would seem to be impossible. In a course that lives in cyberspace, where do students go for lab? By applying some mental jiu jitsu to this dilemma, we suggest a way to offer bona fide labs that are MOOC-compatible and, we argue, superior to the current instructional lab experience of many on-campus students.

In principle, an instructional lab should offer engaging, real world, hands-on experiences with scientific concepts and practices; in practice, introductory labs often fall short of this ideal. On-campus, students typically attend and perform labs in rooms that are expressly designed and specially equipped for the purpose; the separateness of this environment in conjunction with the oftentimes “cookbook” nature of student lab activities communicates the dual message that science stops happening once you step out of the laboratory, and that science has a script. Reinforcing this disconnectedness is the common practice at many colleges and university to operate the introductory lab independently from (or, at best, poorly coordinated with) the lecture component of the course. As a result, the overall impression conveyed by many on-campus labs is a “what happens in Vegas, stays in Vegas” attitude toward laboratory science – namely, the activities performed in the on-campus lab are largely unrelated to the real world and especially unrelated to the students’ “intuition” developed from their own personal experience.

Our MOOC, which emphasizes concepts and content typically covered in the first semester of calculus-based introductory physics, offers hands-on experience through what we call the “Your World is Your Lab” approach. The course (which is hosted by Coursera [1]) focuses on mechanics, the science of motion; students are guided to seek and to study examples of motion in their own surroundings. These inquiries require only one piece of lab

equipment that almost all students already possess – the video camera on their cell phone (or, alternatively, the webcam on their laptop, or a dedicated video recorder – anything that can record digital video). For each lab, we instruct the students to study a general type of motion; for example, in the first lab on constant velocity motion, students are asked to observe an object that appears to be moving in a straight line at a fixed speed. After students capture motion observations on video, they use free, open-source software both to extract data from the video and to apply physics principles to build models that describe, predict, and visualize the observations. Each student reports his or her own findings by creating a video lab report and posting it online; these video lab reports are then distributed to the rest of the class for peer review. The process of presenting and evaluating video lab reports provides students with opportunities to practice important communication and critical thinking skills in a scientific context.

The MOOC labs are woven together with video lectures, textbook readings, homework, and quiz assignments and class forum postings. The lecture videos aim to attract and to hold student interest by focusing on a single topic in a short presentation (~10 min), by embedding in-video “clicker” questions, and by making extensive use of whiteboard animation. The course uses a well-known introductory physics text with a proven track record (*Matter and Interactions, 3rd edition*, by Ruth Chabay and Bruce Sherwood) [2]; MOOC students have been provided free online access to the textbook by special arrangement with the publisher (John Wiley & Sons, Inc.). Students complete and submit homework assignments and course quizzes online using methods similar to those in wide use in on-campus courses. We also provide students access to an online forum thoroughly moderated by instructors and TAs; this forum provides the primary venue where students interact with each other as well as with helpful experts.

The physics MOOC has drawn from numerous prior contributions of other educators and education researchers in physics and in other STEM fields. Earlier work by Priscilla Laws and Robert Teese guided the use of video analysis in our MOOC labs [3]. Students in our MOOC analyze motion on video using the software tool, Tracker, which was developed and is maintained by Douglas Brown and is freely available from the Open Source Physics project [4]. Once the students have their motion observations, we then guide them in developing computational models which accurately predict that motion. The process of constructing models in the labs is inspired by the well-known Modeling Instruction methodology [5]; students construct computational models, which include 3D visualizations, using the open source software package VPython [6], which is an integral component of Chabay and Sherwood’s *Matter and Interactions* curriculum [2]. The labs provide opportunities for students to gain experience with important scientific practices highlighted in the framework for Next Generation Science Standards, including analyzing and interpreting data, developing and using models, computational thinking and evaluating/communicating scientific information [7]. Student evaluation of peers’ lab reports, inspired by prior work involving Calibrated Peer Review™ [8], enables both substantial practice with constructive

critical evaluation of scientific communications and a practical method for providing timely, individual feedback on student lab work. Our goal in emphasizing peer review in our MOOC is not simply to provide our (many!) students with an adequate substitute for expert grading; we believe the peer review process itself is an important practice which every science student should experience.

The instructional materials developed for the MOOC are also being used on-campus at Georgia Tech to “flip” the classroom in a limited number of sections of calculus-based mechanics. In this approach, on-campus students view video lectures and perform lab activities outside of class. On-campus contact hours (one 3-hr period and three 50-minute periods weekly) are focused on face-to-face interactions emphasizing small group work on solving problems and small group live presentation of and feedback for lab reports drafts. In the face-to-face meetings with students, the instructors and teaching assistants help facilitate student group work on both problem solving and technical communication/evaluation. Our initial experience with the flipped classroom approach suggests helping teaching assistants to be good facilitators requires providing access to good training.

Developing, operating and sustaining a MOOC poses a number of substantial challenges. Content creation and course administration are very time-consuming, requiring the tireless efforts of several student, postdoctoral, and faculty collaborators. Large numbers of students sign up for the MOOC: 20113 enrolled in Summer 2013 and 16489 enrolled in Fall 2013. However, student participation rapidly drops within the first few weeks of each session; the number of students who complete the course successfully (final course grade of 70% or better) is relatively tiny: 107 students in Summer 2013 and 48 students in Fall 2013 earned a certificate of completion, which does not convey college credit. Free access by MOOC students to the course textbook was arranged on a trial basis; the terms for textbook access in future sessions are currently unresolved. Our MOOC platform of choice, which is still under development, currently has limited flexibility for homework and peer evaluation assignments; these constraints were partially overcome by using WebAssign™ in conjunction with custom software for facilitating peer grading.

A large amount of very granular data has been collected from the MOOC. The data include responses to standard concept inventory and survey instruments (the Force and Motion Concepts Inventory and the CLASS and E-CLASS attitudinal surveys), demographic data, anonymized location data and “clickstream” data which gives us a full, moment-by-moment record of every student’s interactions with every lecture video. This mountain of data will inform the future development of the MOOC, and enable us to answer a number of research questions. Our analysis is ongoing, and already yielding interesting insights. In sum, we are hopeful that experience with the MOOC will lead to long term positive impacts on learning for both on- and off-campus students.

Partial support by the NSF and the Bill and Melinda Gates Foundation for the development of the MOOC is gratefully acknowledged.

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Coming of Age: Open Education Resources for Physics

David Harris, Editor in Chief, OpenStax College

A Critical Turning Point

Increasing under-employment, spiraling costs, and mountains of debt threaten current and future generations of students. The need to prepare students for a technology-based economy has never been more acute. However, traditional barriers and “closed” market systems are curtailing access to critical educational resources. In particular the rising price of course materials has exceeded the rate of inflation for more than two decades. A typical student is struggling to make ends meet and is then confronted with a \$1200 textbook bill. According to PIRG she, along with 6 out of 10 of her peers, will choose not to purchase these materials and this will greatly hinder her chances of success in the course. However, there is another way – a new open model that fundamentally changes the curation, production, and dissemination of content. Thanks to the support of the William and Flora Hewlett Foundation, Laura and John Arnold Foundation, Bill & Melinda Gates Foundation, 20 Million Minds Foundation, Maxfield Foundation, and Rice University, OpenStax College is developing a library of 25 open text books that carry a CC-BY license. *College Physics*, an algebra-based introductory physics text, our first project, was published in June 2012. To date the text has been downloaded hundreds of thousands of times and is in use at over 230 institutions.

Learning, Not Free is the Priority

OpenStax College projects carry an open license and are always free for students to download; however, the real priority is on learning. We employ a rigorous development process in order to meet or exceed professional standards. *College Physics* was extensively peer reviewed and professionally developed. Our texts are designed to meet the scope and sequence of a typical course. *College Physics* is used in traditional courses and flipped classrooms, as well as in online courses. *College Physics* can be viewed online or it can be downloaded to a mobile device. It is available in pdf, in print, and in an iBooks textbook version.

The initial learning data are also encouraging. Professor Eric Christensen of South Florida College found, “I use the nationally-benchmarked Force Concept Inventory (FCI) to assess how well

my physics students are learning the materials. I have been doing this for the past five years. This year, my class scores on this assessment instrument were the highest that I have ever recorded for an algebra-based course.” In the *International Review of Research in Open and Distance Learning*, Dr. David Wiley and his colleagues found that Utah high school students learn the same amount of science in classes using \$5 open textbooks as they do in classes using \$80 traditional textbooks. However, there is clearly a need for more research on the efficacy of Open Education Resources (OER) in higher education.

Flexibility is Important

There are many claims in the media about the effectiveness and challenges of using online resources, especially e-texts. We are finding that student do not tend to exclusively use one version of our texts over the others. Many students will download the pdf and then print out the text as they need it. We have reports of students using the mobile version as a review tool. To date approximately 10% of our users opt for a traditional print version.

A New Distributed Ecosystem

In physics the use of online homework, such as WebAssign, Sapling Learning, and ExpertTA is also prevalent. OpenStax has partnered with these companies; over 30% of our physics adoptions now utilize these services. This partnership offers us insight into how students use their textbook when completing homework assignments. We have found that students who use the online homework systems typically access portions of the text as they work through homework assignments. These partnerships are also part of an emerging “ecosystem” in which OER producers work with “for profit” companies that provide additional products and services. In return these companies provide a modest mission support fee back to OpenStax to assist in the sustainability of the effort. This new distributed model is efficient, improves quality, and drives down overall costs for students.

MOOCs and OER: Free is Not Open

Massive online open courses (MOOCs) are frequently confused

with open education resources. MOOCs are free to enroll in, but the content of the course, the platforms, and related course materials are proprietary. Furthermore, MOOCs are increasingly following a “freemium” model in which the course may be free but students are charged a fee in order to obtain credit or certification for completing the course. Open resources, on the other hand, are openly licensed, meaning that a physics instructor can take the resources, adapt them (the community has already created more than thirty derivative versions of *College Physics*) and re-distribute to the community for free providing that they use the correct attribution. There is some interplay between OERs and MOOCs, however: OpenStax College texts have been assigned for students enrolled in MOOCs.

Challenges and Questions Remain

The initial adoption and reaction to OpenStax *College Physics* is very encouraging; however, the continued success of the underlying values of OER, much like proprietary content producers, will become increasingly dependent on “big data”. A current challenge is to produce intelligent adaptive systems that provide students with clear direction and personalized pathways through identified learning outcomes. This poses tremendous economic challenges at scale, but more troubling are the questions that emerge regarding the potential misuse of all the data this is being tracked. Why

should data on student learning be proprietary? Wouldn't systems get smarter if they were able to aggregate non-personalized data from the largest population pool? How will the use of proprietary system data be commercialized? How can open adaptive platforms provide alternatives that are driven more by learning theory than profit? Will an open software model like Red Hat and Linux work in the education market?

These issues must be addressed as the usage of OERs becomes more prevalent. This requires continued development on content, working closely with the community to measure the effectiveness of the resources, and deploying emerging technology in a responsible way. At OpenStax College we look forward to working with the physics community on these issues in order to realize our mission of improving access to high quality resources for all students.

David Harris is a graduate of the University of Connecticut and has worked extensively in higher education publishing. Most recently David was the president of WebAssign, the largest independent online homework provider. At OpenStax College David hopes to contribute to the teams effort of improving access to high quality materials by working with authors, developers, and partners to substantially lower costs for students.



John Stewart

University of Arkansas

This edition of the Teacher Preparation Section features two PhysTEC sites that are at the end of the funded period and one site in the middle of funding.

Andrew Duffy, Peter Garik, Bennett Goldberg, Mark Greenman, and Manher Jariwala from Boston University discuss the connections that have grown out of a long partnership with the College of Education. They also discuss the transformative role their Learning Assistants (LA) program has had not only in the physics department, but also across the sciences and engineering.

Kevin Dwyer and Laura Henriques from California State University, Long Beach (CSULB) discuss the role of the Teacher in Residence in the CSLUB PhysTEC site. They also discuss some extremely successful and innovative approaches toward community

building. I had the pleasure of seeing Kevin talk about the program at last summer's AAPT meeting and the enthusiasm of the TIRs and the students in the program is infectious.

Karen King of the University of Missouri reports on the effects of their Learning Assistant program. This program is unique in that it places physics undergraduates in local high school classrooms rather than in college classrooms. This program reports impressive growth.

The 2014 Physics Teacher Education Coalition (PhysTEC) Conference will be held May 19-20 in conjunction with the UTeach Institute Annual Conference in Austin, Texas. This intimate conference features presentations by many of the driving forces in physics teacher preparation and is my favorite conference each year.

Three years of PhysTEC at Boston University

Andrew Duffy, Peter Garik, Bennett Goldberg, Mark Greenman, and Manher Jariwala, Boston University

The goal of PhysTEC (the Physics Teacher Education Coalition) is to increase the number of highly trained physics teachers graduating from colleges and universities across the country. PhysTEC is a joint effort of the American Physical Society and the American Association of Physics Teachers, funded by the National Science Foundation. PhysTEC in turn funds, through competitive grants, projects at universities intended to have a lasting impact on the number of physics teachers graduating from those institutions. At Boston University, we are in the third year of a comprehensive grant from PhysTEC and we report here on the factors we have found necessary and important to build a program to support students who want to become physics teachers. These factors include:

- a strong working relationship between the Department of Physics and the School of Education (our PI is from Physics, the co-PI from Education);
- support from the university administration at all levels - the Physics Department Chair, the Deans of the College of Arts and Sciences and the School of Education, and the Office of the Provost;
- a dedicated, visionary and tireless physics teacher-in-residence (TIR), who is personally invested in our physics teacher preparation and recruitment program efforts;
- a vibrant Learning Assistant (LA) program, which provides students both instruction and a low-barrier opportunity to experience teaching for themselves;
- a Noyce Scholarship Program to attract and support physics candidates for teaching.

Cooperation between the School of Education and the Department of Physics

Boston University has a long history of cooperation between the School of Education (SED) and the Department of Physics. Beginning 10 years ago, Peter Garik (SED) and Andrew Duffy (Physics), in conjunction with Arthur Eisenkraft of the University of Massachusetts – Boston, created a comprehensive program for in-service physics teachers, targeting ill-prepared teachers, but also attracting many teachers with a solid foundation. Project ITOP – Improving the Teaching of Physics, has now trained more than 100 Massachusetts teachers with at least one ITOP course, with a significant number taking all ten of the two-credit graduate-level courses.

SED and Physics have collaborated on NSF Graduate Students in K-12 projects, on a summer science immersion program for middle school teachers, in Nanomedicine Camp, in Upward Bound, and numerous other projects. The connections that developed within BU through ITOP led to BU Physics joining PhysTEC. At the annual PhysTEC meetings, Andrew Duffy and Peter Garik learned about national reform efforts, which ultimately led to our PhysTEC grant and related efforts including a Learning Assistant Program (detailed below) and a Noyce Scholarship program (<http://nsfnoyce.org/>) for science teachers, both closely linked to

our PhysTEC effort. This year's inaugural class of eight Noyce science scholars includes two Masters of Arts in Teaching students and one undergraduate who are preparing to teach physics next year in high-need school districts.

University and Departmental support

BU will sustain PhysTEC for three more years beyond NSF funding. Internal funding from the Office of the Provost (Provost Jean Morrison), School of Education (Dean Hardin Coleman), and Department of Physics totaling \$90K per year will be used to support the physics TIR. The support from multiple levels at BU has been important in establishing and growing the program, and will be very important as we work to sustain it. For instance, after months of development and discussion, with the support of former Physics chair Sid Redner and current Physics chair Karl Ludwig, and utilizing our TIR Mark Greenman's three decades of experience in a local high schools, the faculty of the Department of Physics recently voted to establish a separate physics degree track for students who want to become teachers.

The Physics Teacher-in-Residence (TIR)

A master physics teacher-in-residence (TIR) is a critical component of a successful program to recruit, train, and support undergraduates to become physics teachers. The TIR is embedded in the Department of Physics, and is able to positively influence the faculty's attitude towards physics teaching as a profession. The TIR brings years of teaching and administrative experience at the high school level. Based on this first-hand knowledge about what it takes to be an excellent physics teacher, and about the kind of preparation a budding teacher should have, the TIR provides invaluable advice to physics majors who express an interest in becoming teachers. This personal contact is a key component in recruiting.

Our TIRs have led recruiting efforts, ranging from short presentations in undergraduate physics classes, about teaching as a career and about the Learning Assistant program, to having regular meetings with undergraduates who want to be teachers. This model was established by Juliet Jenkins, our first TIR (2011-12), and continued by our second TIR, Mark Greenman (2012-2014). Through their efforts, we now have a few undergraduates who have declared their intention to become teachers.

Our TIRs have also established the Boston University Physics Teacher Network (BU-PTN). Four or five times during each academic year, for two hours on a Monday evening, local teachers meet on campus to share demonstrations and experiments they do in their own classrooms, hear a talk, and spend some time talking with their colleagues. The PhysTEC grant pays for a light dinner and campus parking. This year we have had over 30 attendees at each meeting (one had more than 40). Attendees are teachers, a few undergraduate and graduate students interested in aspects of



BU Physics Teacher Network meeting in October where teachers, BU undergrads, grad students and PhysTEC faculty share ideas, best practices and experiences in urban schools.

teaching, as well as members of the PhysTEC team.

To attract teachers to the meetings, we have relied on contacts built up over many years of Project ITOP, but the TIRs have also used their own personal networks. For instance, for the last several summers, Mark Greenman has run a two-week physics content workshops, with up to 24 teachers attending. Many workshop attendees are now regular participants at our BU-PTN meetings.

Learning Assistant Program

Learning Assistants are undergraduates who have taken a course and return to help current students learn the material. Learning Assistants (LAs) are near-peer teachers working with students in recitation, lab, studio, or lecture settings. LAs take a pedagogy course in teaching methods and science education research that prepares them for peer teaching. At most institutions, LAs receive compensation for being an LA in the form of a stipend or course credit.

LAs are part of an instructional team, working together with other LAs, graduate student Teaching Assistants (TAs), and faculty. Students often find their LAs to be the most approachable members of the instructional team. Because of their own recent learning experience with the course material, LAs are familiar with the learning issues that the current students struggle with. LAs also benefit from the teaching experience, generally improving their own academic efficiency by using strategies discussed in the pedagogy course.

The BU LA program began in the Department of Chemistry in the Spring semester of 2011, modeled after the University of Colorado – Boulder program. The prior October, two Chemistry postdoctoral fellows (Adam Moser, now at Loras College, IA, and Nic Hammond, now at the University of Rochester, NY) and Peter Garik attended the national LA workshop in Boulder. They came back so fired up that they immediately recruited 11 LAs for the Spring-semester General Chemistry class. Peter Garik taught the accompanying LA pedagogy class using the CU Boulder materials.

The BU program spread rapidly to Physics and Biology in Fall 2011, coinciding with the beginning of our PhysTEC program. Currently in our third year, we have LAs in Chemistry, Physics, Biology, Neuroscience, and Engineering. Funding for LAs in the original three departments, at the rate of \$700 per semester, is provided by the College of Arts and Sciences. The College of Engi-

neering funds their own LAs, and the Neuroscience LAs receive course credit.

In Physics, the LA program is closely allied with our PhysTEC effort. Whereas other BU departments and other programs around the country generally use LAs in introductory courses, in Physics we have infused LAs into almost the entire undergraduate program. Several of the LAs who are physics majors have enjoyed the teaching experience so much that they are now seriously considering teaching as a career.

The LA program in physics has grown quickly. In the first semester, we had 12 LAs working in four physics courses, all at the introductory level. Of the 12, only three were physics majors. In Fall 2013, the fifth semester, we had 18 LAs working in nine courses, and 10 of the LAs were physics majors.

Our LAs are a key component of efforts to reform the undergraduate curriculum by introducing more student-centered methods of teaching and learning. Historically, recitation sections had a single

For <u>juniors</u> & seniors:	PY405 E & M	PY408 Mechanics	PY451 Quantum
For <u>sophomores</u> :	PY313 Two flavors of Modern Physics	PY351	PY355 Math Methods
For 7-yr. med's and Physics majors:	PY241 7-year med. students	PY242	PY251 PY252 Physics majors
Intro. courses:	PY105 Life-science students	PY106	PY211 PY212 Engineering students

BU Physics has built a pipeline, with LAs in courses from introductory physics through upper-division classical mechanics, electrodynamics, and quantum mechanics. Seniors teach juniors, who teach sophomores, and so on, forming a vertical learning community for undergraduate physics majors.

TA for 25-30 students, with students passively watching the TA teaching at the chalkboard. Now that we have one LA paired with a TA in each section, students spend the majority of the time working on worksheet-based exercises in small groups, and the LA and TA circulate, answering questions and guiding thinking and peer-learning.

LAs are also having a significant impact in our more advanced undergraduate courses. For example, the instructor in our Methods in Theoretical Physics class has adopted a flipped classroom approach, transforming the recitation sections into group problem-solving sessions, with the students helped by the instructor, the TA, and the LA.

LAs are contributing to reforms in other settings, too. We now teach three (of five) sections of our introductory physics class for life-science majors in a new 81-student studio classroom, and one section (of two) of our off-sequence introductory physics class for engineering majors. In each studio section, students learn with the help of one instructor, two TAs, and two LAs.



One of our LAs in physics, Alina Agamov (center) working with two students in our new Interactive Studio Classroom.

Program Summary

The PhysTEC project at Boston University has been a catalyst for change. The presence of a physics teacher-in-residence has contributed greatly to our efforts to recruit physics majors into teaching; to our course-reform endeavors; and, to the establishment of a network of local high school physics teachers. The strong relationship with the School of Education has advanced the LA program and led to a new teaching track for Physics majors. Three years has not been long enough to complete all of our objectives but, thanks

to PhysTEC funding, much has been accomplished. Over the next few years, we plan to expand the LA program, develop sustainable support, and advance course reform, contributing to an atmosphere at a top research university in which becoming a science teacher, in particular a physics teacher, is perceived as a first-rate career option for undergraduate science majors.

Andrew Duffy is a Master Lecturer in Physics and PI of Boston University's PhysTEC program.

Peter Garik, Clinical Associate Professor of Science Education, is a physicist who is PI for the BU Noyce Scholarship Program for science students and co-PI for the PhysTEC grant.

Bennett Goldberg is a professor of physics, biomedical and electrical engineering and is the inaugural Director of STEM Education Initiatives at BU.

Manher Jariwala is a Lecturer in physics and also directs the department's Learning Assistant program.

Mark Greenman serves as Teacher-in-Residence at Boston University and is a Presidential Award winner and a past recipient of AAPT's Paul Zitzewitz Award for Excellence in K-12 Physics Teaching.

PhysTEC at The Beach! Key Elements from our Successful PhysTEC Project

Kevin Dwyer, Laura Henriques, California State University, Long Beach

A hallmark of the PhysTEC funded programs is the Teacher-In-Residence. This portion of the program brings a high school physics teacher to a college campus to spend a year in the Physics Department. The Teacher-In-Residence, affectionately known as a TIR, helps recruit, support and prepare future physics teachers in a variety of ways. Each campus has its own expectations for what the TIR will do, but all campuses endeavor to fully incorporate the TIR into the life of the department and campus. Good TIRs make a big difference in how a PhysTEC project progresses. California State University, Long Beach's (CSULB) approach for implementing the TIR is a bit different than other campuses in that our TIR is part-time with us and full-time in the high school classroom. We try to utilize the TIRs where they can provide the greatest value added. For us, that has been co-teaching courses with full-time faculty, mentoring physics teacher candidates, and helping build and support a community of physics teachers.

The place where the TIR has made the biggest impact is in co-teaching a course which was developed as part of the CSULB PhysTEC grant, PHYS491 – Pedagogical Content Knowledge in Physics. The course has gone through the university curriculum

review process, making it a part of the official course offerings for physics. The course is offered once per year with a different topic each time. This fall the class was offered (and 14 students enrolled) even though grant funding had ended in summer. The primary goal of the course is to help pre-service and in-service teachers improve their physics teaching skills within a single topic of physics. We want these teacher candidates (and teachers) to leave the course with a better sense of how to structure learning experiences and reflect upon the best ways to help students learn. A secondary goal of the course is to help create a community of physics teachers. All too often physics teachers get hired as the sole physics teacher at their school site. By regularly bringing together pre-service and in-service physics (and physical science) teachers we are helping to build that network.

The course is an upper division Physics course taught by a high school physics teacher (the TIR) and a science education faculty member with high school physics teaching experience. It focuses on the teaching of a different topic area each semester (so far we have offered waves/sound/optics, force and motion, energy and momentum, and electricity and magnetism). It is a blend of a phys-

ics course and a methods course with the goal of building pedagogical content knowledge. The class is open to physics majors, physics credential candidates, and in-service teachers. The course has students investigate common student misconceptions and how they can be challenged. We critically examine labs, demonstrations, simulations, activities and textbooks with an eye towards modifying them to meet the needs of all learners, especially English learners. The sequencing of instruction and the planning of a full unit is a whole class activity which requires students to carefully evaluate all the material seen during the semester. Students also do a grant writing activity. Students find, research and present physics demonstrations as part of the class.

Another requirement of the class is to attend professional development workshops. Choices available include California Science Teacher Association's Science Education Conference, local AAPT meetings and the Southern California AAPT New Physics Teacher workshops. When the state Science Education Conference is local, the class presents 60 minutes of demonstrations and labs. Each student has approximately five minutes to share something from the semester's topic. In addition to actually doing the presentation at the conference (a nerve-wracking experience for some!), students prepare the PowerPoint slide that goes along with their demo, write an explanation of the physics involved, and describe where in the unit they might use the demo. The materials they create (PPT and explanation) are posted on the conference website.

The impact of the Physics Teaching course at CSULB can be measured in multiple ways. At the beginning of the course, students take a pre-assessment to gauge their knowledge of the physics content for that semester. Post-assessment results show statistically significant gains in content knowledge. Both assessments also require students to rate how confident they were for each answer. The students showed content gains, increased confidence in their knowledge, and an indication that the increased confidence is warranted. In other words, at the end of the course they are confident in what they accurately know and they recognize areas where their content knowledge is weaker. Many students start the semester thinking they know all the content even when they don't, so this metacognitive shift is noteworthy.

Another measure of the success of the class is the number of students who have taken the class multiple times (allowable since the physics topic changes each semester). This course is an elective, not counting towards the physics teaching credential or the physics major. This was intentional so that we would not be bound by the state and College of Education assessment and accreditation requirements. Yet, students take the class multiple times, even though it doesn't "count" because they find value in it.

To achieve the secondary goal of developing a community of physics teachers, CSULB instituted monthly Physics Demo Days. Held on campus in the late afternoon, these events are advertised to local high school physics teachers and the campus community. Each month addresses a different topic in the high school physics curriculum. The Demo Days are well attended, typically 35-50 people.

The audience includes high school teachers, prospective physics teachers, students in the PhysTEC course, university professors, and others including graduate and undergraduate physics students. Attendees are not required to bring a demo, but all are encouraged to share. The events have lots of lively discussion, questions about the demos and physics, and suggestions for modifications/extensions. The Demo Days often run past the scheduled time and the conversations continue in the hallway afterwards. Students in the PhysTEC course prepare and present a demo and receive feedback on their presentation. As part of the course, they also reflect on their presentation so that they can make improvements for next time. We want them to become contributing members to the science teaching profession and this is one way to start them on that path.

Other ways our PhysTEC program has tried to build a physics teaching culture and community at CSULB include the PhysTEC Open Houses and Physics Social Mixers. The PhysTEC Open House is a community building event that takes place at CSULB each semester. The Open House invites high school physics teachers and several of their students to campus to hear a keynote speaker, do some hands-on activities, have brunch with the university faculty, tour the physics labs and listen to a panel discussion with physics undergraduate and graduate students. There are ample times for networking within and across these groups. It is exciting to see teachers return to these events and to see them exchanging physics teaching ideas. It is also exciting to see their students matriculate with us in subsequent years. We anticipate having them join us as physics majors.

At the campus level, the PhysTEC Social Mixer brings together CSULB physics students, prospective physics teachers, and physics faculty for food and some friendly team physics competitions. Announcements at these events include commercials for how to become a physics teacher and the benefits and rewards of that career choice. A common factor in all of the community building events (the Demo Days, Open Houses, and Social Mixers) is food. If you feed them, they will come!

While it is difficult to measure, many connections have been made between members of the Long Beach/Orange County physics community. Physics teaching candidates from CSULB will, upon graduation, have numerous contacts in the local schools to draw upon for support and advice. They also have contacts with engaged physics teachers to observe during their credential program. The high school teachers have made connections with the university faculty and each other. They have reached out to CSULB physics faculty for content expertise and guest presentations at their school. They have also helped make connections between their high school students and the CSULB physics department. The high school teachers have also made connections with each other, helping ease the isolation associated with being the lone physics teacher on campus.

The course and PhysTEC in general have brought about a cultural change within the Physics department, as faculty now see the value

in developing strong high school physics teachers and relationships with physics teachers. Where in the past they encouraged strong physics students to consider graduate school, research or working in industry, faculty now support and encourage physics teaching as a viable and valuable career option. The high quality of our Teacher-In-Residences coupled with strong programming elements has supported this cultural shift and the development of our physics teaching community. It has been a winning combination for all.

Kevin Dwyer is a physics teacher at Cypress High School in the Anaheim Union HSD. He was the CSULB PhysTEC Teacher-In-Residence during 2012-2013.

Laura Henriques is Professor of Science Education at California State University, Long Beach and President of the California Science Teachers Association.

Tomorrow's Outstanding Physics Teachers at the University of Missouri

Karen E. L. King, University of Missouri

A recent editorial in the *New York Times*, “Who Says Math Has to Be Boring?”, once again brought national attention to the great need for highly qualified science and math teachers (Rosenthal, 2013). As noted in the article, less than 50% of all physical science (including physics) high school classes are taught by teachers with a major in the subject (Hill & Gruber, 2011). Given this trend, it's not surprising that colleagues grumble about our incoming students' lack of curiosity and problem-solving skills. Yet we are in a position to improve the preparation of these students by investing in our current undergraduates – and encouraging them to consider teaching as a career. The Physics Teacher Education Coalition (PhysTEC), as a project of the American Physical Society and the American Association of Physics Teachers, aims to transform secondary physics by drastically increasing the number of new teachers who actually *have a physics degree*; this national recruiting effort is coupled with a commitment to improve the *quality of physics teacher education*, with the aim of improving high school student achievement.

As a starting point, we need to take an inventory of what our own institutions are doing to prepare physics teachers. A nationwide survey of physics departments by the Task Force on Teacher Education in Physics (T-TEP) found that only 7% of responding departments had an active physics teacher education program, where “active” is defined as graduating two or more undergraduate students per year (The Task Force on Teacher Education in Physics (T-TEP), 2012). This survey had a 77% response rate, with 578 departments responding. Missouri has historically mirrored this national trend, reporting physics teacher shortages for all but one year in the past decade (DESE, 2012). From 2007-2011, Missouri schools graduated only 5.6 new physics teachers per year from all standard undergraduate programs combined (DESE, Public Records: Physics Courses and Physics Certification 2007-2011, 2011). The flagship institution, the University of Missouri (MU), conferred an annual average of only 0.22 B.S. degrees in secondary physics education from 2004-2012. Meanwhile, demand has grown, both nationally and in Missouri, where enrollment in secondary physics courses increased by 49% from 2007 to 2011

(DESE, Public Records: Physics Courses and Physics Certification 2007-2011, 2011). Clearly, MU, like other universities, could do more to help meet the growing demand for physics.

In 2012, the University of Missouri in Columbia launched Tomorrow's Outstanding Physics Teacher (TOP Teacher), a new initiative supported by PhysTEC. The goals of the program are to:

1. Increase the number of MU students earning degrees that lead to highly qualified secondary physics certification to at least 3.33 per year by 2015.
2. Better prepare teachers with physics-specific content and pedagogy.
3. Contribute to the national PhysTEC model to effect statewide and nationwide change.

The state standard for secondary physics education is below our own criteria for what we consider “highly qualified.” While Missouri allows physics certification through “test endorsement” (i.e. passing the physics Praxis test), TOP teacher graduates include only students who earn dual B.S. degrees in physics and in physics education, or those who earn an M.S. in science education after having attained a B.S. or B.A. in physics or similar field (e.g. engineering). Since we initiated reforms in Fall 2012, MU has graduated two new students who fit this qualification. An additional nine students are officially enrolled in the dual B.S. physics education degree program, and several other students have indicated that they plan to enroll in either the B.S. or M.S. programs. Comparing our average number of physics education B.S. degrees in the nine years before reforms (0.22/yr) to the average number anticipated in the first four years of reforms (2.25/yr), we anticipate > 900% growth. Furthermore, the trajectory is increasing (six students are expected to graduate in 2016), and we hope to have an additional 1-2 new physics graduates annually from the M.S. in science education program (compared to a prior average of 0.56/yr), helping us meet our goal of more than 3 students per year.

So what has made the difference?

The University of Missouri has implemented what PhysTEC and

the T-TEP report have determined to be key components of a successful teacher preparation program, including:

- hiring a Teacher in Residence from the local school district;
- building a Learning Assistant program to promote early teaching experiences;
- introducing new courses and advocating for reforms in others;
- recruiting (and retaining) students using diverse tactics;
- facilitating multiple entry points for students to commence physics education programs; and
- nurturing collaborations between the College of Education and Department of Physics and Astronomy.

Leveraging existing partnerships among and within local schools, the university, and the physics department, Tomorrow's Outstanding Physics Teacher (TOP Teacher) at MU has taken on its own local version of each of these essential components.

The Positive Effects of a Teacher in Residence

Using a cornerstone of the PhysTEC model, our TOP teacher program hosts a high school physics teacher who takes a leave of absence from teaching to work at the university. Our current Teacher in Residence, Mr. Doug Steinhoff, has been hugely influential in building a more effective program for attracting physics students to the teaching profession and educating them in best practices. A master physics teacher with more than 25 years in the classroom, Mr. Steinhoff also brought more than a decade of experience working with MU physics faculty on education initiatives. In the past few years, he has served as an instructor over the summer in the NSF-sponsored "A TIME for Physics First", aimed at providing >10 weeks on-site professional development and three years of academic year support for more than 60 ninth grade physics teachers across Missouri (Chandrasekhar, 2011). The strong relationships that have been built among Columbia Public Schools teachers and administrators as well as MU physics faculty have greatly eased the implementation of new program components, such as opportunities to explore high school teaching, and a new physics course taught by Mr. Steinhoff (both reforms are described in the next two sections). Mr. Steinhoff's practical knowledge of teaching physics and his contagious enthusiasm for inspiring and challenging kids have made him an excellent resource and effective recruiter for the TOP teacher program.

Learning Assistants in Columbia High Schools

We have found the single most important recruiting tool to be our unique high school learning assistant (LA) program. Physics, engineering, and physics education students are encouraged to apply for paid positions to help in local high school physics classrooms. Most work in ninth grade classes where the MU Physics First modeling and inquiry-based curriculum is taught. They attend the class every time it meets for the duration of the semester. This time commitment greatly exceeds the 20-24 hours per semester of field experiences that education students take with each of their three science teaching methods courses. Significantly, this early teaching experience is also available to physics and engineering majors, rather than limited to education students. As a recruiting tool, the frequent interaction with high school students lets them experience

the rewards of teaching and touching people's lives.

A physics major who participated in the learning assistant program commented in our end-of-semester evaluation that the "best part of being an LA was connecting with students." Indeed, LAs who are hired for a second semester request to be in the same classroom so that they can continue to work with the students they have already gotten to know. As an educational opportunity, those who will ultimately become teachers gain additional experience with excellent cooperating teachers who have been carefully selected by the Teacher in Residence. In comparison to their field experiences, physics education majors have told us that they learn much more from the extensive learning assistant program. Indeed, when the cooperating teachers have had substitute teachers, the high school students routinely turn to the LAs for help.

Undergraduates who wish to serve as an LA for a second semester are required to take our new physics course, "Teaching Physics", aimed at introducing students to effective practices in high school physics instruction. By asking students to take this additional step along the pathway towards a teaching career, the program remains committed to investing in the education of future teachers.

Course Reforms and a Growing LA program

In the Spring 2014 semester, we will employ our first group of LAs in MU classes, starting with College Physics I. Working from the standard model developed at the University of Colorado at Boulder, the LAs will facilitate a variety of collaborative learning in this large enrollment course, the first semester of the algebra-based introductory sequence. As required for the position, all seven of these LAs have served as high school LAs in a previous semester and have taken (or are enrolled for the Spring semester in) "Teaching Physics". Thus, they are familiar with the research-based active learning strategies that will be implemented in the course. Recitations will have greater emphasis on conceptual understanding, and thinking about one's own thinking (metacognition) using a combination of University of Maryland open-source tutorials (Elby) and Activity Based Physics Thinking Problems (Redish, 2001). Each section (maximum enrollment = 40) will be led by a team of 1 graduate teaching assistant (TA) and 1 undergraduate learning assistant (LA), who will guide students working together in groups. Aligned with the principles of Just in Time Teaching, lectures (maximum enrollment = 200) will be "flipped"; students will be expected to prepare for class ahead of time (e.g. by reading the textbook or watching a mini-lecture and providing formative assessment feedback in the form of online questions and discussion boards). In-class time will be informed by this student feedback and will focus more engaging activities such as peer instruction (Mazur, 1997), interactive lecture demonstrations, clarification of questions, and practice with problem-solving. The lecture hall, with students grouped at tables of two, will be divided by recitation sections with an LA assigned to each section.

Entering our fourth semester of the LA program, we have seen the greatest interest in the program yet – 7 new students were hired to work in high school courses in the spring, out of a pool of 14 new

applicants. An additional 7 students are enthusiastic about assisting in the reformed College Physics I course at MU.

Recruitment into Multiple Entry Points

A dual degree in physics and physics education at MU is difficult (or near impossible) to complete if students have not chosen their degree plan by the end of their sophomore year, yet it is well known that college students often change their major (sometimes several times). Offering post-baccalaureate programs provides increased opportunities for potential physics teachers to earn certification. We have found that the learning assistant program and the Teaching Physics course allow such students to explore teaching as a career, knowing that the M.S. in science education program is available to them if they choose to become certified. Furthermore, it has become a way to engage these students in teaching experiences as juniors and seniors, rather than having to wait until they graduate to begin the process of teacher education. Being in just our second year of the reformed program, it is hard to predict how many of our current students will choose this path. However, as many as four of our current or former LAs have indicated a serious interest in the program.

We have employed multiple tactics for recruiting into the two degree programs (B.S. and M.S.). For both programs, the primary strategy is to attract students by asking them to apply for the paid learning assistant program. We make visits to introductory and advanced physics classes, as well as spreading the word by posters, websites, Facebook, department-wide emails, and a HDTV wide-screen monitor outside the lecture halls for the large enrollment introductory courses. For all of our advertisements, the message is clear: the LA position is an opportunity to explore physics teaching as a career. The high school placement seems to attract applicants who are sincerely interested in (or at least curious about) teaching as a career. The word-of-mouth effect has caught on this semester; now that we have a critical mass of LAs within the department, many new applicants have told us that their friend told them about the opportunity. We are open to sharing any and all of our recruiting materials; please contact the corresponding author.

Essential Partners in Physics Education

Almost all of the program components rest on the solid foundation of existing partnerships. We are fortunate to have an excellent relationship with the College of Education, which has been hugely supportive of this initiative. The education faculty and staff have helped us clarify advising sheets for students, been open to degree plan changes (including the new “Teaching Physics” pedagogical content knowledge course), help us track students, and send any curious students our way. Before embarking on a new or reformed teacher preparation program, we would highly recommend building and nurturing relationships with colleagues in education. The top three strategies we have found to be most helpful are:

- *Pursue a faculty line for a joint appointment in physics and education.* The College of Education and College of Arts and Sciences has three faculty members with joint appointments. These colleagues have been instrumental in connecting fac-

ulty across campus.

- *Serve on committees.* Several of our physics faculty serve on doctoral and masters students committees in education. We have also participated in science education faculty searches.
- *Write grants together.* In addition to collaborating on the Phys-TEC award, physics and education faculty work together on the NSF-sponsored “A Time for Physics First” grant (aimed at high school teachers) and an NSF-sponsored “Quality Elementary Science Teaching (QUEST)” grant.

These collaborations within MU have spilled over into collaborations with the local school district. Many of the science (especially physics) teachers have served on the Physics First and QUEST grants. Additionally, we have a great working relationship with the science coordinator for the school district. This support has proven invaluable to negotiating leave and compensation for our Teacher in Residence and has made the placement of LAs in the classrooms a welcomed proposal.

Meeting the Statewide Need

We have seen tremendous growth in the past year; based on the upward trend in enrollment, we hope see graduation rates of five or more new teachers per year. Indeed, this would place our department among the 1% of physics departments nationally that currently report more than four graduates per year (The Task Force on Teacher Education in Physics (T-TEP), 2012). Clearly, however, this would still not be enough to meet the needs of all the schools in Missouri. We are pleased to learn of the new Noyce Program at Truman State University, which offers dual degrees in physics and math education, and we look forward to learning more about the learning assistant program at Missouri University of Science and Technology in their upcoming LEAD workshop in February 2014. In the coming years, we aim to build a network of colleagues across Missouri who are also committed to physics teacher preparation, that we might eliminate the current teacher shortages and enhance student learning across the state.

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- Dr. Karen King (kingkar@missouri.edu) is an Assistant Teaching Professor in the Department of Physics and Astronomy at the University of Missouri. She serves as PI on the PhysTEC award and as key personnel on two NSF-sponsored projects aimed at teacher education, Quality Elementary Science Teaching (QUEST) and A TIME for Physics First.*

Browsing the Journals

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

- Solving for the eigenstates and energies of a hydrogen atom is a standard problem in introductory quantum mechanics. The radial part of the wavefunction exponentially tails away to infinity. But what happens if the atoms are confined, as might be an approximation of an exciton in a quantum dot? Then we must impose the boundary condition that the radial part goes to zero at some finite radius rather than at infinity. That in turn means we need to keep the second solution of the Schrödinger equation, known as Kummer functions. Read more about this analysis on page 860 of the November 2013 issue of the *American Journal of Physics* (<http://scitation.aip.org/content/aapt/journal/ajp>). Variations on this problem are a one-dimensional simple harmonic oscillator confined between two plates off which it bounces elastically, or a point charge in a capacitor (as a model of a biased quantum well).
- There is an interesting study published in *Physical Review Special Topics–Physics Education Research* in January at <http://prst-per.aps.org/toc/PRSTPER/v10/i1> about a comparison of different methods to compute a particular partial derivative involving a van der Waals gas. I present my own short solution to the studied problem at http://usna.edu/Users/physics/mungan/_files/documents/Scholarship/PartialDerivativeVanDerWaals.pdf.
- Page 434 of the October 2013 issue of *The Physics Teacher* (<http://scitation.aip.org/content/aapt/journal/tpt>) has an article entitled “Variations on the zilch cycle.” A zilch cycle has a “figure 8” shape on either a P-V or T-S graph, chosen so that the two lobes of the “8” have equal area but are traversed in opposite directions. That way, both net work and net heat are zero during a cycle. A zilch cycle is thus intermediate between a heat engine (which converts net heat input into work output) and a refrigerator (which converts work input into a net heat transfer). Readers should be alert to catch and correct a number of typos in the equations in this article, however.
- Some interesting experiments using a Levitron (magnetically levitated spinning top) are reported on page 67 of the January 2014 issue of *Physics Education*, accessible at <http://iopscience.iop.org/journals>. By setting up outrigger magnets on and off the baseplate, one can tilt the spin axis of the top from the vertical all the way to a horizontal orientation! Analogs and applications of the precession and nutation are discussed.
- A common science fair project is to make a battery. But typical projects use lemons which have very limited current density. A much better battery can be constructed using plates of aluminum and copper, table salt, and Drano drain cleaner, as described on page 1341 of the October 2013 issue of the *Journal of Chemical Education* at <http://pubs.acs.org/toc/jceda8/90/10>. In a similar vein of science fair projects, see the article on page 1353 which considers the best way to construct a “soap boat” that is driven by differences in surface tension between water and another liquid (using alcohol rather than soap), as well as the article on page 1358 which cleverly considers how to build a reasonable solar cell out of household ingredients (well... except for the ITO glass slides used as substrates).
- Is it possible to create molecules out of photons? Apparently yes, in a cold atomic gas, as discussed in the blurb at <http://physicsworld.com/cws/article/news/2013/sep/26/physicists-create-molecules-of-light> that references an article in *Nature*.



Web Watch

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- San Francisco's Exploratorium science museum has a comprehensive website at <http://www.exploratorium.edu/explore>. Check out "Everyday Science" or "Material World." Boston's Museum of Science has engineering resources available at <http://www.eie.org/>.
- The Physics Teacher Education Coalition (PhysTEC) has plenty of materials online at <http://www.phystec.org>.
- The University of Chicago Library has a set of online resources about Enrico Fermi and his Nuclear Pile at <http://guides.lib.uchicago.edu/content.php?pid=414238&sid=3385424>.
- The Howard Hughes Institute has some useful materials for young scientists at <http://www.hhmi.org/educational-materials/lab-management/for-early-career-scientists> including an online book for new faculty and advice on how to write letters of recommendation.
- Amazing Space at <http://amazing-space.stsci.edu/eds/tools/> has loads of facts, visuals, and activities about astronomy with ideas about how to use them in the classroom. Also see NASA's comprehensive library at <http://nasawavelength.org> and click on "Higher Education" for example.
- The half-hour PSSC video on "Straight Line Kinematics" has been uploaded to YouTube at <https://www.youtube.com/watch?v=-FHoiQL2-tY>
- Indiana has a collection of STEM resources at <https://www.istemnetwork.org/resource/educational/lesson.cfm>. Another collection is that of FirstBook at <http://stem.firstbook.org/>. Also see Iowa State's materials at <http://www.cesmee.hs.iastate.edu/>.
- The higher education journal Issues in Science and Technology, which is a forum for discussion of public policy, can be found online at <http://www.issues.org/backissues.html>.
- The University of Colorado at Boulder's PER group has a large collection of useful materials for teaching physics across the undergraduate curriculum at <http://www.colorado.edu/physics/EducationIssues/cts/>.
- Science in the Classroom at <http://scienceintheclassroom.org/> is a collection of annotated articles and teaching accompaniments supported by the NSF.
- The Smithsonian has a set of teaching resources (mainly for middle schools) in different areas of science at <http://www.ssec.si.edu/ms-teaching-resources>.
- A large variety of open-access online physics courses have been aggregated into one page with a uniform look at <http://www.onlinecourses.com/Physics/>.
- A great set of books, web sites, and techniques for interactive teaching have been summarized at <http://www.une.edu/cas/core/teaching.cfm>.
- Looking for hard data on science graduate education and employment, federal research funding, and technical research facilities? NSF has collected together its survey reports at <http://www.nsf.gov/statistics/surveys.cfm>.
- The National Nanotechnology Infrastructure Network has some nicely organized curricular materials for different levels and subjects at <http://www.nnin.org/education-training/k-12-teachers/nanotechnology-curriculum-materials>.



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Upcoming newsletter deadlines:

Summer 2014: June 1st, 2014

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