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Forum on Education
American Physical Society

Spring 2017 Newsletter

Richard Steinberg, Editor

In this issue:

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From the Chair

John Stewart, West Virginia University

Officer roles change at the Forum on Education Executive Committee (ExComm) meeting held at the April meeting (held in January this year). I am writing this note a few weeks before the meeting, so I hope I also capture the sentiments of the still current chair, Tim Stelzer (University of Illinois Urbana-Champaign). By the time this newsletter is published, Tim will become the Past Chair, I will be the Chair, Larry Cain (Davidson College) will be Chair Elect, and Laurie McNeil (University of North Carolina – Chapel Hill) will join the ExComm as the newly elected Vice Chair. Larry discusses the election process and results in the article which follows. The Past Chair oversees the awards process including the nomination of APS Fellows, the *Excellence in Physics Education Award, and the Jonathan F. Reichert and Barbara Wolff-Reichert Award for Excellence in Advanced Laboratory Instruction*; be sure to pass on nominations to Tim. The Chair Elect is the chair of the program committee which sets the invited program at the March and April meetings. The FEd has also sponsored a session organized by Heather Lewandowski at the DAMOP meeting for the last few years. Heather finished her term on the ExComm last April. The program committee is always looking for ideas for interesting sessions and people willing to organize them; direct those ideas to Larry. I would like to welcome Noah Finkelstein as the new Forum Counselor, and welcome back Charles Henderson as secretary/treasurer. Both have already given extensively of their time to support APS and physics education. I am also pleased to once again work with new members-at-large Chuhee Kwon and Beth Lindsey. Chuhee has spent many years supporting the development of highly trained physics teachers through the PhysTEC project. Beth returns to the ExComm after a short break; she served 3 years as newsletter editor. Richard Steinberg, who took over for Beth, is just completing his first year as editor (and doing a fantastic job).

We said goodbye to past president Randy Knight who managed the complicated process of updating the Forum's bylaws to conform to the new APS governance structure during his time in office. Gay Stewart also leaves after two terms as Forum Councilor; she was instrumental in giving education a voice with the APS Board of Directors. The counselor represents the Forum at APS council meetings and communicates the discussions at those meetings to the ExComm. Some members of the Board of Directors are elected from the council. We are quite pleased that Gay's role will be in the capable hands of Noah Finkelstein. Also leaving the ExComm are members-at-large Jorge Lopez and Wendy Adams. I thank all departing members for their service.

The program committee put together a set of March Meeting invited sessions that should appeal to current and future educators. The **Reichert Award** session will feature award winner Richard Peterson as well as a number of other experts in improving advanced lab instruction; thanks to organizer Heather Lewandowski. The **Preparing Physics Students for 21st Century Careers** session will allow industry and academic experts to discuss how physics departments can produce graduates with the skills needed outside of academia; thanks to Ted Hodapp for organizing. For new faculty (or students who may become new faculty) we present **The New (and Future) Faculty Workshop in Three Hours** to introduce research-based educational methods; thanks to Mary Mogge for organizing. For students (or faculty who have students) we present an overview of the physics career landscape in the session **How to Get a Job: Preparing for a Career in Physics**. I hope those attending the meeting can find some time to get away from the cutting edge science to learn more about education and careers.

Forum on Education Election Results

Larry Cain, Vice-Chair APS Forum on Education, Davidson College

The 2016 election results for new officers were announced in a December email to members of the Forum. The Forum on Education congratulates the following candidates who were elected to office. Noah Finkelstein of the University of Colorado Boulder was elected to a four-year term as APS Forum Councilor. He became a member of the APS Council of Representatives on January 1, 2017 as the FEd representative. Laurie McNeil of UNC-Chapel Hill was elected FEd Vice-Chair. She will serve a four-year term, becoming Chair-Elect, Chair, and Past Chair. Her responsibility as Vice-Chair will be organizing next year's election. Charles Henderson of Western Michigan University was re-elected as Secretary/Treasurer for another three-year term. Chuhee Kwon of California State University Long Beach was elected to a three-year term as Member-at-Large. Beth Lindsey of Penn State Greater Allegheny was elected to a three-year term as APS/AAPT Member-at-Large. These last four newly elected FEd officers will begin their term of office immediately after the APS April meeting (this year at the end of January).

The Forum also thanks the other candidates who agreed to be part of this outstanding slate: Susan Blessing, Amber Stuver, Ken Heller, Andrew Hirsch, and Joe Kozminski. It should be considered an honor to be nominated by your Forum colleagues to run for office. I hope all candidates who were not elected will remain active in the Forum and that many will be elected to serve in the future.

The excellent and thoughtful work of the nominating committee produced this outstanding slate of candidates. This year the nominating committee was composed of Larry Cain (chair), Geraldine Cochran, Paul Cottle, Chandralekha Singh, Gordon Ramsey (representing AAPT) and Ted Hodapp (representing APS). A new committee will be formed for the 2017 election with Laurie McNeil as chair. Nominations for candidates for Vice-Chair, Member-at-Large, and APS/AAPT Member-at-Large may be sent to Laurie at mcneil@physics.unc.edu.

Nominations Sought for FEd Awards

Randy Knight, Past Chair APS Forum on Education, California Polytechnic State University

The Forum on Education sponsors two major awards. First, the Excellence in Physics Education Award. This award is normally given to a team or group of individuals who have exhibited a sustained commitment to excellence in physics education, although in exceptional cases it can be awarded to a single individual. Second, the Jonathan F. Reichert and Barbara Wolff-Reichert Award for Excellence in Advanced Laboratory Instruction. The winners receive a monetary award and give an invited talk at an APS meeting.

The awards process is driven by nominations. Outstanding teams and individuals can't receive the recognition they deserve unless someone makes the effort to nominate them. Making a nomination is not onerous, and the task of gathering the necessary information can be shared by two or three nominators.

If you know individuals or groups worthy of recognition, please nominate them! Go to the FEd award page http://www.aps.org/units/fed/awards/index.cfm to learn more about the awards and find a list of previous winners. Each award has a "View APS website" link that will take you to a page with award rules and information on how to make a nomination. The nomination deadline for both awards is June 30, 2017.

Fundraising Challenge for the Excellence in Physics Education Award

Randy Knight, Past Chair APS Forum on Education, California Polytechnic State University

The Forum on Education announces the kickoff of a Fundraising Challenge to finish endowing the Excellence in Physics Education Award. As an incentive for success, the Forum will match individual donations one-for-one up to a total of $15,000.

The FEd's Excellence in Physics Education Award was established in 2007 after a successful appeal to FEd and APS members raised enough money to endow the award itself. However, the endowment is not sufficient to pay for the winners' travel to the APS April meeting where they give invited talks. The Forum has been covering travel out of its annual budget from APS, but that is not a sustainable funding model for the long term.

The goal of the Fundraising Challenge is to raise $65,000 by the end of 2018. This will fully endow the award so that we can continue to honor excellence in physics education year after year.

Please help us meet this challenge! You can make a tax-deductible donation online by going to the FEd homepage http://www.aps.org/units/fed/ and following the link given there. You will also find information about how to donate by check if you prefer.

The PIPELINE Project

Crystal Bailey, Careers Program Manager, American Physical Society

In November, APS announced the publication of the Joint Task Force on Undergraduate Physics Programs (J-TUPP) report which addresses ways to enhance the career readiness of undergraduate physics students. APS is also proud to announce a new program, called PIPELINE, which is focused on developing and disseminating approaches to integrating innovation and entrepreneurship-focused experiences into the physics curriculum. These experiences are designed to explicitly prepare students for careers beyond academia - a goal which is strongly aligned with the J-TUPP report recommendations. You can learn more about the PIPELINE program on the APS website.

PIPELINE brings together the efforts of six institutions (Loyola University Maryland, Rochester Institute of Technology, William and Mary, The George Washington University, the University of Colorado Denver, and Wright State University) to develop activities which convey professional skills (e.g. leadership, communication skills), develop a deep technological expertise that can be applied to innovative solutions (e.g. maker spaces, laboratory prototyping), and create a greater familiarity with private sector concepts (e.g. intellectual property, business structures). The project will also advance our understanding of how the adoption of these practices affect student and faculty attitudes towards innovation and entrepreneurship in physics.

Developed materials will be disseminated through sessions at APS and AAPT meetings, as well as through the PIPELINE website. A special mailing list has also been established to provide monthly updates on new developments in physics innovation and entrepreneurship (PIE) education. Visit the PIE webpage to join this list, and to access information and resources to help you teach PIE at your institution.

In explicitly supporting the career development of physics graduates, the PIE movement can make the physics discipline more robust, more diverse, and more able to capitalize on its natural habits of innovation in order to solve important global problems. We hope that you'll take a look at the important work that's being done and consider joining a growing community of PIE practitioners.

Director's Corner

Theodore Hodapp

In the midst of the US civil war, President Lincoln and the US Congress passed the Morrill Act and established public land-grant universities in this country. These institutions have become a cornerstone for supporting the education of ordinary citizens, and a very public commitment on the part of the federal government and the states to this vision.

Unfortunately, that vision is fading, as state support has fallen dramatically – shrinking by about a third in just the last decade. A new report by the American Academy of Arts & Sciences, *Public Research Universities: Recommitting to Lincoln's Vision—An Educational Compact for the 21st Century* (www.amacad.org/lincoln), details some of the crisis. At stake here, is the premise that we as a country commit to educating our citizens. For physicists, we risk some of the most important ways in which we help students learn physics and appreciate the role physics plays in driving the economy, providing innovation and discovery that impact our everyday lives, and solving difficult problems that confront us from many directions.

With the evolving political scene jostling the applecart of our understanding of the role of government in supporting education, we need to pay particular attention to how public colleges and universities will fare in the face of new ideologies. Protecting education and educational opportunities must become a task for all of us. I urge you to read the AAA&S report, and consider how APS can help you make the message known about the importance of supporting education to your state and federal elected representatives.

Sharing the Wealth in Physics Education

Bruce Mason, University of Oklahoma

Physicists, physics educators, and physics education researchers are a very generous group. Our community is focused on helping our students, creating new approaches to learning and teaching, and sharing these results broadly. The many workshops, conferences, projects, and coalitions hosted by the APS, the AAPT, and their members are evidence of this desire to share. We have used the continual growth and changes in technology to develop many of these new tools for physics education. More importantly, this technology has increased the many ways we have to collaborate on the use and improvement of the tools.

The following articles give an outline of four projects that are leveraging technology and the web to build and share quality resources in physics education.

Kathy Perkins gives an update on the PhET Interactive Simulations and the PhET Community. She describes both the background of PhET and some of the latest developments that extend the simulations to all the devices our students carry these days. More importantly, Kathy outlines the many ways to become connected to the community of PhET users through various social media tools, and encourages all to contribute.

Colleen Countryman and Wolfgang Christian describe "Mobile Device Models" that connect physics simulations, smart phones, and interactive lecture demonstrations to give students, even in large lectures, "hands-on" explorations. The connection between the simulations and smart phone sensors gives students a better feeling for the connections to the real world. As a development of the Open Source Physics project and Easy Java/Javascript Simulations, Colleen and Wolfgang point out that any instructor can use and modify these activities.

Robert Teese gives an overview of the Interactive Video Vignettes (IVV) project that brings to the web tutorials based on video analysis of physical problems. Video analysis as a learning tool has been used for years to engage students; IVV brings these tools online embedded in carefully structured learning activities. Bob gives a few examples of IVV results and encourages users to use the available studio software to build their own.

Kelly Roos introduces us to the Partnership for Integrating Computation into Undergraduate Physics (PICUP), a group working to address the roadblocks to the wide-spread inclusion of computational methods in the physics curriculum. Kelly provides a background to these problems and introduces the face-to-face and online community efforts underway to fix them.

Bruce Mason is an Associate Professor in the Department of Physics and Astronomy at the University of Oklahoma University. He is also director of the ComPADRE network of educational resource collections (http://www.compadre.org).

PhET Interactive Simulations: Joining the PhET Community

Kathy Perkins and the PhET Team, University of Colorado Boulder

With a collection of 134 interactive simulations for teaching science and math, and over 100 million simulation uses per year worldwide, the PhET Interactive Simulations project has come a long way since its beginning in 2002. Founded by Carl Wieman as the "Physics Education Technology" (PhET) project, Carl's vision was to make physics engaging and accessible for all learners, tapping into their natural curiosity about real world phenomena. Each PhET simulation creates a game-like environment where students can engage in exploration and discovery of key science and math concepts. The design supports learners to naturally and productively ask questions, conduct experiments, discover cause-effect relationships, reflect on results, or test their ideas; and it is grounded in education research to address known student difficulties. Today, PhET simulations cover many physics topics – from physical science ideas in elementary school to standard introductory physics to quantum mechanics and a smattering of advanced physics topics.

Making PhET simulations available for free to the entire community has been a priority from the beginning of the project. We leverage the Internet for easy dissemination at scale and use a Creative Commons Attribution license to allow free use by anyone, including commercial companies. To support those with no or poor Internet, we make it easy to download one simulation or the full website for offline use. In response to the declining support for Java and Flash technologies, which has threatened access to PhET simulations, we built a next generation HTML5 code base for PhET simulations and are engaged in a massive redesign and redevelopment effort. In 2017, more physics simulations will be published in HTML5, including Pendulum Lab, Projectile Motion, and Circuit Construction Kit among others.

Building a highly flexible resource – one that can be used with diverse learners, across different settings, and in a variety of ways – has been another priority. Educators know their students, their learning goals, their environment, their resources, and their constraints. Along the way, we have partnered with K12 and college educators in our community to identify and synthesize effective strategies for using PhET simulations and to develop teaching materials. Through these collaborations, for instance, we found that allowing students 5-10 minutes of open play and using challenge questions are two effective approaches for sim-based lessons.

Here we highlight many ways to join the PhET community, from getting started using PhET simulations to sharing your teaching materials to spreading the word. We invite those new to PhET to learn more, and those already part of our PhET community to deepen the connection.

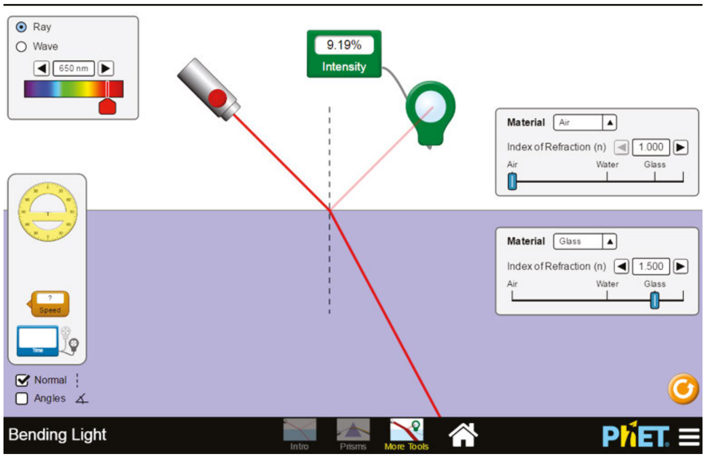
Using PhET simulations at work or at home, online or offline: As a flexible tool, PhET simulations can be used to support many different scenarios – classroom teaching, afterschool programs, homeschooling, museum experiences, online learning, teacher training, tutoring, self-learning, or just independent play. At the PhET website, you will find a collection of teaching resources available that can help get you started, including tips for using PhET in a variety of ways and a collection of over 1,400 user-contributed teaching materials. In addition, each simulation's webpage includes a description of its topics and learning goals, teacher tips, and easy access to all the lessons using that simulation. For example, you can find a collection of clicker questions using the *Wave on a String* simulation and lab activities using *Circuit Construction Kit*. Some teacher preparation programs creatively use these teaching materials for training – asking their pre-service teachers to access, evaluate, implement and revise a PhET lesson as part of their exploration of teaching with technology.

As you begin to explore the website and the simulations available, it is important to attend to the code base of the simulation – HTML5, Java, or Flash. HTML5 simulations will run on any device from computers to chromebooks to iPads. Java simulations, however, will only run on computers while Flash simulations will run on computers or chromebooks. If at first the Java simulations do not run on your computer, please visit our Help Center where you will find a collection of frequently asked questions to help you get them running. If you have an iPad, we have a new PhET iPad App that improves the user experience on iPads.

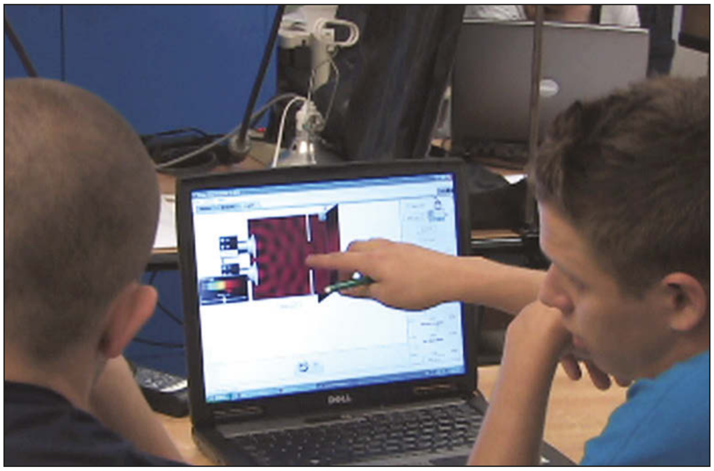
Connecting with PhET: If you use PhET simulations in your teaching or outreach work, or you just want to stay up-to-date, we encourage you to register to create a user account. Registering is free, and gives you access to the growing collection of teacher resources at the PhET website, and is one way to stay informed about new simulations, teacher tips, initiatives, and any scheduled maintenance. Our 250,000 registered users are a diverse group. The largest constituents are college faculty and K12 teachers, with smaller numbers of translators, researchers, parents, students, and others.

Contacting PhET: We love to hear from our user community. If you want to report a bug, share an idea for a new simulation or an improvement, or just seek technical support, you can contact us at phethelp@colorado.edu. While we cannot act on every suggestion, our community has been a great source of ideas. Indeed, the *Bending Light* simulation emerged from a simple emailed recommendation by teacher-user Brad Gearhart, and is now one of our most popular simulations with over 1.5M uses per year. We put every idea and improvement suggestion on our list, and revisit these when we are redesigning old or considering new simulations.

Sharing your teaching materials: From lab activities to homework, from clicker questions to student-created video explanations, educators are using PhET in many creative and effective ways. We encourage you to share your ideas with others! Your contributed lessons can be really helpful – especially for new



The Bending Light *simulation was inspired by a user's suggestion.*



College students explore the Wave Interference *simulation in lab.*

teachers and teachers new to PhET – and can have a significant impact, reaching many teachers and learners. Our longtime colleague and K12 teacher Trish Loeblein has contributed numerous lessons to the PhET activity database, and while she is now retired, her activities are still downloaded more than 1 million times per year. Submission is easy – just login and then navigate to 'Teacher Resources > Share Your Activity'.

Translating PhET: We are deeply grateful for our dedicated community of volunteer translators. Together, this community has translated the individual simulations into more than 80 languages and the entire website into 40 languages. However, for many languages, there are more simulations to be translated (see list). If you are bilingual, we invite you to join our efforts to bring these simulations to every language worldwide. Translating one simulation can take less than 30 minutes.

Joining the conversation: Our community of users is active and growing on our social media channels – particularly on Twitter (@PhETsims) – sharing simulation and lesson ideas for particular topics. We have ambitions to create an online space specifically for our teacher users, with discussion boards, simulation and lesson reviews and recommendations, etc., but currently do not have the resources needed to make big improvements.

Spreading the word: We applaud our community for sharing PhET simulations with their local communities, and beyond. At conferences, we often see community members giving talks on their own work with PhET simulations. We see recommendations pop up on forums, hear about teacher Professional Development events in school districts, and field inquiries from individuals who want to disseminate PhET's full website installer to rural areas around the world. Your actions fuel PhET's mission, and we thank you.

If you have been a member of the PhET community, we hope you've seen some of our recent improvements – more HTML5 simulations published, improved discovery of teacher activities, more active social media channels, more teacher support resources, and new sim-primer videos that are designed to provide a quick orientation so teachers can assess whether the simulation addresses their learning goals. In the years ahead, we will continue to work to enhance our community engagement and teacher resources, within the constraints of available funding. Watch for improvements in 2017, and please keep in touch.

Kathy Perkins is Director of PhET Interactive Simulations and Associate Professor Attendant Rank of Physics at University of Colorado Boulder.

Using Simulations on Mobile Devices on Class

Colleen Countryman, North Carolina State University
Wolfgang Christian, Davidson College

Motivation

Following the tradition of micro-computer based interactive lecture demonstrations (ILDs), we developed a series of web-enabled interactive lecture demonstrations for students' smartphones and tablets. Effectiveness of ILDs for introducing physical concepts has been demonstrated, and there is evidence of significantly improved "learning and retention of fundamental concepts" with students that participate in ILDs.[1] Now, students' personal electronic devices provide us with further opportunities to engage them in these interactive activities. In particular, one study indicates that the use of students' smartphones as data collection devices in introductory labs can strengthen their beliefs about real-world connections, and improve their attitudes about the labs.[2]

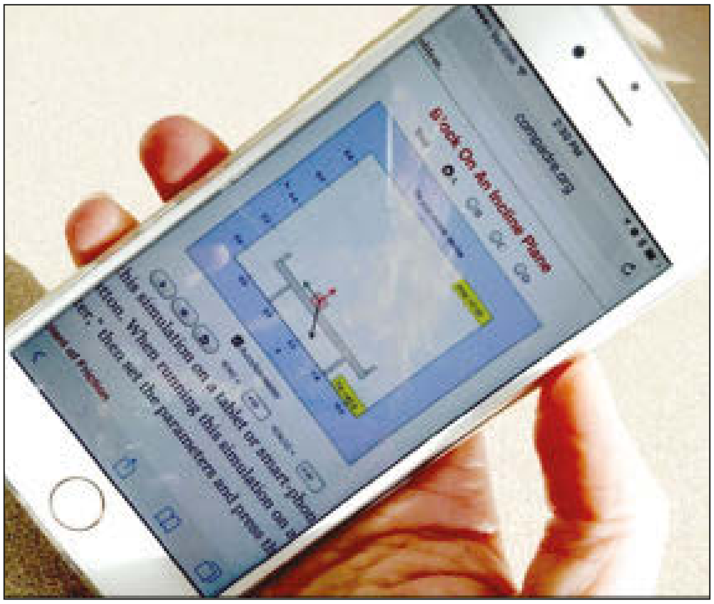
Development

The web-based environment used in these simulations does not require an additional app download. In fact, students can access the simulations through their smart device's built-in browser. The simulations use the Physlet approach presenting students with small, single-concept interactive exercises embedded in a web browser,[3] however these simulations are unique in that they collect acceleration data from the smart devices' internal sensors to impact the motion of the objects of interest in the simulations. Simulations used in the book are distributed with source code through the OpenSource Physics collection hosted on the AAPT ComPADRE website. The simulation source code can be edited, recompiled, and redistributed using the Easy Java/JavaScript Simulations (EJS) authoring and modeling tool developed at the Universidad de Murcia, Spain, by Francisco Esquembre.[4] The only restriction is that these JavaScript simulations must be distributed at no cost under a Creative Commons Attribution-NonCommercial-ShareAlike license.

Our mobile device simulations have been collected and augmented with activities in *Mobile Device Models*,[5] a ComPADRE digital book of explorations, problems, and lecture demos. The activities were the result of examining the learning objectives of a typical introductory physics course, and determining opportunities which could most effectively utilize simulations with controls based on the movement and physical orientation of the device and they are currently being tested at NC State University at Raleigh.

Simulations and Data

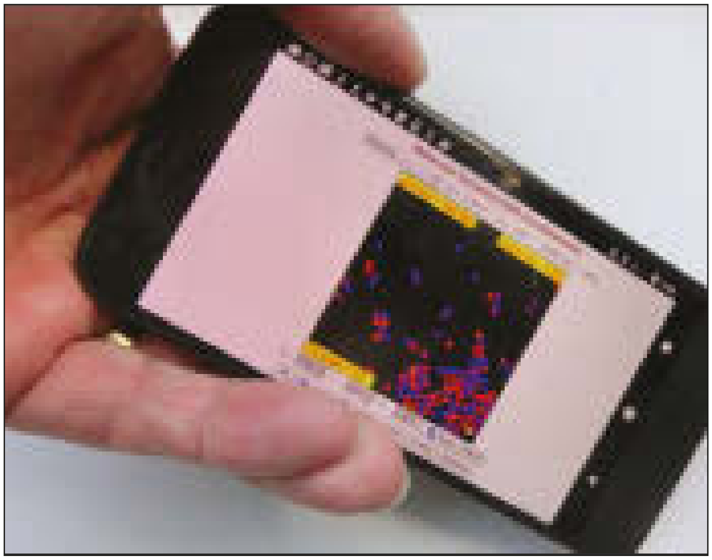
Mobile Device Models features eight different simulations intended for introductory and advanced mechanics classes. We will discuss two in detail here.



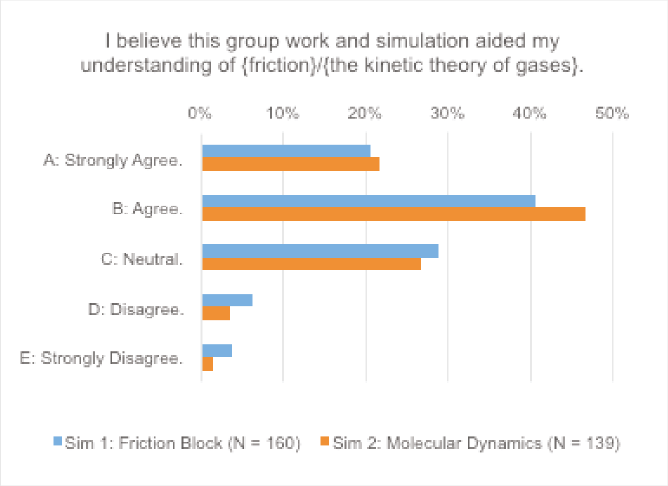
The free body diagram in the "Block on an Incline Plane" simulation responds to the orientation of students' smartphones.

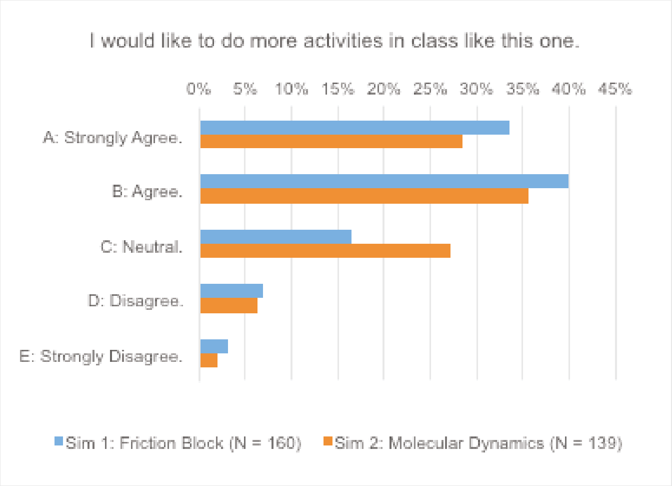
First, in the "block sliding on an incline plane" simulation, a block rests on a table with friction. A free body diagram of the block is drawn. The surface of the plane is fixed to an edge of the smartphone so that as the smartphone rotates, the block experiences a component of the gravitational pull down the inclined plane. The goal of the activity is to determine the static (and, ideally, kinetic) coefficients of friction between the block and the plane.

This simulation and accompanying activity were piloted at North Carolina State University in an introductory calculus-based large-enrollment physics course. Before introducing the simulation, students were asked to work in teams of two to draw a Free Body Diagram of a block on an inclined plane, and determine an expression for the coefficient of static friction between the block and the plane.



Molecules in the simulation clump in the lower right hand corner in response to the orientation of the smartphone.





Students were then asked to navigate to the simulation with their smart devices, and determine the coefficient of static friction between the block and the plane in the simulation. 94% of our 165 study participants brought a smartphone or tablet. The others shared with their partners. 76% of students obtained the correct coefficient of static friction. Given more time, students could have also been asked to determine the coefficient of kinetic friction.

Secondly, we adapted and piloted a molecular dynamics simulation first developed by Dan Schroeder.[6] In the modified simulation, simple molecules in a two-dimensional container respond to the gravitational sensors as well as adjustable thermal parameters. Although the value of the gravitational acceleration is not to scale for a molecular model, the simulation allows students to qualitatively explore the connection between micro- and macroscopic properties of matter, such as the change in density in a gas acted on by an external force.

After a brief lesson on the kinetic theory of gases, students were asked conceptual Clicker questions regarding their expectations of the molecules' motion and average kinetic energy of molecules, as well as the structure of the system of molecules as heat is added. Then, students were asked to explore the simulation and determine how the molecules react to rotation of the screen, and heat added to or removed from the system (in terms of the molecules' color, average speed, total energy of the system, and structure of the system). For an additional challenge, students were asked to try to return the molecules to their original state.

With self-reported data after each simulation activity, we determined that students' attitudes during these activities were consistently positive. More than 60% of the students agreed or strongly agreed that the group work and simulations aided their understanding of the topics at hand, and more than 64% of the students indicated that they would like to do more activities like these in class.

Conclusions

Instructors can capture the accessibility of Interactive Lecture Demonstrations by utilizing the internal sensors within students' smartphones. These new technologies paired with the accessibility of the AAPT ComPADRE digital library allow instructors an opportunity to deliver engaging and interactive content freely to their students. Students have reported that these simulations, paired with thoughtful group work aid their understanding and our survey data contributes to a positive affect.

Colleen Countryman is a Teaching Assistant Professor of Physics at North Carolina State University. She acquired her Ph.D. from NC State in 2015, specializing in Physics Education Research under the guidance of Dr. Robert Beichner and Dr. Michael Paesler. She has researched the impact of various educational technologies, including smartphones in physics labs, YouTube videos as resources to bridge math and physics classes, and online reading quizzes to promote preparation for class.

Wolfgang Christian is Emeritus Professor of Physics at Davidson College where he taught for 33 years. He is a fellow of the APS and of the AAPT and he is the author or co-author of nine books including: An Introduction to Computer Simulation Methods: Applications to Physical System *(Addison Wesley 2006) and* Physlets: Teaching Physics with Interactive Curricular Material *(Prentice Hall, 2001). He was Chair of the APS FEd in 2003 and he was the co-Chair of the 2008 Gordon Research Conference on Physics Research and Education.*

(Endnotes)

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Interactive Video Vignettes

Robert Teese, Rochester Institute of Technology; Priscilla Laws, Dickinson College; Kathy Koenig, University of Cincinnati

One of the common threads of Physics Education Research (PER) is that the educational process must be *active* rather than passive.[1] Video lectures, which have become more common in recent years to support online textbooks and "flipped" classrooms, are passive experiences.[2] An Interactive Video Vignette (IVV) addresses these concerns. It is a web application that combines video with interactive elements such as video analysis, graphing, multiple-choice questions, and question-based branching. The structure includes a series of video segments that are interspersed with questions and other activity-based screens. A typical simple vignette might consist of an introductory video, some type of measurement and analysis, and a wrap-up video to conclude the lesson. A more complicated one might include several experiments or demonstrations with discussions of the theory.

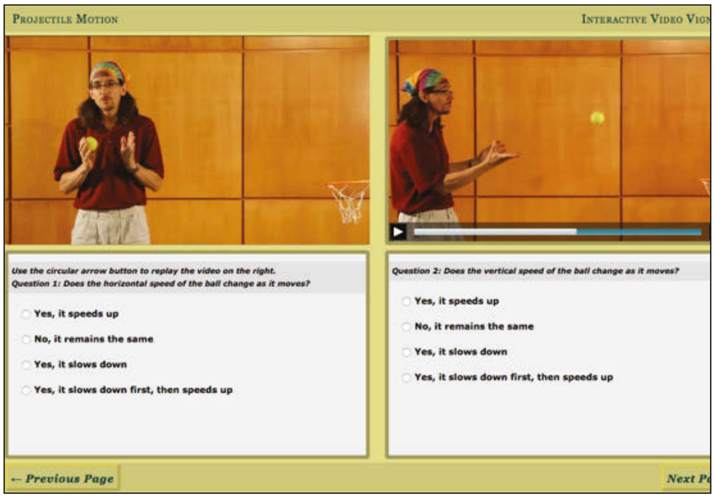
This new genre of online teaching materials was created in the LivePhoto Physics project. It is being developed by a collaboration between Dickinson College, Rochester Institute of Technology and the University of Cincinnati. For the past five years, faculty and students at those institutions have been writing software, making videos and testing the resulting IVVs in physics classes. At the project website (http://www.compadre.org/IVV) physics teachers can learn more about the project, get sample IVVs, and download software for making their own.

The vignette on projectile motion is a good example of a typical IVV. It is narrowly focused on the independence of horizontal and vertical motion. Although it is a simple concept, it is one that frequently confuses students. This vignette takes students five to seven minutes to complete.

In the introduction of this IVV, the narrator discusses some basic aspects of projectile motion. The discussion is illustrated with a dramatic shot of a person being thrown high into the air and landing in a lake. At the end of the introductory video, the narrator tosses a ball into a basket. Students are able to replay the tossing of the ball into the basket as many times as they want (Fig. 1). Meanwhile, the narrator asks the student to watch the tossed ball and focus on the horizontal motion separately from the vertical motion. Before moving on, the student must answer two multiple-choice questions about the horizontal and vertical motion of the tossed ball (is it speeding up, slowing down, etc.).

In the next segment, the horizontal motion of the ball is investigated using video analysis. Students click on the center of the tossed ball to mark the position of the ball in each frame of the video. After each click, the horizontal position of the ball is marked with a vertical line (Fig. 2). The narrator asks the student to deduce something about the horizontal motion of the ball. On the next page, the video analysis results are shown along with the prediction the student made earlier. The narrator explains that since the time between video frames is constant, the equal spacing of the lines means the ball moved in the horizontal direction with a constant speed. In the next segment, the process is repeated, with the student creating horizontal lines for the vertical motion and seeing that the ball slows down going upward and then speeds up going downward.

The development project is research-based. The IVVs are designed based on research-validated curricular frameworks (such as *Elicit-Confront-Resolve)*[3] as well as research on student misconceptions.[4] Controlled studies are taking place at the University of Cincinnati to gauge the impact of IVVs on student learning in physics. We have collected IVV pre-post-performance data on well over 3000 students of 17 faculty. For example, a controlled study conducted in Spring 2014 involved faculty teaching the calculus-based



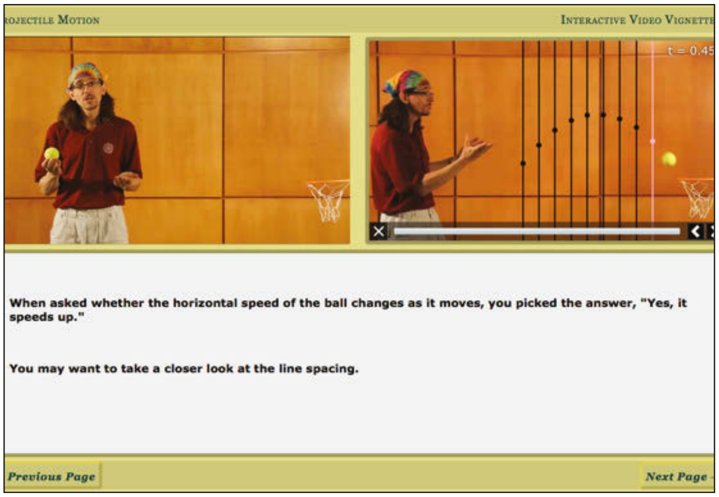
Use the circular arrow button to replay the video on the right.
Question 1: Does the horizontal speed of the ball change as it moves?

○ Yes, it speeds up
○ No, it remains the same
○ Yes, it slows down
○ Yes, it slows down first, then speeds up

Question 2: Does the vertical speed of the ball change as it moves?

○ Yes, it speeds up
○ No, it remains the same
○ Yes, it slows down
○ Yes, it slows down first, then speeds up

Fig. 1. Two multiple-choice prediction questions in the Projectile Motion vignette.



When asked whether the horizontal speed of the ball changes as it moves, you picked the answer, "Yes, it speeds up."

You may want to take a closer look at the line spacing.

Fig. 2. Results of video analysis (top right), showing the student's prediction (bottom).

courses at the University of Cincinnati.[5] Each instructor taught two sections using similar teaching approaches and materials. In one section, each instructor assigned four IVVs (projectile motion and Newton's Laws), while ordinary homework was assigned in their other section. The students were pre- and post-tested the first and last week of the course using the FCI[6] and five additional questions written for our research. For questions involving projectile motion, the pre-test scores for the treatment (229 students) and control (157 students) groups were similar. On the post-test, however, 91% of students in the treatment group but only 79% in the control group indicated that the horizontal speed of a projectile is constant. The pre-to-posttest normalized gains were 67% and 33%, respectively. Both groups performed similarly on the post-test question involving vertical speed, but this was expected due to how the topic was covered in class.

Newton's First and Second Law IVVs also impacted student learning. For example, when asked on the post-test what happens to the speed of a puck on ice *after* being kicked, 86% (55% gain) of students in the treatment group and 81% (34% gain) of students in the control group indicated that the speed remains constant. Similarly, given a constant applied force, 63% (33% gain) of students in the treatment group and 47% (23% gain) of students in the control group indicated that the speed continuously increases at a constant rate.

Studies across nine semesters have been conducted at the University of Cincinnati in both algebra- and calculus-based physics courses. The results of the different studies are confounded, as expected, by the teaching practices and assignments of each instructor and therefore cannot be merged. However, when confounding factors are taken into account on an individual instructor and pre/post-question basis, the results are consistent with those described above.

Vignettes are implemented using HTML5, so they run on tablets as well as laptop or desktop computers. *Vignette Studio*, a free, easy-to-use Java application being created by the project, allows instructors to make their own vignettes. Using its drag-and-drop interface, a developer moves pages into place on a workspace. Individual elements, such as images, videos, questions, video-analysis modules, graphs and so on can be dragged into place on each page. The user's input on one page can be echoed back on a different page, allowing users to compare their predictions to the results of experiments. Question-based branching can be set up, so that each answer to a multiple-choice question links to a different subsequent page. In this way vignettes can provide remediation that is specific to the user's needs. Additional software capabilities are planned for implementation in the remaining years of the project. The software and user manual can be downloaded from our ComPADRE website (http://www.compadre.org/IVV/studio.cfm)
.

The project team has created a set of sample vignettes that illustrate various styles and teaching techniques. In addition to examples of using a single narrator (as in the *Projectile Motion* vignette) or person-on-the-street interviews (as in the *Newton's Third Law* vignette), the ComPADRE website has IVVs with an instructor interacting with one or more students, an instructor engaging in Socratic dialog with a group of students, and two instructors talking to each other. The topics covered include Newton's Laws, circular motion, conservation laws in an inelastic collision, and electrostatics. The goal of making these samples is to help other people develop script ideas by creating and testing a collection that illustrates various ways of making vignettes.

There are also two related projects. First, at Bethel University, Keith Stein, Chad Hoyt and Nathan Lindquist are making pre-lab activities for use in advanced physics lab courses. The topic areas include fluid mechanics, AMO (atomic, molecular, and optical) physics, plasmonics, and nano-optics. These researchers are using *Vignette Studio* to make the activities, and are helping to enhance the IVV software with the inclusion of new capabilities. For example, in one IVV students analyze high-speed and shadowgraph videos of a ping-pong cannon to study supersonic flow and shock waves. Second, a team at RIT and Alfred University is authoring a set of interactive modules for introductory biology courses. The online priming activity in each module is an IVV. So far, vignettes on osmosis, acid/base buffers, natural selection, fermentation, genetics, scientific graphing, and photosynthesis have been finished and are being tested in biology courses.

Cengage Learning has adopted Interactive Video Vignettes for use in WebAssign homework to accompany their physics textbooks. The project members will continue working with online homework providers, textbook publishers and physics-related websites to create opportunities for instructors to use research-based IVVs.

Robert Teese is a Professor of Physics at Rochester Institute of Technology. He led the LivePhoto Physics Project.

Priscilla Laws is a Research Professor at Dickinson College. She invented Workshop Physics, co-authored Understanding Physics, and won the Robert A. Millikan Medal.

Kathleen Koenig is an Associate Professor for the Department of Physics at the University of Cincinnati. Her primary research efforts focus on undergraduate student learning and retention in the STEM majors.

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Lowering Barriers to Curricular Change in Physics: Injecting Computation into the Undergraduate Curriculum

Kelly Roos, Bradley University

The AAPT’s Statement on Computational Physics (http://aapt.org/Resources/policy/Statement-on-Computational-Physics.cfm) quite succinctly makes the case that computation should be an integral part of the undergraduate physics curriculum. Accompanying the AAPT’s statement is a “Rationale” that includes the following assertions:

> *Contemporary research in physics and related sciences almost always involves the use of computers. . . . Computational physics has become a 3rd way of doing physics & complements traditional modes of theoretical and experimental physics. . . . almost all undergraduate students who take physics courses will use computational tools in their future careers even if they do not become practicing physicists.*

Building on this statement on Computational Physics, the AAPT, in 2013, established the Undergraduate Curriculum Task Force (UCTF) to develop recommendations for modernizing the undergraduate physics curriculum. The UCTF’s “AAPT Recommendations for Computational Physics in the Undergraduate Physics Curriculum” was endorsed by the AAPT in October of 2016. This report, in its entirety, can be viewed at https://www.aapt.org/Resources/upload/AAPT_UCTF_CompPhysReport_final_B.pdf. The implications of the AAPT Computational Physics statement and recommendations document for STEM education are poignant, especially in the context of modernizing and improving the undergraduate physics curriculum, where, with a few exceptions, computation is largely non-existent.

To be sure, over the last decade, several new undergraduate physics degree programs, specifically for a BS in computational physics, have cropped up in the manner of the pioneering efforts of Oregon State University and Illinois State University of a few decades ago. Furthermore, a cursory internet search reveals that many physics departments across the country now offer at least one elective course in computational physics. There have even been computational incursions into high school physics through the use of Chabay and Sherwood’s *Matter and Interactions*.

Yet, despite the AAPT’s urging, little has been done on a larger curricular scale, especially in introductory physics, to formally integrate computation directly into individual physics courses such that computation plays an important role in developing both, a deeper conceptual understanding of physical principles and problem-solving skills.

In 2005, the journal, *Computing in Science and Engineering (CiSE),* commissioned a survey[1] that was sent out to 762 physics departments in the US. The survey queried the attitudes towards computation in the undergraduate curriculum, and solicited information on the use of computation in undergraduate physics courses. Interestingly, the survey demonstrated a ubiquitous concurrence by physics faculty on the importance of computation in the undergraduate curriculum, but a dearth of actual implementation. If nearly all physics faculty concede the importance of computation, why has there been little progress in its inclusion in the undergraduate physics curriculum?

In the neighborhood of 2007, the author teamed up with two of the principal investigators of the aforementioned survey project, Norman Chonacky (then Editor-in-Chief of CiSE and Applied Physics, Yale University) and David Winch (Physics, Kalamazoo College) to investigate, and ultimately do something about this discrepancy, if not disconnect, between physics in STEM professional practices and physics in education. Thus was born an informal organization, which has come to be known as the Partnership for Integrating Computation into Undergraduate Physics (PICUP), with the following mission:

> *“To create a vibrant community of educators, a forum for open discussion, a collection of educational resources, and a set of strategies and tactics that support faculty committed to improving undergraduate physics education through integration of computation into their undergraduate physics courses.”*

With funding from such sources as the Shodor Foundation, the National Computational Science Institute (NCSI), and the Extreme Science and Engineering Discovery Environment (XSEDE) PICUP has, over the past decade, convened conferences and workshops involving physics faculty from around the country in order to study and address the lack of computational instruction in the undergraduate physics curriculum. We were able to identify the predominant barriers that precluded physics faculty from integrating computation into their courses, some of which are:

- **Faculty time constraints**-to prepare and administer a course that radically deviates from tradition requires a significant time investment. It is so much easier, time-efficient, and comfortable to just keep doing things the way they’ve always been done. There is a particular risk for non-tenured faculty to implement any kind of non-traditional approach in the classroom, especially a computational approach.

- **Lack of faculty rewards**-few physics departments reward faculty for innovative efforts in the classroom, even if the innovations are demonstrably effective for student learning.
- **Assumption that there is no room for computation-**it is believed that some fundamental core topics would have to be dropped in order to make room for computational activities.
- **Aversion to programming-**physics faculty are generally leery of having students engage in actual programming. The reasons for this wariness are widely varied, but span the spectrum from insufficient familiarity with a programming language on the part of the instructor, to concern that the course may take on too much of a computer-coding emphasis.
- **Textbooks**-undergraduate physics courses are "locked" to textbooks**,** and there are very few textbooks that integrate computational activities and thinking into the traditional format of physics courses. The predominant tool for learning physics supported in most physics textbooks is still almost solely analytical, non-computational theory.
- **Faculty preparation**-the mathematical underpinnings of computation - numerical instead of analytical - are arguably unfamiliar to traditionally educated physicists, possibly intimidating to some faculty, and counter to what is typically taught in mathematical courses.
- **Lack of departmental support-**even if a faculty member is completely sold on an idea of innovative pedagogy, it is difficult to implement if one has to go it alone. The presence of other faculty members of like mind in a department, or better yet-a team effort-may provide the resource development and support necessary to successfully include computation.
- **Computational resources**-there is a lack of computational educational resources sufficiently focused on real classroom needs.

PICUP has very recently received NSF funding for a national-scale project to address and lower these barriers for physics faculty-we believe we have a viable answer for each of them! It is a 4-year, transformative faculty development project aimed at building and nurturing a community of physics faculty, from a diversity of institutions across the country, who are committed to integrating computation into undergraduate physics courses. Our central strategy includes a week-long faculty development workshop each summer, wherein faculty are guided in planning and implementing their own approach for integrating computation into their upcoming course(s), combined with continuing, community-based support for faculty participants. Crucial to this strategy is the development of online computational pedagogical resources that are barrier-lowering in nature, easy to search and interact with, are readily adoptable and adaptable (we want faculty to adapt the materials we develop to their own personal pedagogical preferences), are programming language-agnostic, are developed in a uniform format, and are produced according to current best practices in physics instruction.

We believe that the community building and barrier-lowering aspects of the PICUP approach, as well as our unique approach to developing online educational materials can eventually serve as a model for all of the STEM disciplines for transforming the way that STEM education is administered. For more information about PICUP and the national-scale computational integration project contact the author, or go to www.gopicup.org.

Kelly Roos has been at Bradley University for 24 years. After 17 years in the physics department, he has spent the past 6 years in the Bradley Caterpillar College of Engineering and Technology with the charge of enhancing the physical rigor, including computation, of the engineering curriculum.

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Physics Teacher Education Coalition

Section on Teacher Preparation

Teacher Preparation Section

Alma Robinson, Virginia Tech

This issue of the Teacher Preparation Section continues a theme that we began in the fall: to feature programs and activities that have fostered the recruitment and training of physics teachers without the assistance of PhysTEC funding.

Tiffany-Rose Sikorski explains how incorporating doing science activities in science pedagogy courses at George Washington University has encouraged their pre-service teachers to better understand scientific inquiry, modeling, and how to design engaging lessons.

William Newton describes how Texas A&M University – Commerce increased both the number of physics teacher candidates and physics majors in their department by incorporating some of the best practices outlined by PhysTEC and the APS SPIN-UP report. In addition to a Noyce Capacity Building grant, the financial and moral support of the department, college, and university were instrumental to their reforms.

Doing Science in Science Education Courses

Tiffany-Rose Sikorski, The George Washington University

Introduction

One of the most valuable lessons I learned as physics teacher-in-training at Boston University was how to get students *doing science* using historical scientific documents. Over time, two documents became my favorites: Alexander Graham Bell's *Family Papers* on tetrahedral kites and Franklin's *New Experiments and Observations on Electricity*.[1] Now, at The George Washington University, I engage future science teachers in doing science using historical science documents. In the conversation below, three teacher candidates—Martin, Susan, and Chris—study an excerpt from Franklin's work on static electricity:

> *1. A person standing on wax [Susan], and rubbing the tube, and another person on wax drawing the fire [Martin]; they will both of them, (provided they do not stand so as to touch one another) appear to be electrised, to a person standing on the floor; that is, he [Chris] will perceive a spark on approaching each of them with his knuckle. 2. But if the persons on the wax touch one another during the exciting of the tube neither of them will appear to be electrised. 3. If they touch one another after exciting the tube, and drawing the fire as aforesaid, there will be a stronger spark between them, than was between either of them and the person on the floor.*[2]

Martin: I think Chris's idea is right. By us being close enough, somehow, charge goes from me to you.

Susan: But is it me to you, or is it the tube to you?

Martin: Well if you're losing charge, the charge would have to be coming from me to you. And then from you into the tube.

Susan: But then where would the shock come from then?

Martin: The shock would come from the observer in either scenario because we both have less negative charge than the observer.

Susan: But isn't it in part 1, we're shocked?

Chris: I think what makes this confusing, at least to me, is between 1 and 3. Where it talks about how in 1, if I come up to either of you guys, I get a shock. But then it says that you guys would shock each other if you guys touch.

Much of our time is spent this way, trying to understand what exactly the scientists did and observed in their experiments. Conversations like these exemplify what we mean by *doing science* in pedagogy coursework at GW.

Rationale for Doing Science

The National Science Teachers Association recommends teacher education programs "create a learning environment that encourages inquiry "and offer coursework where teacher candidates can "construct science concepts with understanding and reflect on the history and nature of science."[3] To address these and other needs related to *Next Generation Science Standard*s, GW's post-baccalaureate (M.Ed.) teacher education program began integrating doing science experiences into pedagogy courses in the fall of 2012.

In Susan's cohort, all five science teacher candidates had undergraduate degrees in the content area for which they sought licensure (biology, chemistry, or physics); three had advanced degrees in their content area; all had undergraduate or graduate research experience; and two had professional science experience in the university or private sector along with peer-reviewed publications in science. Given these strong science backgrounds, one might argue that our pedagogy courses ought to be strictly focused on issues of pedagogy. Indeed, "in the usual model, it is assumed that physics teachers learn physics in the physics department and then learn how to teach in their certification program."[4]

We integrate doing science into our science education courses for many reasons. First, in our experience, we cannot assume that students who earned 'As' in undergraduate science programs developed the sophisticated understanding of scientific concepts, practices, and inquiry needed for science teaching. Second, our teacher candidates' identities as "physics (or biology or chemistry) people" are a valuable resource for engaging in questions of science pedagogy.[5] Third, doing science offers us an opportunity to demonstrate some of the techniques that we would like teacher candidates to implement in their future classroom, such as planning lessons that work with, rather than against, students' ideas. Finally, in doing science *together*, we develop shared experiences that we can refer back to throughout a teacher candidate's coursework and clinical experiences.

Design of Doing Science Experiences

Doing science generally begins in one of four ways: It can start with close reading and discussion of a science text like Franklin's letters on electricity. It could also start with an open-ended question, like "How does movement affect heart rate and blood pressure?" Eleanor Duckworth describes starting by having teachers explore science with simple materials like balloons and string.[6] Doing science can also begin spontaneously while teacher candidates discuss examples of student work collected from K-12 classrooms.

We work on the same question or text for the entire semester, spending approximately a third of our class time, or one hour per week, on doing science. Instead of following any pre-set curriculum, we choose how to spend our time in each session with an overarching goal of arriving at an evidence-based, consensus model or explanation that we all understand.[7] While facilitating, I am careful to emphasize aspects of science that may have been overlooked in teacher candidates' prior science courses. For example, even if they "know" the currently accepted model of a phenomenon, teacher candidates are challenged to develop multiple models and explanations. They compare these models for usefulness, plausibility, coherence, causality, predictive power, and other criteria central to the work of science. Each doing science session includes a reflection on progress made, the challenges encountered, options for what to do next, and takeaways for 7th-12th grade classroom teaching.

Evidence of Impact

Through their course reflections and evaluations, our teacher candidates indicate that doing science is a significant part of their program experience:

> *...The Ben Franklin letter activity was by far the most influential due to the ability of everyone to form ideas based on their own understanding and the nature of the discussion that was facilitated in the class.*

Chris, the sole physics teacher in Susan's cohort, spontaneously asked for a copy of Franklin's letters, which he later used during his teaching internship. In asking Chris to describe how he used the materials, he wrote:

> *...we had students explore electrostatics through the use of household items — styrofoam cups, fur/cloth, glass and plastic rods, straws, aluminum pie plates, string, styrofoam, and other items. We asked students to record observations and develop claims regarding charge — the build up of charge, the transfer of charge, and the conservation of charge. After students developed their claims, we had students examine the writings by Ben Franklin...Students developed claims as to what Benjamin Franklin was observing and writing about...We then reflected as a class on how science develops…*

Within science education research literature, Emily van Zee and colleagues noted that while doing science, teachers began to use language more precisely, became attuned to distinctions between different ideas, and began to try out competing models and explanations of phenomenon.[8] After an entire course of doing science, Leslie Atkins and Irene Salter noticed changes in teacher candidates' qualitative reasoning about magnification and the focusing of light rays.[9] Their teacher candidates also reported more strongly valuing and using scientific ideas in their everyday lives, as compared to their traditionally taught counterparts. Through analyzing video recordings of our doing science experiences at GW, we have observed similar changes in how our teacher candidates describe and work with ideas.

Resources for Doing Science in Science Education Courses

Multiple published descriptions and videotaped examples of doing science are available to teacher educators seeking questions, texts, and problems to launch doing science in their pedagogy courses.[10] However, *doing science* by design does not follow a set of pre-formulated activities, so it helps to work with an experienced facilitator to learn how to make in-the-moment decisions during doing science. At GW, we have also explored a co-teaching model, where science education and science faculty work together to facilitate doing science. In this way, doing science becomes a nexus of *collaboration*, a PhysTEC key element, between Schools of Education and Arts and Sciences.

Acknowledgements

Thank you to Susan, Chris, and Martin (pseudonyms) and classmates for participating in a study of doing science in science teaching methods course at The George Washington University. This material is based upon work supported by the National Science Foundation under Grant No. DUE 1439819. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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Teacher Preparation at Texas A&M University-Commerce

William Newton, Texas A&M Commerce

The context: who we are and where we started

Texas A&M University-Commerce is the second largest campus in the A&M system. Its enrollment of 13,000 is drawn from rural northeastern Texas and the Dallas-Fort Worth metroplex. It is a primarily undergraduate and Master's institution, and has historically had a focus on teacher preparation.

The Department of Physics and Astronomy has 9 faculty, and graduates an average of 5 undergraduates and 5 Master's students yearly. Although our department has a physics teacher preparation program and a Master's track for in-service teachers, they had lain essentially dormant until two years ago.

Motivated to increase our program's enrollment as a result of the Texas Higher Education Coordinating Board's requirement that the 5-year average graduation rate for programs should be 5 students/year, our department united behind efforts to renew our undergraduate and graduate programs and revive our moribund teacher preparation programs.

What we did

Faculty champions. Two new tenure-track faculty were hired with specific responsibilities in physics education: I was hired in 2012, and Dr. Robynne Lock, a physics education researcher, in 2014. In PhysTEC's parlance, Dr. Lock and I have been the department champions,[1] acting to implement a number of best practices outlined by PhysTEC[1] and the APS SPIN-UP report.[2]

LA program and studio physics. In Fall 2014 Dr. Lock and I piloted a Learning Assistant (LA) program in the general science classes that we teach for K-8 pre-service teachers. Four to five LAs cover the 5 sections of these classes each semester. In Fall 2015, Dr. Lock and I transformed the two semesters of our introductory calculus-based physics course to studio mode, and expanded our LA program into these classes (6 LAs across the 3-4 sections). We model our studio physics classes on NCSU's SCALE-UP[3] project, and our LA program follows the CU Boulder model,[4] including a weekly LA pedagogy class taught by Dr. Lock.


Some of the first cohort in our new Master's program for physics teachers, together with Drs. Lock and Newton (second and third from the right, respectively)

Reinvigorating the physics teacher preparation program. We overhauled the curriculum, reduced the credit hour load to 120 hours, and advertised relentlessly. With the help of the Department of Curriculum and Instruction, a specific sequence of STEM educa-

Dr. Lock (on the right) and our teacher in residence (and graduate from our Master's program) Angela Burke (on the left).

tion classes was incorporated into our program. Students now take the same education classes as other STEM teaching majors, and almost the same physics classes as other physics majors, reinforcing their identity not only as a STEM teacher but also as a physicist.

Improving recruitment and retention of physics majors. In Fall 2015 we began holding semesterly "Physics Days" for high school and community college students and their teachers/professors, which involve physics activities, talks about faculty research, and a Q&A panel featuring undergraduate and graduate students and faculty.

We have worked hard to increase the sense of community amongst our undergraduate students. In 2015 we repurposed a lab to create a physics lounge where students can work and hang out together. In 2015 Dr. Lock set up an undergraduate mentoring program. Our students and LAs have become our best recruiters, and we have maximized the number of opportunities they have to advertise our programs to current and future students.

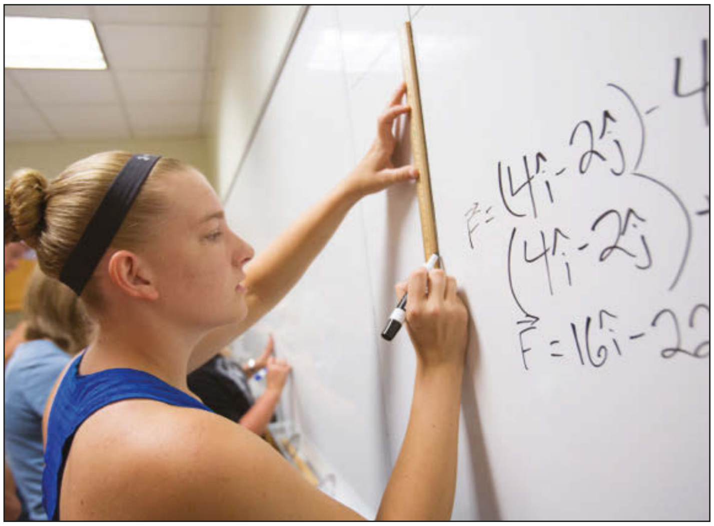
A Master's in Physics for High School Teachers. Starting in 2014, Dr. Lock and I each created 3 new Master's-level physics classes designed for high school physics teachers that feature physics content alongside pedagogy and physics education research. Initially taught face-to-face, we now also have online versions of the courses, and in Summer 2016 a new Master's in Physics for Teachers was approved to be offered online. Currently we have around 40 high school teachers enrolled, hailing from Texas and beyond.

Teacher in Residence/A Community of Teachers. In Summer 2016, we were awarded an NSF Noyce Capacity Building grant. We recruited a teacher-in-residence (TIR) who has been working with our LAs to develop new research-based labs for studio physics and high school physics. Our TIR is also facilitating collaboration with the local Educational Service Centers (which provide training and consulting to school districts) to organize regular meetings for high school teachers in NE Texas. The teachers involved will mentor the pre-service physics teachers during their residencies and first years of teaching.

How we did it

Substantial planning and support was required to implement the activities detailed above. Dr. Lock and I do not yet have tenure, so it was also important that our department and college supported our activities as contributing towards that goal. Our department head, Dr. Matt Wood, was a tireless advocate for all our activities, and our Dean has fully supported our plans. Having a physics education researcher on our faculty has been invaluable in providing knowledge of the resources and research necessary to successfully implement the activities, as well as the skills to assess their efficacy. Studio physics, for example, has been embraced by all teachers of our introductory physics classes.

In addition to attending PhysTEC conferences and an LA alliance workshop, we invited colloquium speakers from departments that have built successful teacher preparation programs in similar circumstances to provide information and inspiration. For example, Dr. Gay Stewart, then AAPT president and faculty at the University of Arkansas, visited in 2012 to discuss the success of Arkansas' program.



Students in our studio physics class.

Without initial external funding, we needed to leverage all available institutional resources. Department and college funds were used to refurbish two classrooms to make them suitable for studio physics. LA salaries are also supplemented by department funds. Dr. Lock and I received internal faculty fellowships to implement studio physics and develop the online courses for the Master's program for teachers. The fellowships provided course release (the time we needed!), support staff, and travel money.

We fostered close ties with the Department of Curriculum and Instruction by teaching the general science classes for K-8 education majors, conducting reviews for K-8 science education tests, helping organize symposiums for teachers, and advertising their programs in our classes. We successfully solicited the Department of Curriculum and Instruction to co-fund the LA positions in the K-8 science classes.

The LAs for studio physics classes are funded by our university's Supplemental Instruction (SI) program, and although we manage the LAs, they are classed as SI instructors. The SI program director was motivated to supply funds by the fact that physics instructors had been difficult to recruit, and by counting the LAs also as SIs, the SI program has been able to demonstrate significant growth.

Semesterly interviews with students and LAs reveal an improved awareness of our physics teacher preparation program among STEM majors. Having instructors and LAs regularly talk about physics teaching as a career option in our classes has directly led to students enrolling in the physics teacher preparation program.

We were able to relaunch our Master's in Physics for Teachers by offering classes for free using institutional funding. The Master's program has allowed us to develop strong relationships with local physics teachers, one of whom is now our TIR. These teachers advertise our program and will mentor the new physics teachers.

Finally, the Noyce grant funds our TIR.

Outcomes

Over the past four years we have implemented every one of PhysTEC's effective practices without PhysTEC funding.

As of December 2016, we have 6 students enrolled in the physics teacher preparation program (compared to 0 most of the previous decade) and over 40 high school physics teachers enrolled in our new Master's program. We have doubled the number of physics majors and we currently have the highest enrollment in the department's history.

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Dr. William Newton received a Master's and DPhil in physics from University of Oxford, and an MSc from University of Tennessee. He has been at A&M-Commerce for 8 years, the last four as an Assistant Professor. As well as his involvement in physics education, Dr. Newton is a nuclear astrophysicist who specializes in the structure of neutron stars.

Endnotes

1. Physics Teacher Education Coalition: Key Components - http://www.phystec.org/keycomponents/
2. Hilborn, R.C., Howes, R.H. and Krane, K.S., *Strategic Programs for Innovations in Undergraduate Physics: Project Report,* American Association of Physics Teachers - https://www.aps.org/programs/education/undergrad/faculty/spinup/spinup-report.cfm (2003).
3. SCALE-UP: Student-Centered Active Learning Environment with Upside-down Pedagogies, North Carolina State University - http://scaleup.ncsu.edu
4. University of Colorado Learning Assistant Program - https://laprogram.colorado.edu

Browsing the Journals

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- If you give multiple-choice tests, you may be interested in Heidi Wainscott's analysis in the November 2016 issue of *The Physics Teacher* (http://aapt.scitation.org/journal/pte) of the effect when students change their answers during an exam. In the same issue, the rotation of a can suspended near a jumping ring apparatus is a novel "twist" on this familiar demonstration. Another interesting surprise is Yaguo Ogawara's proof that one gets improved traction by driving a front-wheel car backward up an icy slope than by driving forward. Finally, Hewitt's *Figuring Physics* column concerns the difference in force when punching a heavyweight versus a lightweight boxer.

- Two intriguing articles involve entropy in the January 2017 issue of the *American Journal of Physics* (http://aapt.scitation.org/journal/ajp). The earth receives low-entropy energy from the sun and exhausts high-entropy energy to space; a paper on page 14 turns things around and imagines receiving energy from the cosmic background and exhausting it to a black hole instead. Then an article on page 23 devises a *reversible* way to exchange the temperatures of a hot and a cold body by splitting each of them into infinitesimal pieces and sequentially bringing those pieces into thermal contact.

- Article 015009 in the January 2017 issue of *Physics Education* (http://iopscience.iop.org/journalList) investigates numerically and experimentally the fastest descent along two connected inclined planes. I have written up a noncalculus analysis for the case when the second plane is horizontal (in response to the chocolate-bar challenge in Footnote 1 of this article) at https://www.usna.edu/Users/physics/mungan/_files/documents/Scholarship/DescentRampTrack.pdf. In the same issue, I also enjoyed the video analysis of a bullet fired underwater in article 015024.

- The Indian Academy of Sciences journal *Resonance* often has useful review articles about topics in science and mathematics. Ones that caught my eye recently include a discussion of phase transitions in terms of the Ising model in the October 2016 issue, the temperature of gas in the interstellar medium in the November issue, and the inequalities among the arithmetic, geometric, and harmonic means (with applications and problems) in the December issue. These articles can be freely accessed at http://www.ias.ac.in/listing/issues/reso.

- An article on page 1961 of the November 2016 issue of the *Journal of Chemical Education* presents an experimental method to measure the speed of sound in various gases. The Fourier transform is taken of the sound recorded while white noise is generated in an acoustic tube. The white noise is created by the expansion of gas rushing into the evacuated tube. The journal archives are at http://pubs.acs.org/loi/jceda8.

- Article 020134 in *Physical Review Physics Education Research* at http://journals.aps.org/prper/pdf/10.1103/PhysRevPhysEducRes.12.020134 discusses student facility with the divergence and curl in an intermediate-level undergraduate electromagnetism course.

Web Watch

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- ESA Sky at http://sky.esa.int/ is a mouse-driven visual portal providing a variety of astronomical images of the entire sky, both in the visible and in other spectral ranges.

- The National Science Teachers Association has classroom resources at http://ngss.nsta.org/Classroom-Resources.aspx.

- A movie of Schrödinger-cat behavior of iodine gas molecules is presented and discussed at http://www.sciencealert.com/physicists-have-filmed-schroedinger-s-cat-behaviour-in-atoms-for-the-first-time.

- The American Chemical Society has some interesting PDF posters (also available for purchase full-size) online at https://www.acs.org/content/acs/en/pressroom/reactions/infographics.html.

- We can all use with tips to improve our writing. Check out the ones published daily at http://www.dailywritingtips.com/.

- Futurity is a site dedicated to presenting research news from a select list of universities at http://www.futurity.org/.

- A new vibrational mode called a relaxon has been proposed to help explain thermal transport in insulators, as discussed at http://physics.aps.org/articles/v9/118.

- Interested in 3D printing but daunted by CAD programs? You might want to try the free online program Tinkercad at https://www.tinkercad.com/.

- Ambitious Science Teaching is devoted to authentic instruction for K-12 classrooms at http://ambitiousscienceteaching.org/.

- A recent APS *Physics* synopsis at http://physics.aps.org/articles/v9/138 considers the question of why undergraduate students choose physics as a major.

- A new web search engine focused on scientific research which organizes the results into clusters of topics is http://scienceresearch.com/.

- An amusing tale at Physics World about how physicists are helping a potato chip factory can be read at http://live.iop-pp01.agh.sleek.net/2016/10/26/the-journey-of-a-crisp/.

- An extensive collection of videos from the Hubble Space Telescope can be perused at http://www.spacetelescope.org/videos/.

- A verbal essay about the physics of rainbows is available at https://www.theatlantic.com/science/archive/2017/01/rainbow-physics/512027/.

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