Forum on Education
American Physical Society

Summer 2014 Newsletter

Beth Lindsey, Editor

From the Chair

Michael Fauerbach, Florida Gulf Coast University

The summer newsletter is always the time to welcome new members to the executive committee and to say good-bye to some others. This year is no different.

I would like to thank Paul Cottle for his hard work as Chair this past year. He truly left some big shoes for me to fill, but with the help of the other members of the executive committee, I will try my best. Thankfully, Paul will still be a member of the executive committee for the next year, as Past Chair and Chair of the Fellow Nominating Committee. Although by the time you read this it will be too late for the current cycle, please remember to think about deserving colleagues and nominate them for fellowship in the future.

Special thanks go out to our outgoing Past Chair Renee Diehl. Over the past four years Renee has done tremendous work for the forum and I always enjoyed her advice and our conversations. I'm sure she will be happy to have to deal with much fewer emails in the future.

We will also have to say good-bye to Angie Little who has served as APS/AAPT Member at Large for the past three years. I had the pleasure to work closely with Angie, as she was very active in the forums nomination and program committees that I chaired.

Lastly, we have to say good-bye to our Secretary/Treasurer Scott Franklin. Scott will still be active within the APS as he decided to lend his talents as the Secretary/Treasurer to the newly formed Topical Group on Physics Education Research (GPER). Congratulations and good luck to Scott, GPER will certainly benefit from his talents.

We welcome our newly elected members to the executive committee: Wendy Adams (APS/AAPT Member at Large), Jorge Lopez (AAPT Member at Large), Charles Henderson (Secretary/Treasurer), and Tim Stelzer (Vice-Chair).

With both the March and April National Meetings barely in our rearview mirror, it is hard to believe, that we already have to start looking forward to 2015. Randy Knight (Chair-Elect) already has put together the program committee for the 2015 March and April meetings, and you will hear a call from him for suggested sessions soon.

As the new Vice-Chair, Tim Stelzer will solicit nominations for the elections to the executive committee. With your help and input we can put together a strong slate of candidates that will assure future strength and success of the forum.

Please keep in mind that the forum can only be meaningful and successful, if its members are actively engaged. Therefore, please feel free to contact any of the members of the executive committee or the newsletter editor, if you have suggestions or contributions to our missions.

Letter from the Editor

Beth Lindsey, Penn State Greater Allegheny

For this edition of the FEd newsletter, I chose to invite articles from a few exemplary Learning Assistant (LA) programs. At the University of Colorado where it was developed, the LA program is described as follows (taken from http://laprogram.colorado.edu/):

"The Colorado Learning Assistant (LA) Model at the University of Colorado-Boulder uses the transformation of large-enrollment science courses as a mechanism for achieving four goals:

- To recruit and prepare talented science majors for careers in teaching
- To engage science faculty in the recruitment and preparation of future teachers
- To improve the quality of science education for all undergraduates
- To transform departmental cultures to value research-based teaching for ourselves and for our students

The transformation of large-enrollment courses involves creating environments in which students can interact with one another, engage in collaborative problem solving, and articulate and defend their ideas. To accomplish this, undergraduate LAs are hired to facilitate small-group interaction in our large-enrollment courses."

What followed from my invitation to contribute to this newsletter was a happy coincidence that I never expected: the faculty at both institutions asked if it would be all right if their students – the LAs themselves – were to contribute to the articles. I was thrilled to provide an opportunity to let the students' voices be heard. Thus this newsletter does not present the typical rundown of research results on the benefits of LA programs (and the research is plentiful; some of it has been carried out by the authors of these articles, both faculty and students). Instead, I present two articles in which undergraduate students describe their experiences as Learning Assistants, and how this experience has contributed to shaping their roles as physicists, as students, as teachers, and as researchers. One of these articles is much longer than is typical for this newsletter, but I felt the richness of the article was such that it deserves the space it is given. Perhaps these articles will inspire you to create, modify, or expand your own LA program.

Call for 2015 Program Suggestions

The 2015 March and April meetings are many long months away, but the Program Committee has already started its planning. The FEd sponsors or co-sponsors 4 invited sessions at the March Meeting and 5 at the April Meeting. In addition, we can sponsor contributed sessions if there's a topic of interest.

If you have a suggestion for a speaker or for a session topic, please send that to me right away. The Program Committee has to have a fairly complete lineup by the end of July. In addition, we need volunteers to chair FEd sessions. If you know that you'll be attending next year's March or April meeting and would be willing to chair a session, please let me know.

Randy Knight
Program Committee Chair
rknight@calpoly.edu

Call for nominations for FEd Executive Committee

December seems far away, but the next FEd election will be upon us before you know it. Three executive committee positions will be open: vice chair (who, in subsequent years, becomes chair elect and then chair), member at large (3-year term), and an APS-AAPT member at large (3-year term). The latter must be a member of both the FEd and AAPT. The newly elected members will assume their duties in April 2015.

The Forum on Education only exists because of volunteers willing to give a little of their time; it has no paid staff. Please consider running for one of the three positions. It's perfectly OK to nominate yourself! Or nominate a colleague who you think would do a good job. Serving as an officer is an excellent way to learn more about APS and its many educational missions.

Please send suggestions to
Tim Stelzer (tstelzer@illinois.edu)
FEd Vice Chair, and Chair of the Nominating Committee

On-line Resource to Help Increase the Number of Research Opportunities for Undergraduates Being Jointly Developed by APS, CUR, AAPT and SPS

Do you or does your department have a practice, funding strategy, internship placement strategy or course with research embedded in it that, if adopted by other physics or astronomy departments, would help increase the number of undergraduate research opportunities? The American Physical Society, Council on Undergraduate Research, American Association of Physics Teachers, and Society of Physics Students are collecting articles that will be published on-line to serve as a resource to departments, faculty and students as they work to meet the challenge put before the community that all undergraduate physics and astronomy majors at 4-year colleges be provided with a research experience. We invite you to submit an article for publication in this new resource that highlights any practice that encourages, leads to increases in, or enhances research experiences for undergraduates.

The idea that all undergraduate physics and astronomy majors should have a research experience was endorsed by the members of the APS Council at their April 4, 2014 meeting when Council members voted unanimously to adopt the statement:

The American Physical Society calls upon the nation's four-year colleges and universities and their physics and astronomy departments to provide or facilitate access to research experiences for all undergraduate physics and astronomy majors.

An accompanying "Context" statement goes on to say:

Research experiences provide students with many benefits, including skills in problem definition, project design, open-ended problem solving, use of modern instruments and techniques, data collection and analysis, analytical and computational *modeling, and communication of evidence-based technical arguments. These skills are of great value to students as they go on to engage in future science, engineering, business, education, government, or other careers. Participation in research has been shown to increase retention in STEM (science, technology, engineering and mathematics) degree programs, support students' decisions to pursue STEM careers, and enable students to move more effectively from the classroom to professional practice.*

The APS statement joins similar earlier statements adopted by the Society of Physics Students, Physics/Astronomy Division of the Council on Undergraduate Research, American Astronomical Society, American Association of Physics Teachers, and the APS Committee on Education. These statements can be viewed on the Society of Physics Students web site at: http://www.spsnational.org/governance/statements/2008undergraduate_research.htm.

Making such declarations and realizing them are, of course, not one-and-the-same. It is now incumbent upon all of us to make undergraduate research experiences for all physics and astronomy majors, either on our campuses or through off-campus opportunities, a reality. Anyone wishing to contribute to this new physics and astronomy resource may do so by emailing the article to John Mateja at jmateja@murraystate.edu (please submit the article as a Word attachment). There are no length limits; the articles can be as long or as short as you need them to be. Articles should be submitted by the beginning of the 2014 fall term, although notification of an intention to write an article would be appreciated sooner.

APS Forum on Education Executive Committee

Beth Cunningham, Executive Officer, American Association of Physics Teachers

Theodore Hodapp, Director, Education and Diversity, American Physical Society

Michael Jackson, Chair, Council on Undergraduate Research, Physics/Astronomy Division

John Mateja, Past President, Council on Undergraduate Research

Toni Sauncy, Director, Society of Physics Students

2014 Excellence in Physics Education Award Recipient

The Excellence in Physics Education 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. In 2014, this award recognizes High School Modeling Instruction. It was awarded to the American Modeling Teachers Association, and to Colleen Megowan, David Hestenes, and Jane Jackson. The citation reads,

"For their impacts on physics teaching nationally through Modeling Instruction Workshops and curriculum materials, and for contributions to physics education research through Modeling Theory."

Award for Improving Undergraduate Physics Education Awardees

The American Physical Society's (APS) Committee on Education (COE) seeks to recognize physics departments and/or undergraduate-serving programs in physics (hereafter "programs") that support best practices in education at the undergraduate level. 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. In 2014, there were three awardees:

Florida International University
Florida International University has undertaken program-wide initiatives to attract and retain students which have led to impressive growth in the number of physics majors. These include a strong program in Physics Education Research, and associated implementation of research-based curriculum, particularly in the first year. Additionally, several alternative tracks within the physics major have been created, including a physics education track, providing students with several possible career paths after graduation. FIU has been particularly successful in recruitment and training of underrepresented minority students.

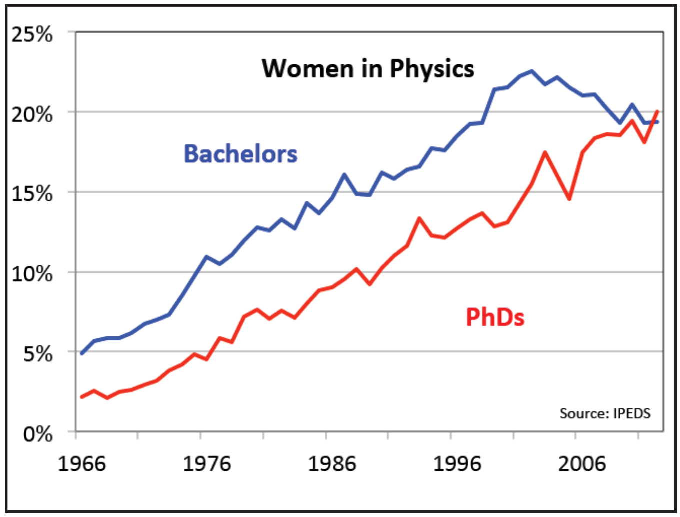
James Madison University
James Madison University sustains a thriving physics department that has grown significantly over the past 15 years. The Department of Physics & Astronomy has developed a culture of engaging students in the education process through an emphasis on undergraduate research experiences, personalized attention and advising, hiring for mission, recruiting and outreach efforts, and an ongoing move to research-based pedagogies and assessment. Especially notable are the range of program offerings to serve a broad student population, including tracks in applied physics and technical communication, in addition to strong teacher education efforts as a PhysTEC site.

University of California, Davis
The University of California, Davis Department of Physics has created curriculum opportunities involving specializations and multidisciplinary applied degrees coupled with vibrant research options for a diverse student population. The emphasis is on student preparation for STEM careers. UC Davis Physics includes an innovative and collaborative introductory sequence, two distinctive career seminars, a series of research-oriented capstone courses, along with multifaceted opportunities for peer and faculty interactions and creative investigations. Within a decade this approach has doubled the number of physics majors, successfully preparing both incoming first-years and increasing numbers of transfer students for both graduate degrees and professional careers.

APS Education and Diversity Director's Corner

Ted Hodapp

The American Physical Society continues to lead powerful programs that are improving physics education at many levels. The Physics Teacher Education Coalition (PhysTEC, phystec.org) is inviting a new round of sites to augment our more than 30 funded sites, and we just reached a major milestone of 300 member institutions or more than a third of all US physics departments. In July, the project will release a comprehensive report on sustainability of PhysTEC programs, which documents the role of champions as well as institutional motivation and commitment in successfully sustained programs. Mark your calendar for the 2015 PhysTEC conference, which will be held 5-7 February 2015 in Seattle. In tandem with the conference, we are planning a workshop on *Building Thriving Undergraduate Physics Programs* (6-8 February). The last workshop held in 2012 was sold out; further information and registration will be posted on phystec.org as it becomes available.



The APS Bridge Program (apsbridgeprogram.org) has also seen substantial increases with 36 underrepresented minority students applying to the program – all of whom were unable to gain acceptance into graduate programs or did not apply. We hope to see more than half of these in graduate programs this fall – a significant chunk of the ~30 per year needed to close the achievement gap between minority and majority students in the US. The Bridge Program recently added Florida State and Cal State Long Beach as new sites, and will hold one more site selection this fall for two additional bridge sites. One of the remarkable lessons we have learned is that many students who apply through the program received poor advice about where (and possibly how) to apply to grad school. One site leader commented that they would have easily accepted “five or six” of our applicants directly into their PhD program, and will reserve slots in the future to accept more students recruited by the APS.

The first year of hosting the APS Conferences for Undergraduate Women in Physics (CUWiP, aps.org/link/cuwip) has built on the successes of the previous conferences with now more than 1,000 women attending at eight regional sites this past January. We have learned a great deal from the assessments given at these conferences, and will inform leaders of the 2015 (and beyond) conferences of ways to not only hold great events, but also how to work to improve the retention of women in physics – something critically important now as the fraction of women earning a bachelor’s degree in physics has stagnated over the past decade (see figure). Selection of 2016 conference sites will occur this fall.

This past fall, the APS Executive Board approved the formation of a Joint Task Force for Undergraduate Physics Programs with the American Association of Physics Teachers (J-TUPP, aps.org/programs/education/undergrad/jtupp.cfm). This group will develop recommendations to help departments understand how the broader curriculum can be shaped to prepare students for 21st Century careers – almost all of which lie outside of academe. The committee has now been formed and expects to begin its deliberations this summer, with a report due in 2016.

Letter to the Editor: Physics Student Recruitment

Stewart E. Brekke, Chicago Public Schools

Recently, the *APS News* reported that another physics major program was being eliminated by a university due to repeated lack of enrollment. While I am not a university teacher, I wish to offer some suggestions on how this situation may be avoided possibly. While substitute teaching in the Chicago Public Schools I found various situations regarding enrollment in different physics programs. In one school with enrollment of about 4,000 students one teacher told me that he was lucky to have one physics course. However, in another school with an enrollment of about 1,000 the high school physics teacher had a full physics program of 4 different courses. The difference in the programs was recruitment. The teacher with a full program with about 1/3 of the students actively recruited the students. He went every year to all the biology and chemistry classes with an interesting experiment and a recruitment talk. He taught regular physics, advanced physics and AP physics every year for years in the smaller high school. Further, when he had the students in regular physics he recruited them for advanced and APS physics. The teacher in the larger high school told me why he only had a partial physics program. He stated that the "students could not hack the math." I worked in inner city schools teaching physics–required in one school for all students. Many of these students had math problems, but I helped them with the math repeatedly. I purchased about 10-15 basic calculators with my own funds and let the students use them. The students in my classes always had a primarily problem-solving course and to my surprise most of the students did well with the calculators and repeated help with the algebra until they became proficient with the algebra.

What is the lesson to be learned from the above story? The moral is "recruitment, recruitment, recruitment." The college and university faculty in physics must reach out to the high schools. They must go to the high school physics and chemistry courses and college physics chemistry classes and recruit students for college physics. To keep the students taking physics they must make the physics courses "user friendly," making problem solving help always available. Physics programs in universities do not have be lost if proper recruiting is done by the physics faculty.

Stewart Brekke is a retired high school physics teacher with the Chicago Public Schools.

Announcing the PERCoGS Newsletter

The PER Consortium of Graduate Students (PERCoGS) has produced its first quarterly newsletter. The PERCoGS Newsletter was created to communicate useful, interesting information to PER Graduate Students (PERGS) but we welcome readers from all members of the Physics Education community. This first newsletter, which features articles on crafting papers, writing reviews and finding jobs post-graduation, may be of interest to graduate students and their mentors in other subfields of physics as well. Look for the next issue of the newsletter by the end of July.

PERCoGS Newsletter
The Future of PER
Volume 1

In This Issue...

- Writing Good Negative Reviews
- Featured Graduate Students
- Job Search Experiences
- Framing Your Research

PERGS (PER Graduate Students): PERGS is the official group name for PER Graduate Students. Just like PER at large has the PER Topical Group (PERTG), which essentially all PER people are a part of, we have PERGS. **PERCoGS (PER Consortium of Graduate Students):** PERCoGS are the PERGS representatives. PERCoGS is made up of its 4 elected members as well as graduate students who are on AAPT committees and wish to be a PERCoGS members.

PERCoGS Members:
Abigail Daane - President
abigail.daane@gmail.com
Enrique "Henry" Suarez - Secretary
enrique.suarez@colorado.edu
Gina Quan - Publicist
gquan@umd.edu
Ben Van Dusen - PERLOC Representative
Benjamin.VanDusen@Colorado.edu
Carolina Alvarado - Committee on International Physics Education
caroal.leyva@gmail.com
Meghan Westlander - Committee on Graduate Education in Physics
meghan.westlander@gmail.com

For more information about PERCoGS, check out:
PERGS Webpage
PERGS on Google+

To suggest and/or contribute content, contact *percogs.excom@gmail.com*

April, 2014

Nominate Graduate Students for PERCoGS!

PER Graduate Students,

Please take advantage of a great opportunity to help shape the PER graduate student community by participating in the process of electing new officers to lead the PER Consortium of Graduate Students (PERCoGS). You can get involved simply by nominating someone for an officer position!

If you or someone you know would like to become a part of international PER leadership, nominate yourself or your fellow grad students to become the next officers of PERCoGS. Click here to submit a nomination.

To learn more about PERCoGS and what we do, check out our site.

There are three officer positions up for election; President, Secretary, and Publicist. The President is a two-year term, and Secretary and Publicist are each 1-year terms. Note: People who graduate mid-term are still able to complete their term when they are no longer graduate students.

A critical component of PERCoGS functionality is that we work collaboratively and share the majority of our tasks. Each PERCoGS officer takes the lead on several items.

- *President* - Ensures PERCoGS continues to serve the current needs of PER graduate students by setting meeting agendas, and overseeing AAPT workshops and crackerbarrels.
- *Publicist* - Ensures communication with PER Graduate students through avenues such as email announcements, newsletters, and Google+ notifications.
- *Secretary* - Ensures smooth running of meetings and documentation of PERCoGS activities, which includes taking notes, scheduling meetings and maintaining newsletters.
- *PERLOC Representative (not currently up for election)* - Maintains communication between PER Graduate students and PERLOC.
- *AAPT Committee Members* - Maintains communication between AAPT Committees and PERCoGS. Any member of an AAPT Committee can join PERCoGS.

Reasons to Consider Participating in PERCoGS:

1) You'll get to shape the community of graduate students, as we continue to grow, into a stronger, more connected, and informed community.

2) You'll develop valuable leadership, organizational, and communication skills.

3) You'll have great networking opportunities with leaders in the PER field and with the future leaders of the PER field.

Please take just a minute to fill out nominations for any one or all three of the officer positions by clicking here. We would like all nominations to be submitted by April 15, 2014.

If you have questions, please email us at percogs.excom@gmail.com or post on our Google+ Community.

We welcome content suggestions and contributions to **percogs.excom@gmail.com**

https://sites.google.com/site/pergraduatestudents/newsletters

Being a Seattle Pacific University Learning Assistant: A transformative experience of listening and being heard

Amy D. Robertson, Erika P. Eppard, Lisa M. Goodhew, Emily L. Maaske, Hannah C. Sabo, Faith C. Stewart, David L. Tuell, and Scott T. Wenzinger, Seattle Pacific University

Introduction

Learning Assistant (LA) Programs – with their three-pronged approach to preparation ("prep"), pedagogy, and practice – provide novice teachers opportunities to articulate theories of knowledge and philosophies of teaching that are grounded in the practice of teaching. Research on the effectiveness of LA Programs has tended to focus on the *outcomes* of these opportunities in terms of: recruitment of K-12 teachers,[1, 2] student and LA learning and attitudes,[1, 3, 4] faculty take-up and/or use of reform-oriented teaching strategies,[1, 3, 5-10] and LA teaching practice or views of teaching.[11-15] Little has been done to understand the *experience* itself – what it looks or feels like to be an LA.

This article describes one adaptation of the University of Colorado-Boulder (CU) Learning Assistant model[1] from the perspective of the LAs themselves. In particular, we describe the lived experiences of seven Seattle Pacific University (SPU) LA co-authors: Erika, Lisa, Emily, Hannah, Faith, David, and Scott. We write from their perspective: these LAs met together (with Amy, the LA Program Coordinator and LA course instructor) to define the content and organization of the article, and each took active editorial and authorship roles on multiple drafts. We use the first person plural – "we" – to refer to the experiences of the LA community (sometimes including Amy), and we use the third person "Amy" when referring to her alone. We answer the questions: what are the defining experiences of SPU introductory physics LAs[a], from their perspective, and how does the SPU LA Program foster such experiences?

Most notably, we (SPU LAs*) experience being heard and hearing others in authentic dialogue with peers*. LA Prep and Pedagogy class sessions break the traditional cycle of triadic dialogue;[16, 17] we speak to one another, rather than through Amy. We revoice one another's thoughts, ask clarifying questions, and respectfully challenge one another's thinking. We do so around the shared experience of teaching introductory physics and engaging with STEM education research. In addition*, we learn to listen to and build on student ideas in our own teaching practice.* In our interactions with students, we practice intellectual empathy, seeking to understand the meaning our students are making, from the students' point of view. We learn to notice "seeds of science" in our students' talk and action – the beginnings of scientific ideas, reasoning or practice. "Seeds" may include, for example, a student making a connection between a physics concept and their everyday experiences, trying to make sense of a phenomenon, proposing an experiment to test an idea, or sharing an idea that has glimmers of canonical thinking. We seek to build on these "seeds of science" by, for example, designing an experiment to test a student's idea, noticing that two students' thinking are in conflict and seeking to foster productive argumentation, or refining a "seed" of a canonical concept in collaboration with students.

In the remainder of this article, we will explore those elements of the SPU LA Program that we (LAs) see as fostering these transformative experiences of listening and being heard, elaborating on the experiences themselves as we go. Before we begin, we will contextualize our claims in general details about the SPU LA Program model.

SPU LA Program Model

Based on the CU-Boulder model,[1] SPU's LA Program takes a three-pronged approach that integrates teaching practice, weekly content preparation, and pedagogical instruction:

- **Practice:** SPU's introductory algebra- and calculus-based physics courses integrate lab, lecture, and small group discussion. The courses extensively use University of Washington's *Tutorials in Introductory Physics*,[18] a research-based, research-validated curriculum that seeks to promote conceptual understanding and address common student difficulties.[19-21] During class, we (LAs) and faculty circulate the room and facilitate discussion among groups of four to six students. We attend every class session and offer tutoring hours outside of class, and some of us grade homework.

- **Prep:** We (SPU LAs) meet twice a week to review course content. First, we meet with the instructor of the introductory physics course that we staff to go over the week's material and/or discuss what about this content may be challenging for students. After this meeting, we meet with Amy (the LA Program Coordinator) to try to understand how the *Tutorials* approach the week's material and what student difficulties the *Tutorials* seek to address (i.e., to develop our curricular knowledge [22, 23]), to brainstorm what are productive student ideas that we may anticipate and build on, and to compose additional "challenge questions" that we may want to ask students.

- **Pedagogy:** SPU's weekly LA Pedagogy course exposes us to educational theory and best practices in facilitating dia-

[a] Seattle Pacific University's Learning Assistant Program staffs our introductory physics courses, our content courses for pre-service elementary education majors, and several of our non-majors physics courses (e.g., Physics of Sound or Nature of Science). This newsletter represents the perspectives of those LAs who staff our introductory physics courses; we will use "introductory physics LAs" and "LAs" interchangeably from this point forward.

- logue. The specific content of the course changes from year to year but maintains a theme of noticing and responding to student ideas and actions, treating sense-making about student thinking as one of our primary roles. We (the community) tend to focus more on ideas, theory, and cases, and less on strategies[b]; Amy frames the course as an opportunity to "try on" various lenses for teaching and as a place that we can pursue the questions and ideas that emerge from our practice. As part of our weekly Pedagogy course assignment, we write teaching reflections that connect what we are learning in the course to our practice.

Unlike in the CU-Boulder program, we are required to participate in Prep and Pedagogy courses every quarter that we are an LA (rather than only the first semester of our LA experience).

Our role as LAs is framed as that of an "expert learner": we are recruited to be facilitators of discussion, not masters of content. LAs differ from TAs in our role in the classroom – we work with faculty to support student learning during class time – and in the regular pedagogical preparation that we receive.

Fostering Transformative Experiences of Listening and Being Heard

We consider *being heard in dialogue with our peers and learning to listen to* and *build on student ideas in our teaching practice* as the transformative experiences that define our participation in the LA Program. In this section, we point to specific programmatic elements and culture that we feel foster these experiences: the LA-driven nature of the Prep and Pedagogy courses, the way that claims are framed in class discussions, the centrality of student ideas to the theories of knowledge we discuss, our search for "seeds of science" in student talk and action, the development of our curricular and pedagogical content knowledge, and the way that the LA Program frames the role of teaching. We flesh out each of these elements and their connection to our experiences of listening and being heard. We do not mean to suggest that these elements are independent of one another; rather, we believe they are entangled but distinctly important.

Our (LAs') experiences, questions, and interests drive the content and discussions in our Prep and Pedagogy courses. Prep and Pedagogy course content and discussions are driven by our (LAs') experiences, interests, and questions. We are given significant agency over the direction the course takes. Sometimes this is implicit: Amy feels genuine excitement about the ideas that we share and takes these ideas up as the backbone of our class' inquiry into teaching and learning. She seeks out resources from the STEM education research literature that respond to our experiences and questions. Sometimes this is more explicit: Amy often brainstorms a number of productive directions our conversation could take and invites us to choose among them. In practice, what often happens is that initial ideas and questions evolve into a central question that we (the community) pursue over an extended period of time, such as, "Is it ever okay to leave students with the wrong answer?," "What is my own theory of learning?," or, "How can we teach in a way that is both responsive to students and responsible to the discipline of physics?" This approach – including the careful, enthusiastic attention to emergent ideas, the connecting of our (LA) experiences to the discipline of STEM education research, and the invitation to us (LAs) to participate in decision-making about the direction of shared inquiry – derives from an emerging body of literature on responsive teaching.[24-30]

We experience the LA-driven nature of our course as influential in promoting dialogue and listening practices in the following ways:

It communicates acceptance of our ideas. That our ideas drive the content and direction of the Prep and Pedagogy course communicates to us that our ideas are seen as productive and sensible – that Amy (and eventually we, as a community) expect these ideas to "get us somewhere,"[31] even if that somewhere is simply a better understanding of ourselves and others. This acceptance and positive regard[32] for our ideas fosters a safe environment in which we can share our ideas and challenge the ideas of our peers; in such an environment, we see challenges as opportunities to clarify and understand, rather than as threats.

It inspires enthusiasm for peers' ideas. Our pursuit of our own thoughts – being challenged to think deeply about what we mean – and having Amy do so with such enthusiasm encourages us to value, get excited about, and pursue one another's thoughts.

It focuses our attention on the substance *of ideas*. Amy gets most excited about the substance of our ideas[33] (what we mean, where these ideas come from, and how ideas interact with one another and education research literature); it is not merely participation that Amy values, it is the content of our participation that she notices and attends to. This brings ideas to the fore and makes them the subject of our class' inquiry. With ideas on display, we can see their diversity and depth, and we can try on different ideas to see what it would feel like to embody these ideas in practice. Engaging with ideas in this way fosters authentic dialogue *between* ideas.

It cultivates a sense of community. Our experiences of having our ideas accepted, having others get excited about our ideas, and having our ideas act as a voice in the content and direction of shared inquiry support and sustain a sense of community among us. Being cared for in community – in particular, be-

[b] For example, this year, we read only two articles that presented questioning strategies: Knuth and Peressini's "Unpacking the Nature of Discourse in Mathematics Classrooms"[45] and Brodie's "Working with learners' mathematical thinking: Towards a language of description for changing pedagogy".[46] The remainder of the year, we focused on theories of learning (*e.g.,* Ref. 35-39), case studies of responsive teaching (*e.g.*, Ref. 25 & 26), epistemic affect (*e.g.*, Ref. 47), and culturally responsive teaching (*e.g.*, Ref. 48).

ing cared for *intellectually*, such that our ideas are nurtured and enjoyed – further supports and sustains the acceptance, enthusiasm, and attention to the substance of ideas that foster community in the first place.[34]

It inspires attention to the substance of students' ideas. Our experience of discussions that are driven by our ideas inspires us to have discussions with students driven by their experiences, ideas, and excitement. We find that we become passionate about teaching and learning – something few of us were interested in initially – through having our voices heard and our ideas taken up. Thus, we wonder whether students who were not originally interested in physics will become passionate about the subject through the experience of having their own voices drive the discussion.

It acts as a model for attending to ideas. Prep and Pedagogy course discussions provide us with examples for enriching dialogue and community-building that we then try to emulate. We practice listening to our peers and valuing their ideas in Prep and Pedagogy class sessions – appreciating the complexity and diversity of ideas that emerge – and this carries over into our teaching practice, focusing our attention on students' complex, diverse ideas.

Claims are framed as ideas to discuss and try on.
Claims made by articles, expert visitors, and peers are framed as ideas to discuss and try on, rather than as voices of authority about teaching and learning. We are encouraged to think critically about how these theories and approaches may build upon our experiences and what we already think. A primary goal of the Pedagogy course is for us to articulate our own theories of learning and philosophies of teaching and to develop a shared, community language with which to express what we think and experience. This framing supports us in (1) participating in substantive dialogue with one another and in (2) listening to and building on our students' ideas by:

Fostering a sense of openness toward ideas that are different than our own. Framing claims from articles, expert visitors, and peers as ideas to discuss and try on distributes the authority for assessment: ideas are weighed against our experiences and open to challenge, no matter the source. This both lowers any artificial barriers between our ideas and those presented in the articles we read – every contribution is worth considering – and reduces the risk of considering others' ideas – we are not asked to agree or adapt unless this agreement or adaptation is authentic. This framing promotes openness to ideas that are different than our own.

Further, the openness that is modeled in Prep and Pedagogy class discussions promotes a stance of openness toward students' *ideas*. It is this kind of openness that supports us in shifting our attention away from *our* ideas – and ultimately away from leading students down a pre-determined path toward pre-determined content objectives – toward *students'* ideas and the natural course that these ideas take.

Instantiating the practices of academic debate in the scientific community. When we take up the framing we describe, we effectively treat papers and expert visitors as our peers, a form of self-initiation into the discipline of STEM education research. Discussions take on the norms of dialogue in the scientific community: we discuss and assess the ideas of our expert "peers," test these ideas in our own teaching practice, and report back to our LA community about our experiences. We often frame our Pedagogy and Prep class activity as coming to consensus and/or understanding existing perspectives, further instantiating norms of disciplinary discussion.

Providing ideas to 'try on' in practice. As we say above, this framing reduces the risk of considering and/or trying on the "ways of being" proposed by the articles we read: we are not asked to agree or to permanently adapt our practice; we are asked to test these perspectives in our teaching and to report back on our experiences. We regularly modify our practice to try on an idea. In many cases, prolonged exposure to an idea shapes our practice in a more permanent way. For example, a major focus of our Prep and Pedagogy courses has been noticing and building on the "seeds of science"[30] in student talk and action. Articles we read and videos we watched – such as the "Sean numbers" episode (see http://deepblue.lib.umich.edu/handle/2027.42/65013) from Ball's "With an Eye on the Mathematical Horizon"[25] – provided us (LAs) with a model for attending to the nascent science in student thinking.

Developing shared language for describing our teaching experiences. As we come to consensus around and/or seek to understand existing perspectives in STEM education research, we develop a shared language for describing teaching and learning (often an adaptation of language from the articles we read). Doing so enhances the dialogue of our community and affects our teaching practice as we take up ideas and lenses from educational research. It supports us in articulating our own teaching values and in instantiating practices consistent with these values.

We (LAs) see valuing student ideas as central to theories of learning.
Throughout the first quarter of the year, we (LAs) engage with and try on different theories of knowledge/learning – constructivism,[35, 36] misconceptions and pieces,[37, 38] and participation and acquisition metaphors for learning.[39] We articulate our own developing theories of knowledge/learning, and we are challenged to try on those theories that resonate less with us, to see what it "feels like" to see learning through these lenses. There is often quite a bit of diversity and disagreement among us (LAs) about theories of knowledge/learning. However, in listening to one another, we realize that what all of these theories (and many of our own personal theories) have in common is the central role of students' ideas to their learning, engagement, and agency. This recognition fosters the transformative experiences of listening and being heard by:

Providing generative content for dialogue. Theories of knowledge/learning is content that is personal and generative – it is engaging, central to the task/experience of being an LA, and connected to our experiences as students. Paired with the LA-driven nature of the course – that our ideas are central, on display, and the subject of our community inquiry – as well as the framing of claims from articles as ideas to discuss and try on, this content fosters rich dialogue.

Providing student-centric theories to try on. We have the experience of realizing that teaching that is consistent with theories of knowledge/learning must start from the same place – the student. As we attempt to implement these theories in our own practice (as a form of testing them), we focus on trying to listen to and build on students' experiences and ideas. These experiences flesh out and reinforce the theories themselves; we *buy into* teaching as listening and responding to student thinking and consider successful interactions in terms of how well we understood what students were thinking.

Reinforcing the importance of student thinking to our personal teaching values. We (LAs) are encouraged not only to articulate our own theories of knowledge; we are also asked to make explicit the *values* that drive our interactions: why do we want to teach? What do we consider to be important goals for learning? What do we strive for in our interactions with students? Conversations around theories of knowledge bring to the fore that we (all of us) *value* student thinking. We do so for different reasons: some of us value student thinking because it helps us to figure out how to lead students to the correct answer; others of us value student thinking as an expression of care;[32, 34, 40, 41] and still others of us value student thinking for its intrinsic sophistication and sensibility.

Recognizing that we value student thinking, we seek to put these theories of knowledge/learning into practice. Doing so not only promotes intellectual buy in to the theories, as above; the success of these interactions – and the pleasure that we experience as we engage with the thoughtful ideas of our students – also reinforces and sustains the experience of valuing student thinking, which further encourages careful attention to student ideas.

We (LAs) look for "seeds of science" in student talk and actions.

Our shared priority of valuing student thinking problematized the question of how to build on this thinking in the classroom. Influenced by our interest in fostering student agency and voice, our community began to think in terms of pursuing "seeds of science" in what students were saying and doing. We read a number of case studies of teachers who attended and responded to the "seeds of science" (or mathematics) in their students' thinking [including Refs. 25, 26, 42], which supported us in articulating (in a preliminary way) the types of "seeds" we might notice. We began to keep teaching journals about the "seeds" we saw in our own interactions with students, supporting us in refining our original list. And we watched video of ourselves and others listening to and building on "seeds" in student talk and action to support us in putting this into practice.

Our final scheme included "seeds of scientific practice," "seeds of scientific reasoning," "seeds of the canon," "seeds of connection," and "seeds of disciplinary affect." "Seeds of scientific practice" echo what practicing scientists do and include, for example, instances in which students are giving reasons that they disagree with one another, formulating hypotheses, testing their ideas, and noticing patterns. "Seeds of scientific reasoning" are productive beginnings of mechanistic reasoning, instances in which students' reasoning is reasonable, mechanistic, causal, or sensible. "Seeds of the canon" are ideas that may be productive for getting the canonical answer, including ideas that are correct in certain contexts but not properly applied in a given instance, or ideas that are not fully developed but may be the beginnings of canonical answers. "Seeds of connection" are instances in which students draw on their everyday experiences to make sense of classroom physics. And "seeds of disciplinary affect" are affective experiences that mirror those experienced by practicing scientists, or that sustain and promote participation in science, such as empathizing with an object of study, expressing pleasure in figuring things out, or persisting through frustration toward figuring something out.[c]

Intentionally noticing and building on the "seeds of science" in student thinking is itself one of the transformative experiences that defines our participation in the SPU LA Program. To illustrate what this looks like in practice, we share two excerpts from our weekly teaching reflections. The first is Erika's reflection on her interaction with students as they worked through the *Electric Field and Flux* Tutorial:

> Towards the end of class, I was just listening in on the students' conversation about the last page [of the *Electric Field and Flux Tutorial*]. At the top of the page, the tutorial asks the students to "sketch vectors A [area] and E [electric field] such that the electric flux is" positive, negative, and zero. The paragraph above spells out how to draw the vectors so that the electric flux is positive and so that it is negative. The students all did this "correctly." It was when they got to the zero part that they all paused and didn't know exactly what to do. After a long pause, one student said, "Hey, this looks like the same thing we drew for the work tutorial!" This was most definitely a seed of scientific practice and let me tell you, I was excited!! It was awesome that they made that connection.

[c] In articulating this scheme, we were influenced by several articles we read [e.g., Ref. 25, 26, 42, 47], by conversations with researchers who study responsive teaching, and by videos we watched [including videos from the Mathematics Teaching and Learning to Teach website (http://deepblue.lib.umich.edu/handle/2027.42/65013), the Responsive Teaching in Science website (http://cipstrends.sdsu.edu/responsiveteaching/index.html), and the Video Resource for LA Development website (http://www.phystec.org/lavideo/)].

> I continued to listen to their conversation and as a table group they put together that for the electric flux to be zero, the A and E vectors must be perpendicular. Then, I asked them, "Why do you think that is so?" One student chimed in that it depends on the angle between the vectors, while another student added that if the equation for electric flux is similar to work then it should be Electric Flux = E*A*cos(angle). Another student explained that the cosine of 90 degrees is zero thus, making the electric flux zero.

Here, Erika notices that students are connecting the relationship between the electric field and area vectors (in the flux equation) to that between the force and displacement vectors (in the equation for work). She not only sees what they are doing; she celebrates it and becomes curious as to how they are making sense of these relationships, treating her students' ideas as an object of inquiry. The second reflection, written by Hannah, is derived from interactions around the same Tutorial:

> The class was working on the *Electric Field and Flux* tutorial. During the second section of the tutorial, it attempts to build the idea that the ratio F/q_{test} is a constant, and this constant is the electric field, such that F = qE. While I was working with a table, one of the students asked if "E" was like "little g," meaning the gravitational constant on Earth/a specific planet. At first I was confused by what she was trying to say, but then I realized what she meant. $F_{grav} = g*m_1$ and $F_{elec} = E*q_{test}$. So the configuration of the electric field is a constant, in the sense that it is not dependent on the test charge, like *g* is not dependent on the mass. She was able to see similarities between the two that I had not realized. I really liked this interaction because she taught me something. She saw similarities that I had missed. I was also really proud to see how her thinking had been developed and refined over the course of the year. This interaction was really special to me.

Like Erika, Hannah expresses her excitement and curiosity about a connection that her students are making. When she was confused about what her student was saying, she sought to understand what she meant, remaining open and empathetic. In this quote, Hannah expresses her sense that learning from a student is a hallmark of great teaching; she has done something *right* as a teacher when she learns something new from a student – she was not ill prepared or uninformed.

The experience of intentionally searching for and seeking to build on the "seeds of science" in student talk and action are further influential in promoting dialogue within our community and in transforming our practice in the following ways:

It necessitates the (inherently dialogic) negotiation of shared language for building on student thinking. The process of developing a language around "seeds of science" – including the choice of which "seeds" to include in our list – was one of intense negotiation. The process was distinctly disciplinary: it began as a problem to solve – how can we put into practice our shared vision for valuing students' ideas? It evolved into consideration of various perspectives from the literature and was fleshed out by our (LAs') teaching experiences and collaborative viewing of video cases. Because different members of our community resonated more or less with particular perspectives, discussion often involved putting multiple ideas on the board for consideration, seeking to understand each one, and seeking to come to consensus through respectful debate.

It fosters appreciation for the sophistication and diversity of student thinking. The process of articulating which "seeds" were a part of our scheme highlighted additional foci of attention and assessment for us to try on. Doing so provided additional lenses through which to view and value student thinking and action, which fostered an appreciation for the sophistication and diversity of student thinking. In fact, looking for "seeds" often involved seeking to understand where a student was coming from, on his or her own terms, which supported us in framing ideas as grounded in students' sense-making about their experiences. This further supported and sustained our appreciation for the complexity and sophistication of student thinking.

It promotes a sense of trust in the direction that emerges from student inquiry. In searching for "seeds," we frame student thought and action as the beginnings of scientific ideas and practice. With experience, we find ourselves trusting that following students' ideas will take us somewhere productive. This constitutes a significant shift away from our original perception that pursuing the natural course of student ideas is *scary* or is a *loss of control*. It also constitutes a significant shift away from listening *for* the familiar answer or attending to where to take the ideas, toward listening with a stance of openness toward what students are saying and doing.

We (LAs) develop curricular knowledge and pedagogical content knowledge.

Each week, in addition to going over relevant content with SPU introductory physics course instructors, we meet to develop knowledge of the *Tutorials* curriculum – what are the strategies it employs and what are the conceptual difficulties it seeks to address? For example, we infer that the *Tutorials* often employ an elicit, confront, resolve strategy to address common student difficulties.[43] (This process of developing LAs' curricular knowledge is described in detail in a forthcoming paper.[44]) We also seek to develop pedagogical content knowledge[22, 23] including what are the productive ideas students may come to class with, and how might we elicit and build on these ideas? For example, we anticipate that students may have experiences in swimming pools or underwater diving that they can draw on in learning about pressure in a liquid. The process of developing this knowledge – and the knowledge itself – fosters our transformative experiences of listening and being heard by:

Providing generative content for dialogue. Like theories of knowledge/learning, the *Tutorials* curriculum is generative, personal content for us – we have had the experience of learning from the *Tutorials* as students, and we support courses in which *Tutorials* is the primary curriculum. Further, the process of figuring out what are the strategies implicit to the curriculum, the theoretical commitments underpinning the curriculum, and the student ideas that the curriculum is designed to address is intimately tied to our Pedagogy course discussions. Paired with the LA-driven nature of the Prep course and the framing of curricular strategies and sequence as ideas to try on, this content has fostered rich dialogue in our community.

Focusing on the connection between "big ideas" in physics and student ideas. Understanding what the curriculum deems important and anticipating student ideas about particular topics provides us with a framework for connecting students' ideas to the discipline; it contextualizes our focus on building on student thinking. At the same time, knowing the "big picture" – what are the big ideas that the curriculum is seeking to develop and how do those ideas connect to past and future learning – mitigates a strict focus on the answers to specific *Tutorials* questions, giving us the freedom to shift our focus toward student thinking. Knowledge of the curriculum more broadly – its strategies and theoretical commitments – paired with knowledge of specific *Tutorials*, supports us in adapting the curriculum to each student, deviating from the details of particular sections or questions when appropriate.

Teaching is framed as a process of learning and discovery. The SPU LA Program frames teaching as a process of learning and discovery. Amy and our introductory physics course instructors encourage us to use the classroom as a laboratory for learning about teaching and learning, and they celebrate opportunities for us to learn from our peers and students. Our primary role is to support learning (our own and that of our students), and the program does not expect us to be master teachers nor masters of content. This framing of teaching fosters dialogue within the community and affects our listening to our students by:

Alleviating our concern about "having the right answer." Many of us become comfortable – in fact, embrace – not knowing the right answer. Framing our role as co-learners and making it clear to students that we do not necessarily have the right answer means that we can participate as facilitators of discussion and learning rather than a repository of knowledge against which students check their answers. In this process, we often learn more about the content or see it through the eyes of students as we foster dialogue amongst them and come to a table consensus. This sense of comfort in "not knowing" is connected to our conviction that students have productive ideas and that as a community we can put these ideas together in a way that makes sense.

Fostering a sense of excitement about learning from students. Hannah's quote above speaks to the excitement that we experience when we frame our teaching as *discovering what students think*. One manifestation of being comfortable not knowing the right answer is that we can take pleasure in learning from our students.

Fostering collaborative teaching. When "knowing the right answer" is not a status symbol, and when "not knowing the right answer" is accepted and embraced, we can teach collaboratively, drawing on one another as resources in the classroom and fostering in-the-moment dialogue about student thinking.

Promoting students' sharing of their ideas. Experiencing us (LAs) as co-learners – and understanding our intermediate role between that of instructor and peer – encourages students to entrust us with their ideas. The open sharing that is fostered by this trust is critical to developing and sustaining our practices of listening to and building on student thinking.

Discussion

In the spirit of listening and being heard, this newsletter article shares the lived experiences of Seattle Pacific University Learning Assistants, adding to existing accounts of the effectiveness of LA Programs by describing what it is like to be an LA in one adaptation of the CU-Boulder LA model. We report that we (SPU LAs) are transformed by our experiences of (1) being heard and hearing others in authentic dialogue with peers and (2) learning to listen to and build on student ideas in our own teaching practice. We consider these to be the *defining* experiences of our participation in the LA Program, and we feel that these experiences foster an openness and enthusiasm toward ideas in our lives outside the classroom. Others who wish to provide similar experiences to their LAs – or to their students more broadly – may draw on the elements of our program that we perceive as fostering these transformative experiences.

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Erika P. Eppard, Lisa M. Goodhew, Emily L. Maaske, Hannah C. Sabo, Faith C. Stewart, David L. Tuell, and Scott T. Wenzinger were introductory physics LAs at SPU during the 2013-2014 academic year. They span a variety of majors and interests including: physics with an interest in becoming a physics teacher, physics with an interest in pursuing a graduate degree in physics or physics education research, and physiology with an interest in pursuing a medical degree.

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The Physics Learning Assistant Program at Texas State University: My perspective as an LA and as a researcher

By Jessica Conn, with Hunter Close and Eleanor Close, Texas State University

Introduction

Over the last two and half years, the Physics Learning Assistant Program at Texas State University has been the major catalyst of cultural change in the physics department toward more interactivity among students and between students and faculty. Through the introduction of LAs into lecture and lab sections of the introductory calculus-based physics sequence and into the new “Physics Help Center,” which is available to all physics students, LAs promote student conversation about the core ideas and methods of physics. The result has been a more knowledgeable, more interested, more challenged, more socially connected, and happier student community.

Facts about the Program

The Learning Assistant program at Texas State University began as a pilot in the spring of 2012, in one section of introductory mechanics, and had six LAs. As of fall 2014, our program will have expanded to include all sections of mechanics, electricity and magnetism, and waves and heat, for a total of about 30 LAs and 500 students per semester. Of these LAs, about 40% are new each semester, while 60% are returning. New LAs participate in a weekly Physics Cognition and Pedagogy class, and all LAs participate in a weekly LA Prep Session, lasting two hours and pertaining specifically to the class in which they serve as LAs. During these prep sessions, which use *Tutorials in Introductory Physics* from the University of Washington, LAs work in small groups with other LAs and faculty to prepare for the upcoming week. LAs also have the option of tutoring students in the Physics Help Center, which has been funded by the Halliburton Foundation, Noyce, and the College of Science and Engineering. Mechanics labs are staffed solely by LAs and require an additional 1.5 hours per week of preparation, including working through additional tutorials. Normalized gains on the Force Concept Inventory in mechanics ranged from 9% to 15% before implementing the Learning Assistant program, and now average in the 40s. We have also seen a reduction in rates of the grades D, F, and W in all courses in the introductory sequence.

There are differences between our model and the CU-Boulder model: While the program at CU-Boulder pays LAs a per-semester stipend, at Texas State we have chosen to pay LAs hourly in order to accommodate differing workloads among LAs. At Texas State, LAs facilitate small group discussion in the lecture classroom, mostly centered around the UW *Tutorials*. Our program is currently limited to the physics department, and the department faculty has decided together when to expand the LA program into new course sections. In contrast, CU faculty from many departments apply competitively to use LAs in their courses. Our selection criteria for LAs emphasize the applicant’s (1) ability to engage enthusiastically and productively with the small-group, tutorial format, as judged by faculty who knew the applicant as a student, (2) interest in teaching at any level, (3) statement of teaching philosophy, (4) academic record, (5) interest in a physics major or minor, and (6) membership in an under-represented group in physics. Though physics majors and minors are given some preference, we strive to have some diversity of academic interest in our group of LAs. The goals of our program are similar to those of CU-Boulder’s (see laprogram.colorado.edu), with some additional articulations: we want our LAs to (1) have experiences of being competent at understanding physics, and to feel good about it, (2) have experiences of being competent at helping other people learn physics, and to feel good about it, (3) feel that they are a valued member of a community engaging together in physics learning and teaching, and (4) feel that they are valued by the department.

LA Perspective

I (JC) have been an LA for three semesters - Fall 2014 will be my 4th semester. I was approached by my mechanics professor (EC) and asked to apply to be an LA for the following semester. It made me feel special to be recognized in this way (which I needed, because my grade wasn't fantastic in that class). My first semester being an LA, I was assigned to mechanics classrooms, to work in the Physics Help Center and to be a mechanics Lab Instructor. I also enrolled in the Physics Cognition and Pedagogy class. That first semester was scary and exciting at the same time. I felt confident working in the classroom and in my capacity as a Lab Instructor, but felt very unsure of myself in the Help Center. I attribute this to the fact that there were prep sessions for working in the classroom and the lab. We reviewed the material to be covered and discussed possible pedagogical challenges that might come up. However, there was not this kind of preparation for working in the Help Center. The Help Center is structured so that students walk up, sit down, and start working on their work. There are typically two LAs staffing it, and if a student needs help, they raise their hand, or seek out an LA. It is the role of the LA to improvise, using methods learned in the Physics Cognition and Pedagogy class, to help the student find a solution to their question, since it would be impossible to prepare for every possible question that any student might ask. My first semester working in the Help Center left me feeling inadequate. I was getting so much out of the LA program though that my feelings of inadequacy in the Help Center weren't enough to make me think about quitting the program. So, I reapplied for the next semester. Getting accepted as a returning LA is a different feeling than being accepted for the first time: when I was accepted for the first time, thought "My professor thinks I'm a good physics student." When I was accepted as a returning student, I thought, "My professor thinks I'm a good physics student, and a good LA."

In my second semester as an LA, I really felt like part of a community. I was friends with the other LAs, and had much closer relationships to the physics faculty. I felt confident in the classroom and lab, and found that I was doing better in my physics class (waves and heat) than I had in previous physics classes; this was the first semester that I got an A in physics. I found that, as a student, the way I approached class had changed. The LA program had not yet expanded to this class, and it was taught in a traditional lecture style, so I had to take more initiative to learn interactively. I found myself seeking out other students for collaborating and asking the professor for information I needed when I needed it to understand a topic. I felt like a leader in the physics community and wasn't afraid to seek out resources when I needed them. I was starting to do physics education research (PER) in the department, and presented my research at a conference for Women in Science and Engineering. Towards the middle of the semester, I found myself hanging out in the Help Center more - not just to do my own work, but to stop by and hang out. Students recognized me as an LA and would ask for my help with their work. This time, I felt confident. I no longer thought that the only way to help someone was to know already how to solve the problem. I realized that I could help someone think about a problem and that would get them farther along than they were already. Some students enjoyed this process, and others didn't. Some students thought that if I didn't immediately give them the answer then I wasn't doing my job, but this didn't affect my self-esteem at all; I saw those students as simply less mature in the development of their thinking. I enjoyed the time I got to spend helping the other students figure out where their mistakes were.

By my third semester as an LA, I felt confident in all aspects of being an LA at this point and enjoyed mentoring new LAs. I was completely integrated into the physics community and felt comfortable approaching any student or professor for help. I also found that the physics building was my favorite place to be, and I spent as much time there as I could. I collaborated with other physics students on math homework in the Help Center or in the physics student lounge. I found that the way physicists approached math was different from the way mathematicians approached math, and that I could understand math concepts better when working with physics students. I became active in our SPS chapter as treasurer and participated on committees. My research was exciting, and I felt sure that PER was the field I wanted to go into.

Researcher Perspective

As a research assistant in PER, my work has focused on understanding the effects of the LA program on other LAs at Texas State. I have been studying it through a blend of two approaches: *Communities of Practice* and *Physics Identity* (see Close, Conn, & Close, 2014). Our sources of data include LA program applications, LA written reflections, LA end-of-semester program evaluations, and clinical interviews of LAs. Through analyzing this data, I am developing an idea of the transformations that take place by participating in the LA program. Generally, I see the following trend: In the first semester, students' pre-conceptions about what it means to be a good student and a good teacher are challenged. This leads to a sense of unease, which leads to the desire to create a new model about teaching and learning. Our newest clinical interviews include new LAs. What we have found is that many of the transformations we were seeing in the clinical interviews of LAs with two or more semesters in the program didn't exist, or were just beginning, in new LAs. In the second semester of being an LA, students begin creating/refining this new model, which includes statements like, "It's okay to be wrong" and "The LA program taught me how to think." They also feel like part of the community, and gain confidence in their ability to interact within that community. We see this enhanced feeling of inclusion in statements like, "One of the things I really enjoyed about [being an LA] was that I became way more involved in the department and I feel like I have a larger network of help if I need it because of it" and

"As a physics major, when I was just a student, I was too self-conscious to approach a professor to ask questions. But as part of a community, that includes my professors, I can approach them with questions, no problem. Also, building a community of student peers has also increased my academic performance." We also notice students becoming better communicators in the second semester: "In the past two semesters of being an LA, I've learned how to communicate more effectively with people... If someone doesn't understand a concept when I explain it verbally, I can draw them a picture or a diagram instead. If they can't verbalize what they're thinking themselves, sometimes handing over a marker so they can draw something out for me will help me understand where they're at in their understanding of the material." The biggest impact I'm seeing as a researcher is that students change their model of what it means to be competent, and this helps them become better teachers and better students. One student said during her interview, "Being an LA has made me a more competent person all around."

Summary

We have seen a variety of positive impacts of the LA program on students' engagement in physics, especially for those students who serve as LAs. It seems also that there is a process of transformation for LAs that spans more than one semester. We will continue to study this process to understand better how to maximize the benefits for the physics department community as a whole, including improved physics teacher recruitment and preparation and enhanced academic success for physics majors and minors.

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From Competencies to Curricular Objectives: Preparing a new Introductory Physics for the Life Sciences (IPLS) course

Juan Burciaga, Mount Holyoke College; Ralf Widenhorn, Portland State University

Over the last few years science departments have been advised of major changes in the education of both life science majors and pre-med students. The revised MCAT[1] that will be issued in 2015 is serving as a catalyst to prompt changes in the way undergraduate science courses for pre-med students are being taught. But faculty in the physical sciences are still uncertain exactly what will be expected in their courses. The article takes the perspective of preparing to teach a course in Introductory Physics for the Life Sciences (IPLS) as a faculty member studies the reports calling for change and begins to alter a fairly traditional IPLS course.

Introduction

Recent reports[1,2] have called on the physics community to respond to the changing needs of biologist and other life scientists to better prepare them for advanced study in the fields. In addition, the AAMC will be switching to a new version of the MCAT[3],[4] in 2015. There are a number of elements of the transformation that are proving daunting to faculty as they consider revising courses that are predominately taken by life science, pre-medical and allied pre-health majors.

Four of the more puzzling factors are the mapping between the curricular goals of faculty and the targeted competencies of the MCAT; the selection of topics in the physics course; a growing recognition of the differences between the physics being taught in the IPLS course and the application of physics by life science students and by life scientists; and a greater role of biology-based problems in a physics course.

In order to set this discussion on concrete terms we set these challenges in the context of preparing a two-semester, non-calculus sequence taught by one or more physics faculty using a fairly traditional development.

And so our little simulation begins – we are preparing a course for the 2014/15 year, we expect that we will need the course to show that we are being responsive to the new guidelines though we are not sure what the guidelines are, and we must do so with a core of traditional development and a minimum of dependence on undeveloped resources.

The Reports

The *AAMC/HHMI report, Scientific Foundations for Future Physicians*[5] (SFFP), outlines the new vision of both undergraduate and medical school preparation for physicians. A key, and somewhat daunting, aspect of this report is that preparation is not described in terms of courses but in competencies. Hilborn and Friedlander[6] give an excellent discussion of the rationale behind this paradigm shift.

A key element of the SFFP is the emphasis on interdisciplinary "hands on, minds on" pedagogy, e.g., guided-inquiry, group work, active engagement, and inquiry-based labs. These guiding principles are widely echoed by physics education research (PER) and the biology community.[1,2] The message is that courses must incorporate the kinds of scientific inquiry processes and critical reasoning skills that will best prepare future physicians.

This is a boon to faculty who have tried to incorporate active-learning paradigms into their courses but have not been able to gain the needed buy-in from students, their physics department and college, or external agencies.

Table 1 lists the relevant Competencies and Learning Objectives from the SFFP.

Though the Learning Objectives go a long way to making the more nebulous Competencies into terms like our course goals we may not yet be ready to start planning a daily schedule.

A second important document is the *Preview Guide for the MCAT, 2015*[3]. The Preview Guide describes the Competencies in terms of Foundational Concepts and Content Categories. Table 2a lists the five Content Categories from the Preview Guide and Table 2b itemizes the Content Category for one of those Foundational Concepts. The Content Categories reveal the topics in a familiar manner and we can start seeing the day-to-day interplay of the development for those topics.

An even more detailed listing of the topics rated as good preparation for the MCAT is described in *Summary of the 2009 MR5 Science Content Survey of Undergraduate Institutions*.[7] In 2009 the MR5 Committee polled medical schools to determine the essential topics needed by students to succeed in medical school. They then polled faculty teaching the undergraduate courses as to which topics are covered in the standard courses. The report lists the comparison of the two surveys and lists the relative importance of topics and the likelihood of a topic appearing on the MCAT.

The Science Content Survey is a powerful tool in the hands of faculty developing courses to better prepare students for the MCAT. Though we do not intend to "teach to the test" we do have a strong impulse to tailor the course to better meet the needs of our students.[8] To illustrate, conservation of momentum scored low on the survey and will not appear on the MCAT. However, conservation of momentum is an important component of the framework of mechanics and the use of conserved variables in physics and may be considered a keystone in a pivotal learning cycle. As such we may choose to take the time to keep the topic in the course and accept that we will need to trade off time elsewhere.

The Preview Guide also reveals several aspects of the new MCAT that could have a major impact on course design. Introductory physics will consist of 25% of the test but all physics-based problems will be placed in a biological or chemical context. We think then that in order to better prepare students we will now need to incorporate more biologically-based problems in our assignments and tests.

The Preview Guide also describes the critical inquiry and scientific reasoning skills (Table 3) that will be expected of physicians. A natural place for me to emphasize the development for these skills is the laboratory experience.

The Course

We now have enough background to have some confidence in starting the preparation of our course.

We will use a fairly traditional development with a fairly standard algebra-based textbook but the pedagogy of the class will be considerably overhauled. We will use active learning pedagogies in the classroom and the lab will incorporate a guided-inquiry, community active, learning environment.

One of us has written about such a lab experience before[9] and so we will not discuss it in detail here. In summary the learning environment is based on guided inquiry, peer groups, and an extended investigation that is a fair simulation of a research experience. But there are other examples of lab environments that offer practice in inquiry and experimental design, e.g. the Investigative Science Learning Environment[10]. The schedule we prepare will allow students to discover the key concepts in lab and develop them further in class.

But the classroom environment still needs more development.

We have a list of topics but the topics are still too many in number to cover in any but a cursory manner. And there is a great emphasis on developing critical reasoning skills that require class time in order to practice and develop. How do we reconcile the conflicting demands?

This is a familiar question to faculty who have tried to incorporate active-learning pedagogies into their courses. The only solution seems to be to reduce the time in class where we simply lecture to students and allow them more time in discussion, reflection and grappling with the problems and concepts, that is address fewer topics but in greater depth.

There is one last item that needs exploration – problem solving. An intriguing article by Hoskinson, Caballero, Knight[11] explores the problem solving needs and approaches of biology students. Not surprisingly, solving complex problems in biology has many common processes with solving complex problems in physics – transforming representations of problems (words, visual, mathematical), finding relationships, making predictions, and checking solutions. But what PER in problem solving has shown is that to improve these skills we need to emphasize process, practice and the opportunity for reflection. Therefore, we will need to build into our course time for problem solving modeling and practice.

Another useful article by Watkins and Elby[12] points to some interesting insight in how biology students perceive the role of physics and mathematics in biology.

Preparation

We now have a fairly clean map of what we need to do as we prepare to (minimally) revise the IPLS course.

If we are not already familiar with active-learning pedagogies we will need to study and take workshops in one of these pivotal paradigms (Tutorials, Peer Learning, Just-in-Time, Modeling…). During summer 2014 we would have started reviewing our notes from older IPLS course and start studying how to eliminate topics in order to make time for the active learning strategies and problem solving sessions that we will incorporate into my courses.

If we have not done so already we would document our learning goals[13,14] for each class. Learning goals are useful since they encapsulate what students know at the beginning of the class, what they will be able to do at the end of the class and what is the evidence for their learning. Changing our thinking from "Cover Chapter 5.1 to 5.3" to defining learning goals:

"a) Students should be able to transform a word problem of a two-dimensional collision into a visual representation of the conditions before and after the collision.
b) Students should be able to explain why the dynamic equations do not apply during the collision.
c) Student should be able to recognize the system where conservation of momentum can be used.
d) …."

is an extraordinarily time consuming one requiring much practice. But it does allow faculty to document the meeting of each learning goal. And it is an essential first step to matching the learning goals to the Competencies called for in the SFFP. This step is actually useful for a much more important reason than satisfying administrators. Many faculty stumble when adopting active-learning strategies by not taking time to ensure students buy in to the new paradigms. Though, as all of their other courses make the transition to active learning environments (as recommended in the SFFP report), resistance to the greater effort active learning requires may ease for the immediate future we will need to deliberately obtain their good will and so we will need to build in time to discuss the rationale for the (possibly) new pedagogy of the course.

We will also need to explore biology-based problems in other textbooks than our own to broaden our understanding of the application of physics to the life sciences and the medical field. The PER/BER groups at the University of Maryland are developing an extensive set of resources on their NEXUS Wiki[15,16], Hoskinson et al[17] write about adopting the modeling approach to a biology based physics course, and Roth and Hobbie[18] explore the challenges of preparing biology-based e&m problems. Introductory level books e.g. Kane[19], Davidovits[20], and Tuszynsk and Dixon[21] can be used to explore how our physics course can be enriched with relevant biology and medical applications.

We will also start modifying the lab to allow more student practice in generating, modifying, and verifying their own critical inquiry.

A Look Ahead

We have outlined the steps that faculty might take for a fairly minimal transformation of the IPLS. The pedagogy may or may not have been a major shift and the core of the content remains the same. But is this sufficient? For some schools the question is not relevant. They will have too many constraints to respond in any other way. But for many schools the answer is – We can do more.

Resources are being developed that offer a brand new development of physics that will allow a more integrated understanding of both biology and physics.[14] Courses that are based on a truly integrated understanding of biology, mathematics and physics are being explored.[22] The archive of the recent IPLS Conference[23] provides an excellent overview of many developments in this rapidly evolving curriculum.

Demands from biology graduate programs, medical schools, or other health related graduate programs may in the near future increase the pressure on university administrators to implement changes to their introductory science courses. This will provide a great opportunity for physics faculty to engage College Deans, department chairs and faculty colleagues to institutionalize changes and substantially and sustainable enhance the education of both the life science and physics communities.

Acknowledgements

Our thanks and appreciation go to the IPLS community within AAPT and APS who for the last 4 years have been pursuing questions of IPLS reform with an intense vigor, curiosity, and determination in which it has been pleasurable to participate.

Table 1: Competencies and Learning Objectives from the Science Foundations for Future Physicians report.

Competency E1: *Apply quantitative reasoning and appropriate mathematics to describe or explain phenomena in the natural world.*

Learning Objectives:

1. Demonstrate quantitative numeracy and facility with the language of mathematics.
2. Interpret data sets and communicate those interpretations using visual and other appropriate tools.
3. Make statistical inferences from data sets.
4. Extract relevant information from large data sets.
5. Make inferences about natural phenomena using mathematical models.
6. Apply algorithmic approaches and principles of logic (including the distinction between cause/effect and association) to problem solving.
7. Quantify and interpret changes in dynamical systems.

Competency E2: *Demonstrate understanding of the process of scientific inquiry, and explain how scientific knowledge is discovered and validated.*

Learning Objectives:

1. Demonstrate quantitative numeracy and facility with the language of mathematics.
2. Interpret data sets and communicate those interpretations using visual and other appropriate tools.
3. Make statistical inferences from data sets.
4. Extract relevant information from large data sets.
5. Make inferences about natural phenomena using mathematical models.

Competency E3*: Demonstrate knowledge of basic physical principles and their applications to the understanding of living systems.*

Learning Objectives:

1. Demonstrate understanding of mechanics as applied to human and diagnostic systems.
2. Demonstrate knowledge of the principles of electricity and magnetism (e.g., charge, current flow, resistance, capacitance, electrical potential, and magnetic fields).
3. Demonstrate knowledge of wave generation and propagation to the production and transmission of radiation.
4. Demonstrate knowledge of the principles of thermodynamics and fluid motion.
5. Demonstrate knowledge of principles of quantum mechanics, such as atomic and molecular energy levels, spin, and ionizing radiation.
6. Demonstrate knowledge of principles of systems behavior, including input–output relationships and positive and negative feedback.

Table 2a: Content Categories from the Preview Guide to the MCAT, 2015.

***Foundational Concept* 4:** *Complex living organisms transport materials, sense their environment, process signals, and respond to changes using processes understood in terms of physical principles.*

4A. Translational motion, forces, work, energy, and equilibrium in living systems

4B. Importance of fluids for the circulation of blood, gas movement, and gas exchange

4C. Electrochemistry and electrical circuits and their elements

4D. How light and sound interact with matter

4E. Atoms, nuclear decay, electronic structure, and atomic chemical behavior

Table 2b: Content Category for the Foundational Concept 4a from the Preview Guide to the MCAT, 2015.

Content Category 4A: *Translational motion, forces, work, energy, and equilibrium in living systems*

Translational Motion (PHY)

- Units and dimensions
- Vectors, components
- Vector addition
- Speed, velocity (average and instantaneous)
- Acceleration

Equilibrium (PHY)

- Concept of force, units
- Analysis of forces acting on an object
- Newton's First Law of Motion, inertia
- Torques, lever arms

Work (PHY)

- Derived units, sign conventions
- Mechanical advantage
- Work Kinetic Energy Theorem
- PV diagram: work done = area under or enclosed by curve

Energy (PHY)

- Kinetic Energy: $KE = \frac{1}{2} mv^2$; units
- Potential Energy
  - o $PE = mgh$ (gravitational, local)
  - o $PE = \frac{1}{2} kx^2$ (spring)
- Conservation of energy
- Conservative forces
- Power, units

Table 3: Scientific Inquiry and Reasoning Skills from the Preview Guide to the MCAT, 2015 with a sample narrative for one of the skills.

Scientific Inquiry and Reasoning Skills

Skill 1: Knowledge of Scientific Concepts and Principles
Skill 2: Scientific Reasoning and Problem-solving
Skill 3: Reasoning about the Design and Execution of Research
Skill 4: Data-based and Statistical Reasoning

"Skill 2: Scientific Reasoning and Problem-solving

Questions that test scientific reasoning and problem-solving skills differ from questions in the previous category by asking you to use your scientific knowledge to solve problems in the natural and social sciences.

As you work on questions that test these skills, you may be asked to use scientific theories to explain observations or make predictions about natural or social phenomena. Questions may ask you to judge the credibility of scientific explanations or to evaluate arguments about cause and effect. Or they may ask you to use scientific models and observations to draw conclusions. They may ask you to recognize scientific findings that call a theory or model into question. Questions in this category may ask you to look at pictures or diagrams and draw conclusions from them. Or they may ask you to determine and then use scientific formulas to solve problems.

Questions that test this skill will ask you to show that you can use scientific principles to solve problems by, for example:

- Reasoning about scientific principles, theories, and models
- Analyzing and evaluating scientific explanations and predictions
- Evaluating arguments about causes and consequences
- Bringing together theory, observations, and evidence to draw conclusions
- Recognizing scientific findings that challenge or invalidate a scientific theory or model
- Determining and using scientific formulas to solve problems"

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An Adventure in STEM Policy

Dayton Syme, Florida State University

On April 14th, 2013, the President of the United States put forth an aggressive budgetary plan for the 2014 Fiscal Year, which included changes to the tune of $178 million in funding being reshuffled between programs that support STEM (Science, Technology, Engineering, and Math) education. The proposed changes also drafted a complete reorganization of STEM educational programs throughout the federal government, centering them into: the Department of Education (ED), the National Science Foundation, and the Smithsonian Institute. The changes drew some support and harsh criticism from all parties in Congress. This proposal was constantly referred to as the "STEM Reorganization" and made STEM the hot topic of the year. By this point, the Reorganization made people either proudly profess their support for science education initiatives, or they misheard you and would carefully maneuver the conversation thinking the topic was stem cell research.

Around May, Dr. Camsie McAdams – then Senior Advisor on STEM Education, now Acting Director for the Office of STEM in ED – with APS policy specialists Dr. Tyler Glembo and Dr. Francis Slakey agreed to have an APS fellow come in to the Office of Planning, Evaluation and Policy Development (OPEPD) to help her with all things STEM. For the summer of 2013, that fellow was me. By the time I had arrived in DC, in the first blistering week of June, OPEPD was swamped with policy changes crossing through the office. These changes caused confusion in the ED Human Resources office and, as I later learned, a filter kept flagging my résumé to be scrubbed out. The first time I entered into the Department of Education would turn out to be two weeks after my arrival.

I was unusual in the ED in that I was a physicist (I had earned my BS in physics shortly before beginning my fellowship) and had not majored in education, law, or political science. The culture of the interns I met in ED, being of those three main groups, was close to entirely homogenous. It reminded me of the popular quote from Neil deGrasse Tyson about our government in which he asks, "Where's the rest of life?" Once officially accepted into ED, I learned – through interactions with more interns who also did not fit with the cookie cutter majors – a classic lesson turned in to a realization. Having a boss that wanted you there got you there, end of story. It was a humbling and fulfilling moment to know that I really was being fought for to work in ED, both from APS and within the department.

When I did finally meet Camsie, I find it humorous how serious I was in our conversation – which mainly consisted of me furiously scribbling everything that she said and needed me to complete. The projects on the list for someone who had just showed up to their first day were slightly daunting. But the endgame to me was of the greatest importance, to finally establish a connection between ED and the science communities by laying the groundwork for a new APS/AIP/AAAS fellow. As it turns out, the American Association for the Advancement of Science had been trying to place fellows and change science education policy directly in ED for years. From great determination in the APS and through a chance conversation the physics societies were moved into an incredibly rare and exciting position.

I spent the majority of my fellowship researching STEM education in every wavelength of its spectrum. The projects I worked the most on were STEM talking points; covering women, minorities, and jobs. Coming from outside of the political realm, most of what I knew about talking points were that pundits and people alike complained about them. Now I was expected to write them and I was perplexed about what it took to make a good talking point. I met with an AAPT fellow working in AIP at the time and she gave me the basics: have a factoid and use an emotional example to help connect the audience with said factoid. Initially, the idea of linking an emotion with a fact instead of just presenting the fact seemed counter to my image of how science should be represented, but I followed the lesson to the best of my ability. The next day I sent Camsie what I had written, and nail biting ensued. In an email later she effectively suggested that I stick with the facts; with a deep breath and smiling at my computer, I was more than happy to oblige.

Not all talking points were written easily. I remember an embarrassing time when a weak point of mine – not having a very fast typing rate – unveiled itself. Early in my fellowship, Camsie was going to be leading a meeting covering the latest edition of the CoSTEM 5-year plan. Essentially, it was a 143 page framework which the administration hoped the Reorganization would follow. Her meeting was going to start in a few hours, and she wanted talking points on the report. The excitement and fear rushing through my head did little to help me as it felt I was pouncing on every key for every talking point. It was a vicious cycle indeed, as I tried to write as many bulleted facts from the report as possible and send them to Camsie, only to receive the paper highlight with my silly mistakes marked and returned. Looking back now, I didn't realize that what she wanted was closer to a summary and not just a list of bulleted facts. In the end she did receive the talking points in the form she wanted – about 30 seconds before the meeting began; however, she did communicate a slight disappointment in the pace. Ashamed, I used that to remind myself not to be so unprepared.

While that was among my lower points, my highest was at a Women in Science caucus meeting I attended. The department was going to have a table, but in order to attract more people we felt we should have some kind of game to reel people in. It was the kind of moment I was meant for, since I had been a science demonstrator for the three previous years. My solution came from an activity I learned while helping the Society of Physics

Students at a museum a few years prior. The activity was to have people wear diffraction glasses and look at the spectra for red, green, blue, and white LED lights. I – being the physicist that I am – had also brought my trusty green laser which would finally get used. Following a quick conversation with the SPS National, we quickly received a small duffle bag full of SPS-marked diffraction glasses with multiple colors of LED lights. The caucus went great, with our table really just competing against the NASA table. And it has had a lasting impression; I would suggest you take a look at the banner photo on Camsie's Twitter page. Whatever glasses we didn't give out at the caucus went to me, where I then proceeded to strategically hand them to every intern, boss, and interested stranger I could find. The best one so far is the photo I have of me and Secretary of Education Arne Duncan sporting them.

The experience I had was amazing and I am very proud to know that the groundwork I laid has paid off and we currently have an APS fellow operating within the Department of Education. I wish them the very best as they try to improve our American science education on the policy level. Some may feel that it's good to have people who know law and politics be in the thick of it; however, I counter that in our little constitutional republic we need to make sure not only that our representation is adequate, but also that our involvement is beyond adequate. My hope is that these continuing APS fellowships and internships in ED will foster a better dialogue directly leading into better policies that affect science education. At the same time, I must urge you to be active in promoting your students and colleagues in advocating for STEM education and other science initiatives. The implications for failing to act are too great to not be vocal. If you wish to contact me, I have Facebook, email (dsj13c@my.fsu.edu), or Twitter (@WeirdScientist). Make great entropy.

Dayton Syme is currently a PhD student in physical chemistry at Florida State University. He earned his BS in physics at Idaho State University in 2013, then spent the summer of 2013 serving as the APS/AIP Fellow (partially funded by FEd) at the Department of Education. He has been a member of the APS, the AAPT, the Kappa Sigma Fraternity Alumni, and the Society of Physics Students. His research is currently on modeling enzymatic activity for a multi-substrate system and physical structures of organic chemical gardens.

Physics Teacher Education Coalition

Section on Teacher Preparation

Teacher Preparation Section

John Stewart , University of Arkansas

This edition of the Teacher Preparation Section features a description of an exciting new resource to bring research vetted pedagogical methods into the physics classroom. Rachel Scherr and Renee Michelle Goertzen will describe the Periscope Project. This project can be used to instruct faculty, pre-service, and in-service teachers in physics education research developed instructional methods and important issues in the teaching of physics. It features classroom video of real implementations of enhanced teaching methods along with transcripts and discussions of the methods.

Laurie McNeil of the University of Carolina – Chapel Hill will discuss the challenges of sustaining a teacher preparation program at a major research university. UNC was one of the primary funded PhysTEC sites and Laurie offers valuable insight into the need to work with the upper administration and the challenges of maintaining class offerings for often small cohorts of physics teachers.

With the next issue, the Teacher Preparation Section will be edited by Alma Robinson of Virginia Tech. It has been a great honor to bring eight years of articles about the challenges and rewards of physics teacher preparation to the readers of this newsletter.

Periscope: Looking into learning in best-practices university physics classrooms

Rachel E. Scherr (Seattle Pacific University) and Renee Michelle Goertzen (American Physical Society)

Physics faculty who are concerned with physics teacher education often put their efforts toward educating pre-service physics teachers, who are most directly accessible to physicists. A variety of effective approaches to pre-service teacher education have been developed, tested, and replicated, including learning assistant (LA) programs, science methods courses specific to physics teachers, and pedagogy courses that engage undergraduates with themes of teaching and learning. In any of these contexts, pre-service teachers can benefit from structured opportunities to reflect on high-quality teaching and learning practices, learn about key pedagogical concepts in physics education, and observe effective implementation of a variety of research-based and research-validated instructional materials.

Periscope, a new resource under development, provides pre-service physics teachers (as well as physics graduate teaching assistants, undergraduate learning assistants, and faculty) with the opportunity to "look into learning" in best-practices university physics classrooms. *Periscope* is organized into short lessons that highlight significant topics in the teaching and learning of physics, such as formative assessment or cooperative learning. Topics are introduced through captioned video episodes of introductory physics students in the classroom, chosen to prompt collaborative discussion. For example, in one video episode, frustrated tutorial students ask an LA to tell them the right answer, and the LA responds with more questions. Line-numbered transcripts and excerpts of the activity help participants engage with the specifics of the interactions, such as: Which student asked for the answer, and why? What was the tone of the LA's response? Subsequent discussion questions also prompt participants who view the episode to reflect on their pedagogical beliefs and on their own practice: What might the LA in the episode have been trying to accomplish? What are the potential benefits and risks of her approach? What effect did the LA's response have on the students? What else might an LA in that situation have done? Suggestions for further reading connect lessons to scholarship and research in physics education.

Through *Periscope*, LAs and pre-service teachers observe, discuss, and reflect on teaching situations similar to the ones they themselves face, developing their pedagogical content knowledge and supporting their identity as teaching professionals. Video episodes from exemplary sites showcase a variety of research-tested instructional formats such as *Modeling Instruction* and *Tutorials* in Introductory Physics. Since the classrooms featured in the video episodes are university physics classrooms, *Periscope* materials are especially appropriate for undergraduate learning assistants and other university instructors, but they may also serve pre-service teachers and other populations.

The advantages of video-supported pre-service teacher education are substantial. Video supports educators in entering vividly into a real event in teaching and learning, stimulating insight into what happened and why. *Periscope* video episodes provide diverse, intimate examples of what teaching really looks like, including peer discussions without an instructor present. Watching with others reveals both unique and universal interpretations of the *same* events, rarely possible with in-person classroom observation. Watching repeatedly supports testing intuitions against evidence. Discussions of the event with other educators bring out the principles and values that inform instructor and student behavior. Finally, video offers a rare opportunity to stop the classroom action, share observations, and build a repertoire of responses, thus building skills for real-time formative assessment.

For example, in one *Periscope* video episode, four students ("Arlo," "Bella," "Claire," and "Dawn") in a University of Maryland tutorial session are collaborating to draw the velocity versus time graph for a cart that rolls freely first up, then down a ramp. The correct graph would be a straight diagonal line; theirs is curved steeply at each end and flat as it crosses the horizontal axis. During their collaboration, a graduate teaching assistant ("Luke") comes by to check on them.

1. Arlo: All right, let's start thinking about the acceleration at the moment the car reaches its peak.
2. Claire: The acceleration starts out fast, like high…
3. Dawn: It's gonna be going from positive to negative, they're gonna reach
4. Arlo: So it's zero, it's (with Claire:) zero at the peak. Yeah.
5. Claire: That we know.
6. Bella: Right, because the slope was the.
7. [To Luke, who just arrived] Bella: Yeah we figured it out.
8. Arlo: We fixed it.
9. Bella: You tried to fool us.
10. Luke: What does it look like? Hm. [Examines Arlo's sketch.]
11. Arlo: Cause it's going the opposite direction, so thus it would have a negative velocity.
12. Luke: I see.
13. Arlo: We're guessing.
14. Luke: Do you guys agree that it's curved like that?
15. Bella: Hhh
16. Arlo: Ummm
17. Bella: We did.
18. Dawn: We used to agree with that.
19. Luke: I'll let you guys discuss. That's uh, an interesting question to consider.
20. Bella: Torture. This is torture.
21. Arlo: I know.
22. Dawn: Where's that other guy?

Video adds information that is difficult to convey in a transcript, including the hesitation with which Luke backs away from the table during line 19, and Bella's exasperated tone as she drops her head into her hands at line 20.

Each *Periscope* lesson includes a one-page handout; the front page has a photo of the student group in the video episode, site acknowledgment, the physics task the students in the video are working on, and discussion questions that target that week's topic, and the back page has line-numbered transcript and suggestions for further reading. For the episode above, discussion questions support pre-service teachers in making evidence-based interpretations of the events in the video and connecting those interpretations to key issues in teaching and learning, particularly (in this case) formative assessment:

1. *The students' graph has both correct and incorrect features. What features of the graph are correct?*
2. *For the specific features of the students' graph that are incorrect, in what way do they make sense? What reasonable ideas might be supporting their incorrect answer?*
3. *Judging by the end of the episode, this interaction was not a pleasant one for the students. It seems that they place some responsibility for this unpleasantness on Luke (since they want to talk to someone else). What did Luke do that might have contributed to unpleasantness?*
4. *It is worth considering the possibility that this interaction is not pleasant for Luke, either. Did the students do anything that might have made Luke uncomfortable?*
5. *The first step in formative assessment is to find out where your students are coming from. Is Luke effective at this? Does he get a good picture of their ideas? If so, how does he do so? If not, what might he do next to learn more?*

Periscope materials are designed to be used in courses, seminars, or workshops in which discussions are facilitated by physics faculty, education faculty, a Teacher in Residence, or any other leader with expertise in physics education. An article about Periscope in the forthcoming book *Effective Practices for Pre-service Teacher Education: Recruitment, Retention, and Preparation* offers extensive suggestions for facilitating such discussions as well as more information about the materials.

Periscope lessons provide a forum for instructors at all levels to talk substantively about teaching, providing a means for shaping educators' values. They promote individual and group reflection on teaching and learning practices, support engagement with key pedagogical concepts, and provide a glimpse of interactive teaching and learning in action at a variety of institutions.

Pilot materials produced with support from the Physics Teacher Education Coalition are available free to educators at http://www.phystec.org/lavideo. *Periscope* itself will be released in Summer 2014 (still free to educators), featuring more topics in teaching and learning, classroom video from a wider variety of institutions, and an updated interface.

Rachel E. Scherr received her doctorate at the University of Washington and is a Senior Research Scientist at Seattle Pacific University. She is a consultant with the American Physical Society on physics teacher preparation.

Renee Michelle Goertzen received her doctorate at the University of Maryland and is the Education Programs Manager at the American Physical Society, where she works on projects to increase the quality and diversity of physics education. Her research has focused on the professional development of physics instructors.

Sustaining a Physics Teacher Preparation Program: Challenges and strategies

Laurie E. McNeil, Department of Physics & Astronomy, University of North Carolina at Chapel Hill

Members of the APS Forum on Education are well aware of the need for more well-qualified high school physics teachers, and in the Summer 2008 Forum Newsletter I wrote about establishing a teacher preparation program at my institution to help meet this need. Six years later I can now reflect on what we have learned about the challenges of sustaining such a program, and strategies for meeting those challenges.

First, some inconvenient truths. In order to become a well-qualified physics teacher, a student should major, or at least minor, in physics or physics education (that's not all it takes, of course). Currently only about 35% of new physics teachers in the US were physics majors in college.[1] But as the physics community is all too aware, physics majors constitute a very small fraction of all college graduates: in 2010 only 0.3% of bachelor's degrees awarded in the US were in physics.[2] While the fraction varies by institution (MIT has more), the number of physics students a teacher preparation program can recruit will always be small. Further, at a major research university like my institution, few students in any field matriculate with the intention of becoming high school teachers. In North Carolina, young people who want to become teachers are likely to be drawn to one of the schools in the University of North Carolina (UNC) system that has a strong tradition of teacher preparation. According to the North Carolina Department of Public Instruction, of the teachers (all levels and subjects) produced by the 16 universities in the UNC system, almost 40% graduated from either Appalachian State University or East Carolina University, both of which are former teacher's colleges. Less than 10% came from the two research-intensive institutions in the system, the University of North Carolina at Chapel Hill (UNC-CH) and North Carolina State University. While we try to persuade our physics majors to consider becoming teachers, we know that most of them have their eyes on graduate school. This is typical–among institutions that have physics teacher preparation programs the most common number of graduates per year is zero, and the vast majority graduate fewer than two physics teachers per year.[3]

A second inconvenient truth well known to academics is that universities have suffered major budget cuts in recent years, and public institutions have seen significant declines in state support that have not been fully offset by tuition increases. At UNC-CH we saw an 18% cut in our state appropriation in FY2012, on top of a cumulative 29% cut over 2008-11.[4] When budgets are tight, "low-performing" programs are likely targets for cuts. However, the cost of teacher preparation does not scale with the number of graduates—the cost of teaching a physics pedagogy course is about the same regardless of the number of students enrolled in it. The small number of teachers produced and the stresses on institutional budgets combine to create a significant challenge to the continued existence of physics teacher preparation programs.

A good strategy to sustain a small program is to seek allies, and one obvious place to find them is in the other science departments. While physics teachers are in much shorter supply than are teachers in other science fields, secondary schools also experience some shortages when they seek to hire well-qualified teachers in mathematics and chemistry[5] (subjects that physics teachers often also teach). To a somewhat lesser degree, this is true for biology and earth science as well. (A teacher who really wants to feel the love should move to Hawaii, which has a considerable shortage of teachers in all science fields.) Biology and chemistry departments typically produce far more graduates than do physics departments: at UNC-CH the fields of physics, chemistry, mathematics, biology and geology together produced 13% of the bachelor's degree recipients in 2008-10, but 65% of those were in biology and 21% were in chemistry (and only 3% in physics).[6] Further, biology and chemistry departments often have a large population of "post pre-meds" who have modified their initial plans to attend medical school (perhaps as a result of an organic chemistry class) but who nevertheless would like to do good in the world. Becoming a high school science teacher is one way to accomplish that. Creating a joint program to prepare teachers in multiple fields, especially those that produce a lot of graduates, can prevent the program from being labeled "low performing" and becoming a target for budget cuts. With the exception of the pedagogical content knowledge specific to each discipline, the necessary components of a teacher preparation program (typically provided in courses taught by the School of Education) are the same for all the sciences and can easily be shared. All those biology students can help justify the continued offering of the courses on child and adolescent development, families and schools, and the like that the future physics teachers also need.

On the other hand, a physics teacher preparation program that wishes to produce well-qualified graduates needs a physics pedagogy course that embodies the findings of the research literature on the teaching and learning of physics. While combining pre-service teachers from multiple science disciplines into a generic "science pedagogy" course would obviate the need to offer multiple discipline-specific courses that may have very small enrollments, it would not provide the students with the best preparation for teaching their specific subjects. This creates the problem that with only a small number of students preparing to be physics teachers in any given year, enrollment in the physics pedagogy course may be too small to justify offering it (or it may need to be taught as an "overload," thereby burdening the instructor). One way to deal with this problem is to embed the pedagogy course into the physics major curriculum as an elective. A strong argument can be made to students (and faculty) that learning to teach physics deepens one's knowledge of the subject and is excellent preparation for a future career in higher education as well as in high school teaching. Further, since accrediting bodies typically require that the pedagogy course include fieldwork in a local high school, the course may also be able to satisfy a general education requirement for "experiential education," if the institution's curriculum has one. Satisfying more than one requirement with a single course is a very attractive proposition for most students, and this may help to fill the class.

The instructor for the physics pedagogy course needs to have deep knowledge of the physics education research (PER) literature and, crucially, how it can best be applied in the context of a high school classroom. If a university physics department does not have a PER group (or even if it does), it may lack a faculty member with that kind of specialized knowledge and need to hire an instructor for this purpose. However, teaching a single course does not constitute a full set of duties, even when recruiting and advising pre-service teachers is included. In order for the program to be sustainable it is necessary to find additional reasons to employ such a specialist. Fortunately, the value that experts of this kind bring to an institution makes the justification simple to construct. Obviously, a physics education specialist can be extremely useful to a physics department that wishes to join the national movement toward improving college science pedagogy and incorporating research-validated active-engagement techniques into science classes, especially at the introductory level. At UNC-CH over the last decade we have transformed our calculus-based introductory sequence from a traditional lecture mode to a more hands-on hybrid lecture/studio mode, and we are about to do the same in our algebra-based introductory sequence. This transformation, involving multiple course sections and faculty members as well as hundreds of students, would have been far more difficult (perhaps impossible) without the help of the physics education specialist we hired initially to support our teacher preparation program. The funding we have received from NSF for these two course transformation projects has also been very valuable, of course, but having someone at the center of it all who has the necessary expertise in PER (as I do not) and who is not also running a research laboratory and fulfilling the myriad other responsibilities of a tenured professor (and, for five years, a department chair) has made the entire enterprise feasible. As part of the transformation, our specialist also completely revamped the training program for our graduate teaching assistants (TAs), turning it from a one-week "boot camp" mostly focused on how to make the instructional lab experiments work and how to grade a lab report (and get the grades in on time, a less-successful part of the training) into a full-semester, for-credit TA seminar incorporating PER findings and focused on creating self-reflective teachers who understand how students learn physics. The specialist's efforts have therefore broadly influenced the teaching in our department and have helped us to advance the way in which we fulfill our educational mission. These improvements have brought our department considerable recognition from the administration at UNC-CH as well as nationally. In part because of the changes our specialist helped make, UNC-CH was chosen to participate in the Undergraduate STEM Education Initiative of the Association of American Universities (AAU),[7] and the Physics & Astronomy Department is regarded as a leader in educational reform on our campus.[8] All of this would have been more difficult to achieve if we had not started a teacher preparation program and hired a physics education specialist to support it.

This leads to another important strategy for sustaining a teacher preparation program. Producing well-qualified science teachers who can help prepare the next generation for the challenges of the 21st century has proven to be something that campus administrators are eager to talk about with external constituencies. This is especially true at public institutions, which continually need to justify the expenditure of tax dollars. Research-intensive universities, whose mission statements typically say more about "serv[ing] as a center for research, scholarship and creativity" and "an unwavering commitment to excellence"[9] than about providing services to the general public, are especially in need of concrete benefits of their work to point to in order to maintain political good will. It is therefore wise for the leaders of a teacher preparation program to keep their upper-level administrators fully apprised of the successes of the program and the service it provides to the public at large. Given the transience of university leaders, this is a never-ending task. Since 2007 when we began the physics teacher preparation program at UNC-CH as a joint effort of the College of Arts & Sciences and the School of Education, we have had three Chancellors, three Provosts, two Deans of Education, two Deans of Arts & Sciences, and three Senior Associate Deans for Natural Sciences. That's twelve administrators we have needed to educate on the benefits of our program (one Dean became Provost and only had to be reminded). However, all of them have been supportive and have been very happy to have good news to share with trustees, legislators, donors, alumni, parents, and other groups of stakeholders. This in turn disposes them to continue to sustain our program, establishing a feedback circuit that is beneficial for everyone.

Because of the small number of future physics teachers it will attract and the realities of university budgets, sustaining a physics teacher preparation program is not an easy matter on most campuses. However, by enlisting allies among other science departments, embedding the physics pedagogy course in the physics major curriculum, using the expertise of specialists hired for the program to improve the department's own pedagogy, and keeping administrators supplied with information they can use to garner external support for the institution, it is possible for even a small program to continue in good health. Given the great need for more well-qualified high school physics teachers to teach physics to the next generation (and, not incidentally, the next crop of college students), establishing and maintaining a teacher preparation program is a worthwhile thing for a physics department to do.

Laurie McNeil is the Bernard Gray Distinguished Professor at the University of North Carolina at Chapel Hill and has been a member of its Department of Physics and Astronomy since 1984. She was instrumental in establishing the UNC-BEST (UNC Baccalaureate Education in Science and Teaching) program, which graduated its first physics teachers in 2009.

Endnotes

1. Casey Langer Tesfaye and Susan White, *High School Physics Teacher Preparation* (American Institute of Physics, 2012). Available at: http://www.aip.org/statistics/trends/reports/hsteachprep.pdf

2. National Center for Science & Engineering Statistics, NSF

3. David E. Meltzer, Monica Plisch and Stamatis Vokos, eds, *Transforming the Preparation of Physics Teachers: A Call to Action. A Report by the Task Force on Teacher Education in Physics* (American Physical Society 2012). Available at http://www.phystec.org/webdocs/2013TTEP.pdf

4. Office of the Provost, UNC-CH

5. *Educator Supply and Demand in the United States* (American Society for Employment in Education, 2010)

6. Office of the Registrar, UNC-CH

7. http://www.aau.edu/policy/article.aspx?id=12588

8. See http://college.unc.edu/2014/02/26/largelecture/ for an example of this recognition.

9. Mission statement of UNC-CH, see http://unc.edu/about/mission/

Browsing the Journals

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

- Poiseuille's law says the flow rate through a pipe is inversely proportional to the length of the pipe. In the January 2014 issue of the *American Journal of Physics* (http://scitation.aip.org/content/aapt/journal/ajp), Michael Nauenberg explains why the flow rate nevertheless does not diverge if the outlet pipe connected to a hole in the side of a liquid tank is made vanishingly short. The February issue presents a surprising demonstration by the Naval Postgraduate School in which a styrofoam pendulum bob is *attracted* to a loudspeaker emitting high-amplitude low-frequency sound, rather than being *jetted* away from it as in the famous Maxell cassette tape ad (online at http://www.youtube.com/watch?v=XiJzLfxWooo). In the April issue, there are articles on page 280 making interferometric measurements of the collision of a steel ball with a rod on a rolling cart, on page 301 extending the Clausius-Clapeyron equation from first to second derivatives, and on page 306 discussing the advantages of plotting pressure-volume heat engine cycles on a log-log scale.

- There is always so much good stuff in *The Physics Teacher* (http://scitation.aip.org/content/aapt/journal/tpt) that it is hard to choose, but here is just one selection from each of the past five issues. Page 58 of the January 2014 issue demonstrates by breaking a light bulb and cutting off the filament that the glass of the base can be made electrically conducting by heating it with a blowtorch. Page 122 of the February issue challenges readers to construct a stable spinning top from a single paperclip. Page 142 of the March issue experimentally demonstrates the surprising fact that the turning of a paddle wheel in a cathode ray tube no more demonstrates electron momentum than does the turning of a radiometer demonstrate photon momentum. (In both cases, the momentum transfer is drowned out by heating of the residual gas in the tubes.) On page 241 of the April issue, two Portugese educators ask why it requires more work to run on an inclined than a horizontal treadmill? (The answer is simpler in a reference frame attached to the moving belt.) Finally, on page 286 of the May issue, two educators from an institution that I took a college physics course while in high school (Mount Royal University, although in my day it was Mount Royal College) point out that the traditional explanation is wrong for why Kelvin's estimate of Earth's age was so far off. (Accounting for radioactive minerals would only increase his estimate by about 10% which is still way too low.)

- The May 2014 issue of *Physics Education*, accessible at http://iopscience.iop.org/journals, considers the emf generated when a cylindrical bar magnet is dropped vertically through a flat coil on page 319. If the bar magnet is short, it can be modeled as a circular loop, whereas if it is long, it can be modeled as a solenoid, in principle permitting one to estimate the magnetic dipole moment by fitting to experimental data.

- There are several notable articles on thermodynamics in the March 2014 issue of the *Journal of Chemical Education* at http://pubs.acs.org/toc/jceda8/91/3, including a vacancy model for the entropy change of a thermal reservoir on page 380, and a discussion of whether one should use the system pressure or the surroundings pressure in calculating expansion work during an irreversible gas expansion on page 402.

Web Watch

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

- NSF has a collection of physics discoveries that began with their support at http://www.nsf.gov/discoveries/index.jsp?prio_area=11.
- The website of the Field Museum of science in Chicago is at http://www.fieldmuseum.org/explore/. Also visit the website of the Museum of Science & Industry in the same city at http://www.msichicago.org/education/.
- AT&T has put many of their tech archives online at http://techchannel.att.com/showpage.cfm?ATT-Archives.
- Vega Science Trust has many videos on their website at http://vega.org.uk/, notably including four of Richard Feynman. Another set of science videos is Inside Science TV at http://www.insidescience.org/television supported by AIP.
- Jeffrey Schnick has a two-semester calculus-based physics textbook with supporting materials freely available at http://www.anselm.edu/internet/physics/cbphysics/.
- An interesting hypothesis connecting the second law of thermodynamics to the evolution of life is proposed at http://www.simonsfoundation.org/quanta/20140122-a-new-physics-theory-of-life/. Perhaps not surprisingly, the reader comments at its end are about four times longer than the main article itself.
- Going back to even more foundational issues than the origin of life, read Alan Guth's remarks about the Big Bang at http://www.bostonglobe.com/magazine/2014/05/02/alan-guth-what-made-big-bang-bang/RmI4s9yCI56jKF6ddMiF4L/story.html.
- MIT's Media Lab has a webpage devoted to its Fluid Interfaces Group at http://fluid.media.mit.edu/.
- A thoughtful discussion with videos of the demonstration of a long chain of beads leaping fountain-style out of a jar onto the floor is at http://www.nature.com/news/physicists-explain-gravity-defying-chain-trick-1.14523.
- Science in School is a European science education web journal at http://www.scienceinschool.org/.
- Optical circulators are like one-way traffic circles used to measure backscattering from fiber lasers. An acoustic analog has now been constructed, as described at http://physicsworld.com/cws/article/news/2014/jan/31/sound-follows-one-direction.
- Scientific American has a fascinating video explaining the classic puzzle: If you pull straight back on the lower pedal of your bicycle, will the bike move forward or backward? Without spoiling too much, I will simply say that both answers are experimentally achievable! Go watch it at http://www.scientificamerican.com/article/mathematical-impressions-the-bicycle-pulling-puzzle/.
- Okay, it's not physics, but a cool site where you can listen to various animal sounds recorded at various places around the globe is at http://www.naturesoundmap.com/listing-type/video/.
- A new class of efficient solar cells based on perovskite materials have also been found to make good lasers, as described at http://www.cam.ac.uk/research/news/revolutionary-solar-cells-double-as-lasers.
- Finally, a finance company has put up a nice buoyancy puzzle at http://wealthmanagement.com/question/puzzler-odd-balance, apparently as a possible brainteaser job interview question.

Executive Committee of the FEd

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