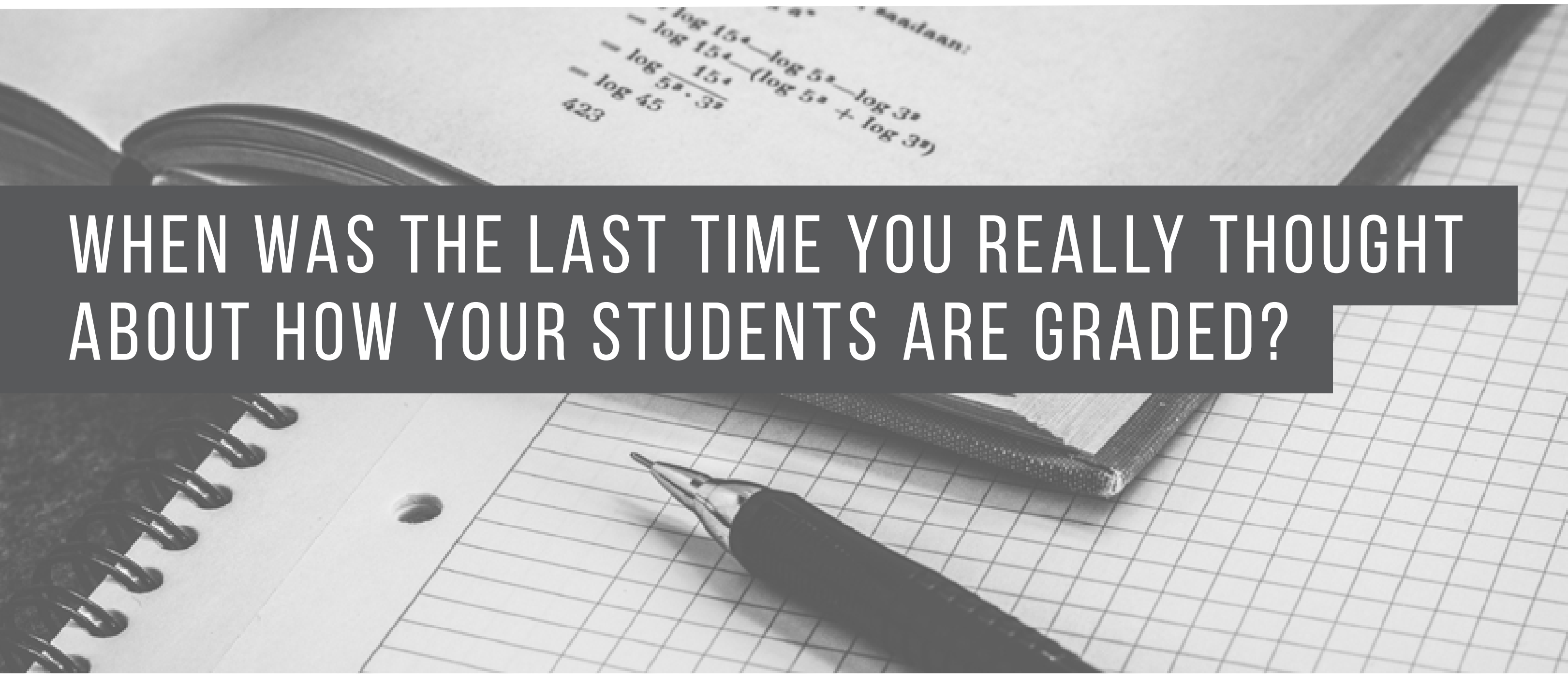
2019
Summer Meeting

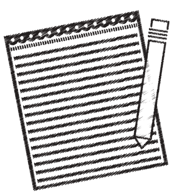
EXPERT ta

LUNCH & LEARN

CASCADE E (LEVEL 3)
11:30 AM - 12:30 PM
MONDAY, 7/22/19

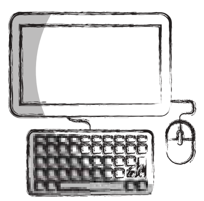


WHEN WAS THE LAST TIME YOU REALLY THOUGHT ABOUT HOW YOUR STUDENTS ARE GRADED?



1980-something

INSTRUCTORS ONCE GRADED FOR PROCESS AND PROVIDED HAND-WRITTEN FEEDBACK.



1999

EARLY ONLINE GRADING IS CONVENIENT, BUT LACKS PROBLEM-SOLVING FUNCTION.

2019

AUTOMATICALLY GRADED FBD DRAWINGS & SYMBOLIC EXPRESSIONS, PLUS STUDENT-PROVIDED FEEDBACK.

REINFORCING THE PROBLEM-SOLVING PROCESS

PHYSICS VIDEO SERIES FOR THE FLIPPED CLASSROOM

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BOOTH 100

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Provo, UT
July 20–24, 2019

Utah Valley Convention Center and Provo Marriott Hotel and Conference Center

AAPT American Association of Physics Teachers

American Association of Physics Teachers
One Physics Ellipse
College Park, MD 20740
301-209-3311
www.aapt.org

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Contact:

Meeting Registration Desk: 301-209-3340

Special Thanks

AAPT wishes to thank the following persons for their dedication and selfless contributions to the Summer Meeting:

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Facebook/Twitter at Meeting

We will be posting updates to Facebook and Twitter prior to and during the meeting to keep you in the know! Participate in the conversation on Twitter by following us at **twitter.com/AAPTHQ** or search the hashtag **#aaptsm19**. We will also be posting any changes to the schedule, cancellations, and other announcements during the meeting via both Twitter and Facebook. Visit our Pinterest page for suggestions of places to go and things to do in the Utah Vallery area. We look forward to connecting with you!

Facebook: facebook.com/AAPTHQ
Twitter: twitter.com/AAPTHQ
Pinterest: pinterest.com/AAPTHQ

Committee Meetings

All interested attendees are invited and encouraged to attend the Committee meetings with asterisks (*).

Saturday, July 20

Finance Committee	6–7 p.m.	MH - Aspen
Nominating Committee	6–7:30 p.m.	CC - Cascade A
Governance Structure	7–8 p.m.	MH - Aspen

Sunday, July 21

Publications Committee	8–10 a.m.	MH - Aspen
Meetings Committee	9–10:30 a.m.	MH - Cascade A
Board of Directors II	10:30 a.m.–4 p.m.	MH - Aspen
Section Officers and Representatives	5–6 p.m.	CC - Cascade C
Executive Programs Committee	5–6 p.m.	CC - Cascade A
Programs and Planning I	6–7 p.m.	CC - Cascade D

Monday, July 22

Graduate Education in Physics *	7–8:30 a.m.	MH - Maple
Educational Technologies Committee *	7–8:30 a.m.	MH - Sycamore
Contemporary Physics Committee	7–8:30 a.m.	MH - Olympus
Teacher Preparation Committee *	7–8:30 a.m.	MH - Willow
Diversity in Physics Committee *	7–8:30 a.m.	CC - Soldier Creek
Science Education for the Public *	7–8:30 a.m.	CC - Battle Creek
PTRA Oversight Committee	7–8:30 a.m.	CC - Silver Creek
Research in Physics Education *	11:30 a.m.–1 p.m.	CC - Ballroom A
Apparatus Committee *	11:30 a.m.–1 p.m.	MH - Arches
History and Philosophy of Physics *	11:30 a.m.–1 p.m.	CC - Cascade C
Physics in High Schools *	11:30 a.m.–1 p.m.	MH - Canyon
ALPhA Committee *	11:30 a.m.–1 p.m.	MH - Zion
Professional Concerns Committee *	11:30 a.m.–1 p.m.	MH - Sycamore
Physics in Two-Year Colleges Committee *	11:30 a.m.–1 p.m.	MH - Aspen

Tuesday, July 23

Physics Bowl Advisory Committee	7–8:30 a.m.	MH - Maple
Awards Committee (closed)	7–8:30 a.m.	MH - Willow
International Physics Education *	12–1:30 p.m.	MH - Oak
Laboratories Committee *	12–1:30 p.m.	CC - Ballroom A
Space Science and Astronomy *	12–1:30 p.m.	MH - Sycamore
Physics in Undergraduate Education *	12–1:30 p.m.	MH - Elm
Interests of Senior Physicists Committee *	12–1:30 p.m.	MH - Willow
Women in Physics Committee *	12–1:30 p.m.	CC - Soldier Creek
Physics in Pre-High School Education *	12–1:30 p.m.	MH - Maple
PIRA Committee *	12–1:30 p.m.	CC - Cascade C
PERTG Town Hall *	12–1:30 p.m.	CC - Ballroom C

Wednesday, July 24

Programs and Planning II	7–8:30 a.m.	CC - Cascade A/B
PERLOC (closed)	7–8:30 a.m.	MH - Aspen
Venture/Bauder Fund Committee	7–8 a.m.	MH - Maple
Membership and Benefits Committee	9:30–10:30 a.m.	MH - Maple
Town Hall with AAPT President *	11–11:45 a.m.	CC - Ballroom C
Papersort Orientation	1–1:30 p.m.	CC - Battle Creek
Nominating Committee II	3–4:30 p.m.	MH - Maple
Board of Directors III	3–5:30 p.m.	MH - Aspen

David P. Jackson
Dickinson College
Carlisle, PA

Helping Students Have Meaningful Learning Experiences in Physics

Monday, July 22
11:00–11:30 a.m.
CC - Ballroom C

David Halliday and Robert Resnick Award for Excellence in Undergraduate Physics Teaching

The 2019 David Halliday and Robert Resnick Award for Excellence in Undergraduate Physics Teaching winner is David Jackson**.** John Wiley & Sons is the principal source of funding for this award, through its donation to the AAPT. Jackson is Associate Professor of Physics, Dickinson College in Carlisle, PA. A member of AAPT since 1994, he served as Editor of the *American Journal of Physics* (*AJP*) from September 2011 through August 2017, and currently serves as Video Abstracts Editor for the journal. His role as editor included service on the AAPT Board of Directors and the Publications Committee. From 2001 through 2004 he was a member of the AAPT Committee on Science Education for the Public.

Jackson's undergraduate work in Physics at the University of Washington was recognized as Magna Cum Laude with distinction in Physics. After receiving his PhD in physics from Princeton University in 1994, he has held faculty positions at Santa Clara University and Dickinson College, including a term as Chair of the Dickinson Department of Physics and Astronomy from 2006-2009.

Jackson played a pivotal role, together with Priscilla Laws and Scott Franklin, in developing the Explorations in Physics course materials at Dickinson. His leadership and pedagogical insight combined in this endeavor to produce a vibrant course for non-majors that emphasizes exploration, inquiry, and the process of doing science while conveying to students that physics is fun. His efforts also resulted in a book published by Wiley and, most recently, in an article that appeared in Science.

In nominating him for this award his colleagues said, "Dr. Jackson has made notable contributions to undergraduate physics education as a teacher of a full range of undergraduate courses at Dickinson College, a developer of award winning curricular materials funded by highly competitive granting agencies, a speaker at many conferences, co-organizer of Gordon conferences undergraduate teaching, the Editor of *AJP* for over three years, and an author of over 40 outstanding journal publications on teaching and research. As a result of these efforts to improve teaching and learning for undergraduates in physics Jackson's influence has been exemplary and has had broad influence in our discipline."

Established as the Excellence in Undergraduate Teaching Award in 1993; it was renamed and substantially endowed in 2010 by John Wiley & Sons. Named for David Halliday and Robert Resnick, authors of a very successful college-level textbook in introductory physics, the award recognizes outstanding achievement in teaching undergraduate physics.

Natalie Ferris

Sunday, July 21
7–7:30 p.m.
CC - Ballroom C

The 2019 Fellows are:

David M. Cook, Lawrence University, Appleton, WI

Deborah Dawn Mason-McCaffrey, Salem State College, Reading, MA

2018 AAPT/ALPhA Awardee

Natalie Ferris, Dickinson College

Franci Taylor

Sunday, July 21
7:30–9:30 p.m.
CC - Exhibit Hall A

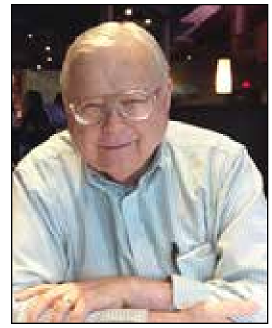
Land Acknowledgment at Welcome Reception

Franci Taylor is Executive Director of the American Indian Resource Center (AIRC) at University of Utah and a cross-cultural consultant for University Health Sciences. She will conduct a Land Acknowledgment at the beginning of the Welcome Reception on Sunday, July 21, 2019.

Land acknowledgment is a campaign to spread the practice of recognizing traditional Native lands at the opening of all public gatherings. Acknowledgment is a simple, powerful way of showing respect. We must work to correct the stories and practices that erase Indigenous people's history and culture. Join us in pledging to respectfully acknowledge ancestral lands by attending the land acknowledgment ceremony during the Opening Reception.

Ms. Taylor earned a BFA and a BS in Anthropology/Sociology at Montana State University. She earned her PhD in American Indian Studies through the Faculty of Archaeology program at the University of Leiden in the Netherlands. She has taught American Indian Studies and Culture for over 25 years locally, nationally, and internationally at all educational levels. She has worked on creating American Indian curriculum for public schools.

Robert A. Millikan Medal 2019



Thomas A. Greenslade Jr.
Kenyon College
Gambier, OH

Adventures with Oscillations and Waves

Tuesday, July 23
10:30–11:30 a.m.
CC - Ballroom C

Thomas A. Greenslade Jr. is the Robert A. Millikan Medal awardee for 2019. Greenslade is a Professor Emeritus of Physics at Kenyon College. In nominating him for this honor his colleagues noted that he has been making "Notable and intellectually creative contributions to the teaching of physics for more than 50 years. Many of these contributions have been in the form of articles published in *The Physics Teacher* (*TPT*). His total number of papers in *TPT* (the earliest in 1969, the most recent in 2019) far exceeds that for any other author. In addition, he has made many hundreds of oral presentations at physics meetings and in other professional settings on a wide variety of topics related to physics teaching. He is a widely recognized expert on the history of physics, especially early teaching apparatus, and shares his vast knowledge and expertise with the broader physics education community in numerous ways."

Regarding his receipt of the Millikan Medal, Greenslade said, "I am pleased to follow in the footsteps of my graduate school advisor Peter Lindenfeld (1989) and my long-time Kenyon College colleague Franklin Miller, Jr. (1970).

He received his AB in 1959 in physics from Amherst College and his doctorate in experimental low temperature physics from Rutgers University in 1965. From 1964 to 2005 he was a member of the Kenyon College physics faculty. When he retired, Kenyon awarded him a DSc. A member of the American Association of Physics Teachers since 1959, Greenslade was recognized with the association's Distinguished Service Citation and in 1987. He was listed as one of the 75 most influential physicists and physics teachers by the American Association of Physics Teachers. He won first prize in the Association's Apparatus Competition in 2007. In 2014 AAPT recognized his life-time of contributions by making him a Fellow of the American Association of Physics Teachers. He is also a fellow the American Physical Society.

Greenslade has been generous in sharing his vast knowledge and expertise with the broader physics community in a variety of other ways. He maintains a website, "Instruments for Natural Philosophy" that includes some 1850 pictures of early physics apparatus along with descriptions and references, and he answers many queries from historians and collectors. His collection of about 775 pieces of physics teaching apparatus from the 1850-1950 era is housed in a wing of his 1857 house in Gambier. Visitors range from children to professors of physics; make an appointment and visit. His large collection of old, primarily 19th century, textbooks and early equipment catalogs preserve original descriptions of historically important laboratory and demonstration apparatus.

The Robert A. Millikan Medal recognizes those who have made notable and intellectually creative contributions to the teaching of physics. The recipient delivers an address at an AAPT Summer Meeting and receives a monetary award, the Millikan Medal, an Award Certificate, and travel expenses to the meeting. The award was established by AAPT in 1962.

Klopsteg Memorial Lecture Award 2019

Jodi A. Cooley
Southern Methodist University (SMU), Dallas, TX

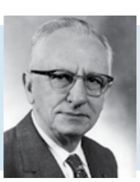
Fantastical Dark Matter and Where to Find It

Wednesday, July 24
8:30–9:30 a.m.
CC - Ballroom C

Jodi A. Cooley, Southern Methodist University (SMU), Dallas, TX, is the 2019 recipient of the Klopsteg Memorial Lecture Award. Cooley is an Associate Professor of experimental particle physics in the SMU Dedman College of Humanities and Sciences. She received a BS degree in Applied Mathematics and Physics from the University of Wisconsin in Milwaukee in 1997. She earned her Masters in 2000 and her PhD in 2003 at the University of Wisconsin - Madison for her research searching for neutrinos from diffuse astronomical sources with the AMANDA-II detector. Upon graduation she did postdoctoral studies at both MIT and Stanford University.

Her career includes many interviews, publications, conference presentations, and talks, including a 2018 Science Friday interview, Dark Matter Eludes Particle Physicists. Cooley is a principal investigator on the Super Cryogenic Dark Matter Search in the Soudan Underground Laboratory in Minnesota; the SNOLAB in Sudbury Canada; and the Assays and Acquisition of Radio-pure Materials Collaboration, whose aim was to develop integrative tools for underground science.

Cooley's love for teaching and her ability to inspire future physicists extends outside of the classroom, as she mentors a diverse range of postdoctorates, graduate students, and undergraduate students in the LUMINA lab. She continues asking questions, teaching even in the lab, stopping to explain advanced concepts to her younger students whenever their faces start looking confused. In that way, she lives up to the name of her LUMINA lab derived from the word lumen for "light" in Latin. Cooley spends her career illuminating dark matter and illuminating the minds of students. She encourages her more experienced students to work with an undergraduate in order to give them a chance to mentor as well. In that way, she helps build future generations of mentors like herself.



Named for Paul E. Klopsteg, a principal founder, a former AAPT President, and a long-time member of AAPT, the Klopsteg Memorial Lecture Award recognizes outstanding communication of the excitement of contemporary physics to the general public. The recipient delivers the Klopsteg Lecture at an AAPT Summer Meeting on a topic of current significance and at a level suitable for a non-specialist audience and receives a monetary award, an Award Certificate, and travel expenses to the meeting. The award was established in 1990.

Homer L. Dodge Citations for Distinguished Service to AAPT

Tuesday, July 23 • 10:30 a.m.–12 p.m. • CC - Ballroom C

Geraldine Cochrane

Geraldine Cochran

Geraldine Cochran, Assistant Professor of Professional Practice in the School of Arts and Sciences and the Department of Physics and Astronomy ata Rutgers University, Cochran is a physics education researcher. She earned her PhD in curriculum and instruction with a cognate in physics and her EdS in science education with a specialization in teacher preparation from Florida International University in Miami, FL and her M.A.T. with a specialization in secondary school physics, her BS in physics and her BS in mathematics from Chicago State University in Chicago, IL. She has been a member of AAPT since 2003 and has been attending meetings since she was an undergraduate. Geraldine's committee work with AAPT is extensive. She has served on the Committee on Diversity, the Committee on Women in Physics, and currently serves on the Committee on International Physics Education. She has served as Chair of the Committee on Diversity and the Committee on Women in Physics. She has also served on the Programs Committee and Nominating Committee and currently serves on the Bauder Fund Committee. She has organized sessions and workshops that have focused on diversity, equity, and inclusion and because of her expertise in this area the AAPT community looks to her as a leader. Cochran served as a guest editor of the 2017 special theme issue of *The Physics Teacher* on Race in Physics Teaching.

Larry Engelhardt

Larry Engelhardt

Larry Engelhardt, Professor of Physics, Francis Marion University, Florence, SC. His B.A. in Physics was earned at Gustavus Adolphus College, St. Peter, MN and his PhD in Condensed Matter Physics at Iowa State University, Ames, IA. He has served as President of his regional (SACS) section of the AAPT; and he has served on the AAPT Committee on Educational Technologies, as a member, Vice Chair, and Chair. While he was Chair, the Committee was recognized with the AAPT Committee of the Year Award. Engelhardt has been a leader for computational physics nationally and within AAPT. He is Co-PI for the Partnership for the Integration of Computation into Undergraduate Physics (PICUP) project and has organized numerous workshops and sessions at regional and national meetings. He is an organizer of the week-long PICUP summer faculty development workshops at River Falls, WI. He is an editor of the AAPT-ComPADRE PICUP site and he has contributed numerous items to that collection.

Laura E. McCullough

Laura E. McCullough

Laura E. McCullough, Professor, Chemistry & Physics Department, University of Wisconsin-Stout, earned her BA in Physics at Hamline University, her MS in Physics at the University of Minnesota and her PhD in Science Education, University of Minnesota. McCullough's contributions to AAPT and to the physics community have been significant, especially in breaking down barriers for female students and women physicists around the world. She has served AAPT in a variety of leadership positions including as a member of several Area Committees and serving on other important committees. Area Committees play a major role in the governance of AAPT. A member since 1996, she has worked on the Committee on Research in Physics Education and the Committee on Professional Concerns, serving as Vice Chair and Chair. In addition, she served on the Nominating Committee, Physics Education Research Leadership Organizing Council as Treasurer, Meetings Committee, Programs Committee, and the Books Committee. McCullough's contributions to the physics community go beyond serving as a volunteer for AAPT. Blending her service and her scholarship, she has presented at conferences and published extensively on issues of gender in the classroom, particularly in physics. Women are underrepresented in physics from high school through senior faculty in physics departments in higher education. Physics educators need to understand how to attract and retain women students from high school through graduate education. Her work in physics education research (PER) sheds light on how the classroom can be more inclusive particularly to female students. It blends physics with the social sciences.

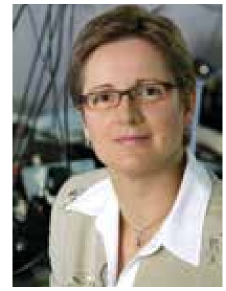
Brian A. Pyper

Brian A. Pyper

Brian A. Pyper, Professor of Physics and Director of Physics Education at BYU-Idaho, is a strong advocate of physics education. He has dedicated his time to not only maintaining the university's physics education program but has also been involved in various AAPT functions. He has served on the AAPT committee for Women in Physics, Physics in High Schools and Science Ed for the Public. He also chaired the Women in Physics Committee in 2010 and is now Chair for the Committee on Science Ed for the Public. He is also currently serving on the national Meetings Committee. He served on the AAPT national Nominating Committee in 2014-15, and has given workshops, talks, and presentations at section and national meetings almost every year since 2001. Pyper has been the Idaho-Utah Section president twice, 2004-06 and 2010-12, each time serving as the conference organizer for the Section meeting, and he has been the Idaho-Utah Section Representative since 2012.

The Homer L. Dodge Citation for Distinguished Service to AAPT was established in 1953, was renamed in 2012 to recognize the foundational service and contributions of Homer Levi Dodge, AAPT's first president. The Homer L. Dodge Citation for Distinguished Service to AAPT recognizes AAPT members for their exceptional contributions to the association at the national, section, or local level.

Plenary – Mid-Infrared Quantum Cascade Lasers and Applications

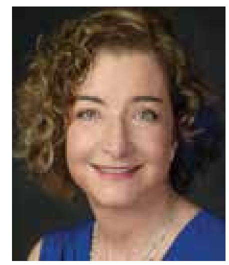


Claire Gmachl

Tuesday, July 23
4–5 p.m.
CC - Ballroom C

Claire Gmachl received the PhD degree (sub auspicies praesidentis) in electrical engineering from the Technical University of Vienna, Austria, in 1995. In 1996, she joined Bell Laboratories, Lucent Technologies, Murray Hill, NJ, to work on Quantum Cascade lasers and microcavity devices. In 2003, Gmachl joined Princeton University in the Department of Electrical Engineering and as adjunct faculty to PRISM; since July 2007 she is Full Professor at Princeton University, and a Eugene Higgins Professor of Electrical Engineering since 2011. Gmachl directs the Program in Materials Science and Engineering. Her group's research is focused on mid-infrared photonics, especially Quantum Cascade lasers, mid-infrared intersubband materials and devices, and applications. Gmachl was the Director of MIRTHE, the NSF Engineering Research Center on Mid-InfraRed Technologies for Health and the Environment, 2006–2016. Gmachl has authored or co-authored more than 400 publications, has given more than 125 invited presentations at conferences and seminars, and holds 30 patents. She has received an E-council/GEC Excellence in Teaching Award in 2018, the Walter Curtis Johnson Prize for Teaching Excellence 2015, a 2014 President's Award for Distinguished Teaching, the SEAS Distinguished Teaching Award 2013, an E-council/GEC Excellence in Teaching Award in 2012, and a Princeton University graduate mentoring award in 2009; she was an Associate Editor for Optics Express and a member of the IEEE/LEOS Board of Governors. Gmachl is a 2005 MacArthur Fellow and a member of several professional societies.

Plenary – Correlated Electrons: The Dark Energy of Quantum Materials



Laura Greene
National High
Magnetic Field Lab

Monday, July 22
4–5 p.m.
CC - Ballroom C

Laura H. Greene is a physics professor at Florida State University and Chief Scientist at the National High Magnetic Field Laboratory. She was previously a professor of physics at the University of Illinois at Urbana-Champaign. Laura Greene studied physics as an undergraduate at The Ohio State University and was awarded a cum laude BS, (1974) degree and Master's (MS) in 1978. For higher education she joined Cornell University. At Cornell, first she was awarded a MS in experimental physics (1980) and then in (1984) she completed a PhD degree in condensed matter physics.

She is noted for her research on Andreev bound states and is an expert in strongly correlated Fermionic systems. During the discoveries of the first high transition temperature (Hi-Tc) superconductors she and collaborators from AT&T laboratories, were amongst the first to report on the role of oxygen and crystal structure in the copper-oxides. Laura Greene is a champion for diversity and is active in promoting equal rights for women and minorities. She is a member of the Department of State supported COACh team, an organization for assisting in the success and impact of women scientists and engineers.

PhysTEC Teacher of the Year Awarded to Matt Blackman

Blackman been teaching AP Physics in NJ for ten years, where he dramatically increased AP enrollment and student AP scores at both Madison and Ridge High Schools. Specifically he has worked to improve the ratio of female to male students taking AP Physics, increasing it from under 20% to over 50%.

Matthew Blackman
Ridge High School

Tuesday, July 23
11 a.m.
CC - Ballroom C

President's Town Hall – Wednesday 11–11:45 a.m. CC - Ballroom C

AAPT is excited to work with all our members to enact our new Strategic Plan. During the next few years we have decided to focus on the following subset of strategies:

- Develop programs, products, and services that meet the needs, build on the strengths, and pique the interest of physics educators throughout their careers.
- Provide and support professional development for physics educators and physics education researchers locally, regionally, nationally, and internationally.
- Develop, improve, and support programs to increase the number of physics students and retain these students in our physics classes, at all levels and from all academic, socio-economic, and cultural backgrounds.
- Develop, improve, and support efforts to recruit and provide professional development for educators of under-represented and marginalized students in physics.

One way to tie these synergistic strategies is to work toward addressing AAPT's priority of supporting equity, diversity, and inclusion in physics through the development of programs, products, and services for students and teachers at all levels. Please join us at the 2019 Summer President Town Hall Meeting to engage in a working session on how best we can move forward on these priorities in a way that allows input from all members. The AAPT Executive Office, Staff, and the Board of Directors are excited to support the ideas from our community that align with our mission, values, and priorities.

Pearl Sandick
University of Utah

Wednesday, July 24
1:30–3 p.m.
CC - Ballroom C

APS Plenary – WIMPs in the Sky

Pearl Sandick is an Associate Professor in the Department of Physics and Astronomy at the University of Utah. She earned a PhD from the University of Minnesota in 2008 and was a postdoctoral fellow in the Theory Group at the University of Texas at Austin before moving to Utah in 2011. Professor Sandick is a theoretical particle physicist studying physics beyond the Standard Model, including possible explanations for the dark matter in the Universe. In addition to her research, she's passionate about teaching, mentoring students, and making science accessible and interesting to non-scientists. She has given a TEDx talk, been interviewed on KCPW's Cool Science Radio and NPR's Science Friday, and received a 2016 University of Utah Early Career Teaching Award. Professor Sandick has recently served on the American Physical Society (APS) Committee on the Status of Women in Physics and as the Chair of the National Organizing Committee for the APS Conferences for Undergraduate Women in Physics (CUWiPs).

Hydrogen Cosmology: Observing the Dark Ages of the Universe from the Farside of the Moon

Jack Burns
University of Colorado

Wednesday, July 24
1:30–3 p.m.
CC - Ballroom C

Jack Burns is a Professor in the Department of Astrophysical and Planetary Sciences at the University of Colorado (CU) Boulder, and is Vice President Emeritus for Academic Affairs and Research for the CU System.

Burns received his B.S. degree, magna cum laude, in Astrophysics from the University of Massachusetts in 1974. He was awarded an M.S. degree in 1976 and a PhD in Astronomy in 1978 from Indiana University.

Burns has held a variety of leadership positions in higher education. From 2001-2005, he served as Vice President for Academic Affairs & Research for the University of Colorado System. Burns provided leadership in the University's efforts to promote teaching, research, creative work, technology transfer, and public service for CU. Burns was Vice Provost for Research at the University of Missouri - Columbia from 1997- 2001. He was responsible for leadership and administration of the research and technology development mission of the university's 12 colleges and 7 interdisciplinary research centers. Burns has overseen research programs in biomedicine, agriculture, satellite remote sensing, engineering, research nuclear reactor science, along with centers in the physical and social sciences.

Burns was Associate Dean for the College of Arts and Sciences at New Mexico State University (NMSU) where he helped to oversee a budget of over $65 million for 23 academic departments and 350 faculty. He was Department Head and Professor in the Department of Astronomy at NMSU from 1989-1996 when department federal grant awards increased by a factor of 45, construction of the $50 million Apache Point Observatory was completed, and the Department raised $1 million for an endowed chair. During his tenure at the University of New Mexico from 1980- 1989, Burns served as the Director of the Institute for Astrophysics and was a Presidential Fellow. He was a postdoctoral fellow at the National Radio Astronomy Observatory from 1978- 1980.

Burns is director of the Network for Exploration and Space Science, a $3.6 million center of excellence funded by the NASA Solar System Exploration Research Virtual Institute. He has over 450 publications as listed in NASA's Astrophysics Data System. His research has been featured in articles and on the covers of Scientific American, Nature, and Science. His teaching and research focus on extragalactic astronomy and cosmology, space science, space exploration, and science policy. Burns is an elected Fellow of the American Physical Society and the American Association for the Advancement of Science. He received NASA's Exceptional Public Service Medal in 2010 and NASA's Group Achievement Award for Surface Telerobotics in 2014. Burns was a consultant for ten years at the DOE Los Alamos and Sandia National Laboratories, where he had a security clearance. Recently, Burns served on the Presidential Transition Landing Team for NASA, providing leadership on earth and space science.

Burns was previously a member of the NASA Advisory Council, serving as Chair of the Science Committee. He served as Senior Vice President of the American Astronomical Society, the world's leading professional astrophysics association, from 2014-17. Burns is currently a member of the Board of Directors of Space Science Institute in Boulder. He has served as Chair of the National Forum for System Chief Academic Officers, as a member of the Executive Committees for the NASULGC Council on Academic Affairs and the Council on Research Policy & Graduate Education, as a founding member of the Board of Directors of the National Center for Women and Information Technology, as Chair of the Board of Directors of the CU University Licensing Equity Holding Inc., as a founding member of the Board of Directors of the Colorado Science Fo rum, and as Chair of the Southwest Regional Space Task Force.

Commercial Workshops

CW01: Expert TA: Physics Video Series, Improved Online Homework, and a Powerful Set of Academic Integrity Tools

Location: CC - Cascade E
Date: Monday, July 22 Time: 12:00-1:00 p.m.
Sponsor: Expert TA *Leader: Jeremy Morton*

We all want the same thing. We want well-crafted materials students can learn from, engaging exercises that help them master the concepts, and we want them doing the work themselves rather than looking up answers online. Expert TA was founded as an online homework company, and for the past seven years has been trusted and used departmentally at hundreds of major universities. Expert TA has now developed learning resources such as a physics video series comprehensive enough to be used as lecture replacements for the flipped-classroom model. To supplement our own learning materials, Expert TA works with University and Institutional partners like OpenStax to develop a diverse collection of custom educational resources that can be leveraged directly from within the Expert TA system. After students review these learning resources, they gain ownership of concepts by working problems themselves. Our independent library is designed to reinforce the problem-solving process. It includes an abundance of multi-step questions that involve symbolic answers, as well as engaging question types like interactive Free Body Diagrams. Based on a six-year data-mining initiative, students receive specific and meaningful feedback for incorrect answers as they work. We understand that no matter how great your educational exercises are, they aren't meaningful if students are cheating. Because of this, we have made academic integrity a core consideration for all of the tools we develop. Join us for lunch to learn more.

CW02: Sector Vector: A Gamified Lab Experience

Location: CC - Cascade D
Date: Monday, July 22 Time: 11:30 a.m.-12:30 p.m.
Sponsor: 4th Law Labs
Leader: Derek Cascio
Franz Rueckert, James O'Brien Greg Sirokman

Vector arithmetic is an integral part of a STEM education, but it's rarely the most exciting. With Sector Vector™ we present a new game-based laboratory designed to better engage students. The game delivers the lesson of vector math within a competitive board game. Teams pilot opposing ships as they battle it out in a space arena. In order to win the game, players must calculate their trajectories, track opponent's moves, and consider every angle. In this workshop, educators and students will come together to experience Sector Vector™, engage with its multiple game modes, and explore its utility as an educational lab kit. Participants will have a chance to play the game, interact with the designers, and learn about its implementation in introductory physics courses.

CW03: MacMillan Learning: Set Your Physics Lab Free

Location: CC - Ballroom B
Date: Monday, July 22 Time: 11:30 a.m.-12:30 p.m.
Sponsor: Macmillan Learning *Leaders: Scott Guile, Lori Stover*

iOLab is a revolutionary hardware/software device capable of performing virtually any algebra- or calculus-based lab in both Physics 1 and 2. Macmillan will provide you with the opportunity to see iOLab in a hands-on environment. iOLab encourages both preparation and creativity allowing both students and you to do more with your lab time. This session will consist of a brief overview of the device from Mats Selen followed by five stations where you will participate in various experiments using the iOLab device. These stations will include labs on 1) Moment of inertia 2) Period of a pendulum 3) Magnetism from electric current 4) Speed of sound 5) Electrocardiogram You will work along with the lab either on your computer or one of the computers provided by Macmillan. Participants who are interested in further exploring using iOLab in their own lab would be able to take a sample device at the end of the session.

CW04: Mechanics Demonstrations with PASCO's Wireless Smart Cart and New Accessories

Location: CC - Soldier Creek
Date: Monday, July 22 Time: 12:00-1:00 p.m.
Sponsor: PASCO scientific *Leader: Dan Burns*

In this workshop you'll see new ways of performing classic mechanics demonstrations with PASCO's Wireless Smart Cart and new Smart Cart accessories. At the end of the workshop we will give away a Smart Cart with a Smart Cart accessory to two participants.

CW05: What's New in PASCO Capstone Software?

Location: CC - Soldier Creek
Date: Monday, July 22 Time: 1:30-2:30 p.m.
Sponsor: PASCO scientific *Leader: Dan Burns*

PASCO Capstone has evolved! Join us in this workshop for an exploration of the revolutionary new features in PASCO Capstone software and how they meet the needs of your physics labs. All workshop participants will receive a free site-licensed version of PASCO Capstone software.

CW06: What's New from PASCO Scientific?

Location: CC - Soldier Creek
Date: Monday, July 22 Time: 10:00-11:00 a.m.
Sponsor: PASCO Scientific *Leader: Dan Burns*

Join us for a look at the very latest from PASCO, including brand-new accessories for PASCO's revolutionary Wireless Smart Cart, exciting new tools for teaching optics and circuits, and the newest additions to PASCO Capstone software. At the end of the workshop we will be giving away some of this exciting new equipment.

CW07: Teaching Online Lab Science Courses: Challenges and Solutions

Location: CC - Cascade D
Date: Tuesday, July 23 Time: 12:00-1:00 p.m.
Sponsor: Carolina Biological Supply Company *Leaders: Shannon McGurk, Samta Nema*

Science education has been challenged by the demands and rapid growth of online education. One challenge is how to run lab sections of science courses online. Basic science can be taught online when accompanied by well-designed investigations that can be completed in the student's home. This session will include the experience of actively taking part in hands-on lab investigations developed for online science courses. These investigations have been designed for the off-campus setting while maintaining the college-level rigor.

CW08: Pearson: College Physics: Explore and Apply 2nd Edition: Help Students Learn Physics by Doing Physics

Location: CC - Cascade E
Date: Tuesday, July 23 Time: 12:00-1:00 p.m.
Sponsor: Pearson *Leader: Eugenia Etkina*

The lead author of *College Physics: Explore and Apply*, Eugenia Etkina, will discuss how she employs an active learning approach with her students and how the changes in the second edition of College Physics address the needs of the changing world. She will show how the written text, Active Learning Guide, and Mastering Physics can engage students in practicing science while learning physics. A myriad of new experiments and innovative problems will motivate your students to learn physics and help them succeed on revised assessments—such as AP exams and the MCAT. Come and learn about the exciting developments in the whole learning system and receive a signed book by the authors!

CW09: Introducing Pivot Interactives from Vernier

Location: CC - Silver Creek
Date: Tuesday, July 23 Time: 12:00-1:00 p.m.
Sponsor: Vernier *Leaders: Fran Proody, David Vernier, John Gastineau*

Pivot Interactives is a customizable online-video environment that is a superb complement to hands-on experiments with Vernier sensors. Students are quickly engaged by these high-production-quality videos of hard-to-implement phenomena, which are a powerful supplement to hands-on experimentation. Explore the possibilities with us!

CW10: Vernier Solutions for Physics and Chromebooks

Location: CC - Silver Creek
Date: Tuesday, July 23 Time: 1:00-2:00 p.m.
Sponsor: Vernier *Leaders: Fran Proody, David Vernier, John Gastineau*

Bring your Chromebook (or use one of ours) and learn how easy it is to connect sensors and collect and analyze data. Test drive the Go Direct Sensor Cart, or see how the Go Direct Photogate can measure a directional velocity. Explore the free and improved Graphical Analysis 4 app for data collection and analysis.

Monday • 10:50 a.m. Fire TV Stick 4K

Monday • 3:50 p.m. Celestron PowerSeeker 70EQ Telescope

Exhibit Hall Raffles

Monday and Tuesday

Fire TV Stick 4K

Celestron PowerSeeker 70EQ Telescope

All-New Fire HD 8 Tablet

Celestron PowerSeeker 127EQ Telescope

(Must be present to win)

CC - Exhibit Hall A

Purchase tickets at Registration desk!

Tuesday • 10:20 a.m. All-New Fire HD 8 Tablet

Tuesday • 3:50 p.m. Celestron PowerSeeker 127EQ Telescope

Bus schedule for workshops

Saturday, July 20

Buses departing Utah Valley Convention Center

Morning

- 7:15 a.m.
- 7:25 a.m.
- 7:35 a.m.

Afternoon

- 12:25 p.m.
- 12:35 p.m.
- 12:45 p.m.

Buses departing BYU

Afternoon

- 12:25 p.m.
- 12:40 p.m.
- 1:00 p.m.

Evening

- 5:15 p.m.
- 5:30 p.m.
- 5:45 p.m.

Utah Valley Convention Center (UVC)
220 W Center Street
Provo, UT 84601

Brigham Young University (BYU)
Department of Physics and Society
Provo, UT 84602

Sunday, July 21

Buses departing Utah Valley Convention Center

Morning

- 7:15 a.m.
- 7:25 a.m.
- 7:35 a.m.

Afternoon

- 12:25 p.m.
- 12:35 p.m.
- 12:45 p.m.

Buses departing Utah Valley University

Afternoon

- 12:25 p.m.
- 12:40 p.m.
- 1:00 p.m.

Evening

- 5:15 p.m.
- 5:30 p.m.
- 5:45 p.m.

Utah Valley Convention Center (UVC)
220 W Center Street
Provo, UT 84601

Utah Valley University (UVU)
800 West University Parkway
Orem, UT 84058

Buses will pick up attendees on the North side of the convention center on W 100 N Street.

4th Law Labs

Booth #312
16 Brooks Park
Medford, MA 02155
978-302-5431
team@4thlawlabs.com, www.4thlawlabs.com

At the 4th Law Labs booth visitors will find playable copies of our premier product, Sector Vector™. This gamified lab kit teaches vector arithmetic as players face off in a space battle board game. Stop by and experience the thrill of math based space combat as you navigate Sector Vector™.

American Association of Physics Teachers

Booth #110
One Physics Ellipse
College Park, MD 20740
301-209-3300, www.aapt.org

Welcome to Provo! Join us at the AAPT booth where you can chat with fellow members, Board members, and spin our prize wheel for your chance to win some free prizes. This year try out an interactive demo based on a favorite "Figuring Physics" cartoon ("Water Roll") from Paul Hewitt and *The Physics Teacher*! We will also have a wide variety of educational resources available, including resources to support teaching like our popular booklet Physics in 21st Century Science Standards: The Role of Physics in the NGSS.

AAPT Idaho-Utah Section

Booth #106
One Physics Ellipse
College Park, MD 20740
301-209-3300, http://idahoutah.aaptsections.org/

AAPT Publications

Booth #108
One Physics Ellipse
College Park, MD 20740
301-209-3300, www.aapt.org

Drop by for information on how you can become part of the AAPT Publications program. Learn why you should submit articles for publication, consider becoming a reviewer, and make sure your physics department subscribes to *American Journal of Physics* and *The Physics Teacher.* It is rumored that it may be possible to catch up with journal editors and other members of the Publications Committee during your visit. If you are an online only member, you'll get a chance to see the print copies and reconsider your choice. If you aren't yet an AAPT member we will do our best to help you decide which option is best for you.

AIP Statistical Research Center

Booth #310
One Physics Ellipse
College Park, MD 20740
301-209-3100, pinchautequiz@aip.org, ww.aip.org

The AIP Statistical Research Center is your source for reliable data on education and employment in physics, astronomy, and other physical sciences, including: Enrollments and degrees at all levels of education in physics, astronomy, and related fields from high school through the PhD. Demographic profiles of physics faculty in high schools, 2-year colleges, 4-year colleges, and universities. Common careers of physicists and astronomers with bachelor's degrees, master's degrees, or PhDs. Workforce dynamics including unemployment, underemployment, staff turnover, retirement, and the number of positions available. Issues that cut across education and employment such as the representation of women and minorities in physics and related fields.

American Physical Society

Booth #406
One Physics Ellipse
College Park, MD 20740
301-209-3200, sharp@aps.org, www.aps.org

The American Physical Society's Public Outreach Department aims to bring the excitement of physics to all. Stop by to grab our new retro poster series, your copy of Spectra's Quantum leap or hear more about www.physicscentral.com. We will also be demoing our new comic book app as well as SpectraSnapp for android.

Arbor Scientific

Booth 203
PO Box 2750
Ann Arbor, MI 48106
800-367-6695, sebastian@arborsci.com, www.arborsci.com

For 30 years, Arbor Scientific has worked with physics and physical science teachers to develop educational science supplies, science instruments, and physics lab equipment that make learning fun, engaging and relevant for students and teachers alike. Stop by our Booth and try the most fascinating, dynamic, hands-on methods that demonstrate key concepts and principles of physics and chemistry. We find the cool stuff!!

Bedford, Freeman, & Worth High School Publishers

Booth #113
100 American Metro Blvd.
Suite 109
Hamilton, NJ 08619
866-843-3715, hsmarketing@bfwpub.com
www.highschool.bfwpub.com/catalog

Bedford, Freeman, and Worth High School Publishers (BFW High School Publishers) is your trusted source for innovative high school science resources. We're proud to publish the new one-of-a-kind textbook program, College Physics for the AP® Physics 1 Course, 2nd edition with lead author Gay Stewart – now available in our digital e-book & online homework platform SaplingPlus!.

Carolina Biological Supply

Booth #213
2700 York Rd.
Burlington, NC 27215
800-334-5551
penny.canady@carolina.com, www.carolina.com/

Carolina Biological Supply Company offers a comprehensive selection of Physics/ Physical Science equipment supporting the 6-16 market. Carolina kits span Physics branches including 3D kits with digital content complementing hands-on activities. Robotics and microcontrollers are available with programming projects. Peruse free articles and pacing guides online to plan your year.

Carolina Distance Learning

Booth #211
2701 York Road
Burlington, NC 27216
800-334-5552
www.carolina.com/distancelearning

Give distance learning students a rigorous lab experience with Carolina lab kits designed specifically for college-level distance education. Choose from 200+ hands-on investigations that effectively teach lab skills, data collection and analysis. Or partner with us to customize lab kits to align with your course requirements.

Discover Grand Rapids

Booth #305
3171 Monroe NW
Suite 545
Grand Rapids, MI 49503
616-233-3556, Tnelson@experiencegr.com
www.experiencegr.com/aapt

Grand Rapids, Michigan, location of the 2020 AAPT Summer Meeting, has been named one of America's Super Cool Cities (Expedia, 2017), 1 of 52 Places to Go Worldwide (New York Times, 2016), the #1 U.S. Place to Visit (Groupon, 2015) and America's #1 Travel Destination (Lonely Planet, 2014).

Expert TA

Booth #100
624 Boston Ave., Suite 230
Tulsa, OK 74119
405-826-2619
main@theexpertta.com, www.the ExpertTA.com

Expert TA is an online homework and physics learning platform. Emphasizing problem-solving by allowing students to show work has always been central to Expert TA. We have an intuitive interface for students to enter symbolic expressions, a robust math engine that recognizes mathematically equivalent answers, and specific data-mined feedback of the most common student mistakes and misconceptions. Instructors can utilize automatically-graded Free Body Diagram drawing problems, both as stand-alone or included as an intermediate part. Our Physics Video Series is robust enough to support the flipped classroom but can also be used as a course supplement. The video series includes complete topical coverage with detailed derivations, application of fundamental equations, and worked-out problem examples. Finally, we recognize that educational exercises are only meaningful if students do the work themselves. We have a comprehensive suite of Academic Integrity tools, and we keep solutions to our problems off the internet.

Gravitational Wave Astronomy

Booth #315
PO Box 159
Richland, WA 99352
509-372-8248
astrunk@caltech.edu, ligo.caltech.edu

The first incident detection of gravitational waves in 2015 by the Laser Interferometer Gravitational wave Observatory (LIGO) opened the era of gravitational wave astronomy and a new way to observe our universe. Gravitational wave astronomers from LIGO, the Laser Interferometer Space Antenna (LISA), and the North American Nanohertz Observatory for Gravitational waves (NANOGrav) explore potential sources across the gravitational wave spectrum including supermassive binary black hole systems and the mergers of black holes, neutron stars, and white dwarfs. Gravitational wave astronomers partner with astroparticle and electromagnetic astronomers to study the multimessenger signals from cataclysmic events in our observable universe.

Klinger Educational Products Corp.

Booth #212
86 Glen Cove Road
Roslyn Heights, NY 11356
718-461-1822
rsaper@klingerEducational.com, www.KlingerEducational.com

This year KLINGER will be introducing new products that cover a wider range of topics and levels to teach physics. In addition to advanced physics teaching equipment we will also have a selection of items for the high school and middle schools. Come visit and see the capabilities of a ballistics car and lab kits that demonstrate topics such as predicting trajectories, circular motion, a simple pendulum, accelerated motion and much more. Also being demonstrated will be the LEYBOLD x-ray apparatus and tomography module. Both now have a locking, storage drawer that fits directly under the main units as well as a HD upgrade for the goniometer, enabling a 10X higher resolution achieved through narrower apertures and software. X-rays are detected with an end-window counter or an energy detector. Additionally we will be exhibiting our dependable Electron Diffraction tube and a Ne Franck-Hertz experiment. We look forward to seeing current and new members of the AAPT to say hello and catch up on events happening in the field of physics teaching.

Macmillan Learning

Booth #111
1 New York Plaza, Suite 4500
New York, NY 10004
212-375-7000
customersupport@macmillanusa.com/, www.macmillanlearning.com/catalog

Macmillan Learning is an educational publishing company committed to supporting students at every point of their academic careers. Macmillan's physics course solutions support the active classroom space, homework and textbooks, and lab activities. We seek to support educators whether they need a last-minute solution or want to craft unique learning resources.

MSSE

Booth #404
P.O. Box 172805
451 Reid Hall
Bozeman, MT 59717
406-994-7485,
msse@montana.edu, www.montana.edu/msse

The MS in Science Education (MSSE) program offers innovative online and campus-based graduate courses designed for practicing science educators. Courses offered in all science disciplines and may be taken for professional development or to earn a graduate degree. Unique program characteristics support both traditional and informal science educators. The MSSE program offers affordable, competitive tuition.

National Science Foundation

Booth #102
2415 Eisenhower Ave.
Alexandria, VA 22314
703-292-8396
cajohnso@nsf.gov, www.nsf.gov

The National Science Foundation supports physics education research through a number of programs. These include Improving Undergraduate STEM Education (IUSE and IUSE:HSI), Robert Noyce Scholarships, NSF Scholarships in Science, Technology, Engineering and Mathematics (S-STEM), Advanced Technical Education Program (ATEP), EHR Core Research (ECR: Core, ECR: BCSER, ECR: PEER), Advanced Informal STEM Learning (AISL), Discovery Research PreK-12 (DRK-12), Innovative Technology Experiences for Students and Teachers (ITEST), HBCU Research Infrastructure for Science and Engineering (RISE), and Tribal Colleges and Universities Program (TCUP), among others. Program Officers and Staff will be available to answer questions about our programs.

OpenStax

Booth #205
6100 Main St., MS-375
Houston, TX 77005
713-348-2961
ss192@rice.edu, www.openstaxcollege.org

OpenStax is a nonprofit based at Rice University, and our mission is to improve access to education. We provide free college and Advanced Placement textbooks that are developed and peer-reviewed by educators, as well as low cost, personalized courseware that helps students learn. Our textbooks have been used by more than 6.2 million students. Through philanthropic partnerships, OpenStax is empowering students and instructors to succeed.

PASCO scientific

Booth 103
10101 Foothills Blvd.
Roseville, CA 95747
916-462-8208
dferrario@pasco.com, www.pasco.com

PASCO is celebrating 55 years of serving the physics teaching community! PASCO designs and manufactures apparatus, lab instrumentation, sensors and software for teaching physics concepts. Visit us at our booth or attend a PASCO workshop to see our very latest physics equipment offering.

Pearson

Booth #302
221 River St.
Hoboken, NJ 7030
201-587-6149
lauren.lopez@pearson.com, www.pearson.com/us

Every learning moment builds character, shapes dreams, guides futures, and strengthens communities. At Pearson, learning gives us purpose. We are devoted to creating effective, accessible solutions that provide boundless opportunities for learners at every stage of the learning journey. For more information, visit www.pearson.com/us.

Phet Interactive Simulations

Booth #303
University of Colorado Boulder
390 UCB
Boulder, CO 80309
303-492-6963
phethelp@colorado.edu, https://phet.colorado.edu/

Interact, Discover, Learn. PhET simulations actively engage students in math and science, impacting millions of students and pioneering innovations in teaching, learning, and assessment. Our HTML5 sims run on Chromebooks and iPads and are translated into over 85 languages.

PlaneWave Instruments

Booth #301
1519 Kona Drive
Rancho Dominquez, CA 90220
310-639-1662
jfarmer@planewave.com, www.planewave.com

PlaneWave Instruments, Inc. (PWI) manufactures professional telescopes (up to 1-meter aperture) and mounts/gimbles for astronomy research, aerospace and commercial applications. In 2008, PWI introduced the CDK (Corrected Dall-Kirkham) optical design and in 2018, introduced the revolutionary L-Series direct drive mounts. PWI is both an engineering and manufacturing global leader in SSA, LaserCom and other strategic applications.

Quantum Experience Ltd.

Booth #400
Moskovich 13/34
Rehovot, 7617413, Israel
972773179301
boazal@quantumlevitation.com, www.quantumlevitation

Stimulate and encourage students to learn PHYSICS by teaching them the amazing phenomenon of Quantum Levitation. Quantum Experience develops educational programs using superconductors and quantum levitation. Our experimental kits and supporting material allow students to study Quantum Levitation, experience in a research process of learning and develop important scientific learning skills.

Society of Physics Students

Booth #304
One Physics Ellipse
College Park, MD 20741
301-209-3008
lquijada@aip.org, www.spsnational.org

The Society of Physics Students (SPS), along with Sigma Pi Sigma, the national physics honor society, are chapter-based organizations housed within the American Institute of Physics. SPS strives to serve all undergraduate physics students and their mentors with a chapter in nearly every physics program in the country and several international chapters. Sigma Pi Sigma, with over 95,000 historical members, recognizes high achievement among outstanding students and physics professionals. SPS and Sigma Pi Sigma programs demonstrate a long-term commitment to service both within the physics community and throughout society as a whole through outreach and public engagement. Partnerships with AIP member societies introduce SPS student members to the professional culture of physics and convey the importance of participation in a professional society. SPS and Sigma Pi Sigma support scholarships, internships, research awards, physics project awards, outreach/service awards, and a job site for summer and permanent bachelor's level physics opportunities (jobs.spsnational.org).

SPS Local Chapters

Booth #306
Society of Physics Students & Sigma Pi Sigma
One Physics Ellipse
College Park, MD 20740
301-209-3300, www.spsnational.org/about/governance/zones

Spectrum Techniques, LLC

Booth #210
106 Union Valley Road
Oak Ridge, TN 37830
865-482-9937
julie@spectrumtechniques.com, www.spectrumtechniques.com

Spectrum Techniques is the leading fabricator and supplier of Exempt Quantity Sources. We have been a longtime designer and manufacturer of nuclear Geiger Mueller and scintillation counting and gamma spectroscopy equipment for the educational and medical markets. New at this show is our ST365 counter, which can be operated in stand-alone or computer controlled mode via WiFi, Ethernet, or USB. Control software is available for Windows and Mac computers or Android devices.

Tel-Atomic

Booth #104
1223 Greenwood Ave.
Jackson, MI 49203
800-622-2866
joe.dohm@telatomic.com, www.tel-atomic.com

TEL-Atomic Inc. provides advanced undergraduate laboratory equipment to institutions around the globe. We offer equipment to explore atomic and nuclear physics, including the TEL-X-Ometer, an x-ray diffractometer which is used to determine the structure of simple crystals. We also offer an affordable Cavendish torsion balance for measuring the gravitational constant. Please visit our Booth to see these and other products.

Vernier Software and Technology

Booth #202
13979 SW Millikan Way
Beaverton, OR 97005
888-837-6437
aharr@vernier.com, www.vernier.com

Vernier Software & Technology is the leading worldwide innovator of real-time data-collection, graphing, and analysis tools for science education. Visit our booth to see our Go Direct Force and Acceleration and Go Direct 3-Axis Magnetic Field sensors, as well as our Graphical Analysis 4 software.

Download Your Mobile App Now!

To Download the App

– Go to your Apple “App Store” or Android “Play Store” and download the “CrowdCompass Attendee-Hub” app

– Under “Search for Event” type in “AAPT” and click on the “2019 AAPT Summer Meeting”

App password: aapt19

Your Event URL **https://crowd.cc/sm-19**
Takes attendees to the online version of your event.

Your App URL **https://crowd.cc/s/35Fa4**
Takes attendees directly to mobile markets to download

TWEET UP

#AAPTSM19

MEET YOUR PHYSICS TWEEPS IRL OR LEARN HOW TO USE SOCIAL MEDIA TO BENEFIT YOUR TEACHING.

SUN 07/21, 5:00PM - 6:00PM

Marriott Lobby Bar

Lactation Room

(CC - First Aid Room)

Quiet Room

(CC - Business Center)

Hours:

Saturday – 7 a.m. to 11 p.m.
Sunday – 7 a.m. to 11 p.m.
Monday – 7 a.m. to 11 p.m.
Tuesday – 7 a.m. to 11 p.m.
Wednesday – 7 a.m. to 11 p.m.

Take this opportunity to meet and mingle with other "Newbies" and Early Career Professionals!

Joe Veras Mexican Restaurant

Appetizers Provided
Cash Bar

K12 PHYSICS TEACHERS LOUNGE

TIMPANOGOS ROOM

New digital resources from comPADRE

Topical discussions

Interactive labs & lesson plans

Sunday, July 21

9:00 - 10:30 **Digi Kit Exploration**
Explore innovative lessons supported with high quality digital resources.

10:30 - 11:30 **Digi Kit: Sound Science Record Player**

1:30 - 2:30 **Digi Kit: Energy Theater**

2:30 - 3:30 **Digi Kit: Dropper Popper**

3:30 - 4:30 **Digi Kit: Photoelectric Effect**

Monday, July 22

9:30 - 10:30 **New Teacher's Gathering**
If you are a teacher in your first 5 years of teaching and are interested in meeting others in your position or a seasoned teacher with a passion in mentoring new teachers, join us in the K12 Lounge.

1:00 - 2:00 **Digi Kit: Analog to Digital**

2:00 - 3:00 **Get the Facts Out**
Join an exploration of unexpected trends in the data on educators in the United States while discussing perceptions of STEM teaching in society.

3:00 - 4:00 **Underrepresented Curriculum Project**
The Underrepresentation Curriculum (http://underrep.com) is a free, flexible resource designed to help physics teachers bring conversations about science and society into their classrooms.

5:00-6:00 **STEP UP 4 Women**
Join a discussion reception on the NSF grant STEP UP for Women aiming to drastically increase the number of women in undergraduate physics through interventions in the high school classroom

Tuesday, July 23

9:30 - 10:30 **Digi Kit: Terminal Velocity**

1:00 - 2:00 **PTRA: Technology in the classroom**
Let's explore how tweaking your existing science experiments can improve student engagement and effectiveness in data collection. Participants will be guided through specific examples of google forms for real-time assessment, google classroom for immediate access + feedback and various apps for data collection.

2:30 - 3:30 **HS Physics Photo Contest**
Come to an information and sharing session about the High School Physics Photo Contest. Learn the details and discuss with others how they have successfully implemented the contest in their classroom.

3:30 - 4:00 **Feedback Session**
Come share your thoughts in person in a discussion about how AAPT K12 programs is and can better meet your needs.

For more information: Tweet @AAPTHQ #AAPTWM18

AAPT PHYSICS EDUCATION

SPS02: 7:30-9:30 p.m. Machine Learning for Quantum Multi-body Systems

Poster – Yanran Li, Sun Yat-sen University, Room 2701, Huayu 1st Street, Liwan District Guangzhou, Guangdong 510000 China; liyr8@mail2.edu.cn

The study of quantum multi-body systems in the field of statistical physics has deepened people's understanding of physical phases and statistical laws, meanwhile, machine learning can do great jobs in classification. Through Monte Carlo, I simulated a 2-D Ising model for ferromagnetism and studied its phase transition. I use the neural network to do the classification of the above configuration: First choose different temperature as the high temperature phase to see differences of the prediction result. Then choose different length of the simulated lattice to see differences of the prediction result. By plotting, two curves can be obtained by inputting configurations with different temperatures, one of which represents the probability of low temperature phase at different temperatures. It can be found that there is a sudden change in the probability, which stands for the phase transition point of temperature.

SPS03: 7:30-9:30 p.m. Effect of Light and Coating on Dye-Sensitized Solar Cells

Poster – Orlando M. Patricio, Laredo College, West End Washington St., Laredo, TX 78040; orlando.patricio@laredo.edu

Emiliano Castillo, Jonathan Gallegos, Jose Juarez, Laredo College

Dye-sensitized solar cells (DSSCs) are not as efficient as the more expensive synthetic solar cells. We will experiment on improving efficiency by coating the DSSCs, and adjusting the amount of light and temperature directed toward the solar cells. The experimental coating will be tested for heat-resistance; improving the light absorption efficiency of the DSSCs. We will be comparing synthetic light, UV-light, and natural sunlight for this experimental procedure. Based on the data gathered, we can conclude how the DSSCs' efficiency has been affected.

SPS04: 7:30-9:30 p.m. Roger That! A Collaborative Celebration of Space Exploration

Poster – Karen Gipson, Grand Valley State University, 213 Hampton SE, Allendale, MI 49401-9403; gipsonk@gvsu.edu

Samhita Rhodes, Deana Weibel, Glen Swanson, Grand Valley State University

Emily Hromi, Grand Rapids Public Museum

Roger That! is a two-day public symposium on space exploration, organized by a multi-disciplinary team faculty at Grand Valley State University (GVSU) in collaboration with staff at Grand Rapids Public Museum (GRPM). GRPM is home to the Chaffee Planetarium, named in honor of local hero Roger B. Chaffee, who lost his life in the Apollo 1 fire. The symposium includes field trips and family-friendly activities, a design challenge for 4th - 6th graders, and presentations aimed at college students and the general public. The keynote speaker in 2019 was astronaut Nicole Stott, the first person to create a watercolor in space. Stott delivered two public talks to audiences that included over 100 local Girl Scouts, delivering the inspiring message to "Dream Big!" The GVSU chapter of the Society of Physics Students (SPS) supported this outreach effort through hands-on activities at GVSU on Friday and at GRPM on Saturday.

SPS05: 7:30-9:30 p.m. Theoretical Study of Accelerator Neutrino Oscillation Experiment

Poster – Weijie Feng, Sun Yat-sen University, 105 Yuandong Area, No.135 Xingangxi Road, Haizhu District, Guangzhou, P. R. China Guangzhou, Guangdong 510275 China; fweijie-12@163.com

Yixing Zhou, Sun Yat-sen University

Neutrino physics has been one of the focused areas in particle physics since last century. Recently, some new physics such as non-standard interaction and neutrino decay has become more and more popular since the discovery of neutrino oscillation. We simulate the baseline from CERN to PINGU and point out the advantages of this experiment. We also study the influence on the parameters of standard oscillation model after introducing the new models and obtain some reasonable conclusions. Furthermore, we give some new restrictions about the parameters of new physical models apart from the standard oscillation model.

SPS06: 7:30-9:30 p.m. Numerical Study of Quantum Scattering in 1D Models

Poster – Trevor Robertson, UMass Dartmouth, 285 Old Westport Rd., North Dartmouth, MA 02747-2300; jwang@umassd.edu

Jay Wang, UMass Dartmouth

Solving the fundamental time-dependent Schrödinger equation (TDSE) is an essential computational task in understanding the behavior of many microscopic systems. Robust and efficient algorithms to solve the TDSE is challenging, particularly in systems with continuum boundary conditions such as that encountered in atomic collision or scattering studies. In this study we use the well-known method for solving the TDSE, the finite difference method (FDM) but with an important modification to conserve flux. We analyze one-dimensional collisions with well-behaved as well as singular potentials. We report numerical techniques for robust extraction of scattering flux and compare with asymptotic theoretical predictions. Because the FDM is difficult for scaling to 2D or higher dimensions, we present preliminary results with mesh-free methods including the radial basis function methods and compare the results between the two approaches.

SPS07: 7:30-9:30 p.m. Student Astronomical Research and Publication within a Community of Practice

Poster – Rachel Freed, Institute for Student Astronomical Research, 416 4th St. W, Sonoma, CA 95476-6511; r.freed2010@gmail.com

Russell Genet, California Polytechnic State University

The opportunities for students to conduct astronomical research and contribute to the scientific literature are growing with the expansion of remote telescope networks. The Las Cumbres Observatory Education Partnership has 22 participating institutions in its second year. Astronomy, referred to as the gateway science due to its intrinsic inspiration for students provides an ideal target for programs that improve scientific literacy. The astronomy research seminar provides a true to life scientific research experience for students early in their educational careers, teaching students to write for scientific publication and to present their research. Over 450 students have co-authored 150 published papers over the past 10 years. For many it has been a transformative experience, as evidenced by the students who have created their own research seminars, coached others through the seminar, gone on to help facilitate international conferences on student astronomical research, and even participated on editorial boards for conference proceedings.

SPS09: 7:30-9:30 p.m. Coefficient of Rolling Friction and Pressure Inside a Football

Poster – Gyaneshwaran Gomathinayagam, The Doon School, Dehradun, India 248001; gya@doonschool.com

Siddhant Singhania, The Doon School

A football at different internal pressures was rolled from rest down an inclined smooth wooden plank. The acceleration of its centre of mass was measured by video analysis using TRACKER software. It was found to increase with excess pressure inside the football until it reached a constant value at an excess pressure of 36.43 kPa and above corresponding to a minimum constant value of rolling resistance. The decrease in the acceleration at lower pressures was linked to the increase in contact area of the football, which resulted in greater hysteresis energy loss due to the deformation of the football while rolling. This was modelled by defining rolling resistance coefficient Sr as the offset distance of the line of action of the normal reaction producing a retarding torque on the football. Sr was found to be an inverse exponent function of excess pressure.

SPS10: 7:30-9:30 p.m. Mechanics of the Bounce of a Ball off an Edge

Poster – Gyaneshwaran Gomathinayagam, The Doon School, Dehradun, India 248001; gya@doonschool.com

Amal Neelesh Bansode, Aneesh Agarwal, The Doon School

A table tennis ball was dropped vertically from rest onto the sharp edge of an aluminium cube and the rebound angle was measured as a function of the separation between the ball's centre and the edge. A Vpython simulation was made by modelling the collision of the ball against the edge using conservation of linear momentum and by treating the collision to be perfectly elastic. The rebound angles predicted by the simulation matched the measurements within the measurement uncertainties. The relationship between the rebound angle and separation between the ball's centre and the edge of the aluminium cube was also derived analytically and confirmed by the measurement data.

SPS11: 7:30-9:30 p.m. Modelling the Motion of a Magnet Falling through an Aluminium Pipe

Poster – Gyaneshwaran Gomathinayagam, The Doon School, Dehradun, India 248001; gya@doonschool.com

Yash Gupta, The Doon School

The motion of a magnet falling through an aluminium pipe with terminal velocity was modeled by assuming the magnetic braking force to be proportional to the velocity of the magnet. The predicted time of fall from the simulation matched the measurements for a wide range of weights for the magnet. The simulation was then used to answer questions such as - how do terminal velocity, time taken to attain the terminal velocity, and the distance fallen by the magnet before attaining terminal velocity depend on the weight of the magnet? The Vpython simulation was thus used as a virtual lab to conduct virtual experiments to answer new questions about the modeled phenomenon, which may have otherwise been rather difficult for a high school student due to lack of the required mathematical skills, apparatus or even time to conduct the experiments.

SPS12: 7:30-9:30 p.m. Creating Multimedia Resources Depending on Instructors' Needs

Poster – Azita Seyed Fadaei, South Seattle Community College, 1527 15th Ave, Apt 408 Seattle, WA 98122; seiedf@yahoo.com

In order to have appropriate multimedia resources, instructors need to prepare multimedia resources for their students. Videos prepared by the instructor can speed up the teaching process and help instructors use the "Multimedia Representation" in their real or virtual class. They can plan, make and prepare some part of curriculum needs, observing a phenomena , demonstrating, simulating and creating questions, practices and lab activities. In the teaching physics course in the subject of mechanics of motion we introduce Logger Pro to our students. So we prepared a video of how they can use this software in their lab activities. For making this video, we used a computer monitor video recording (Screen Recorder) and Logger Pro, which both are open sources. This video has been uploaded on Canvas for students' usage and as an idea for our colleagues.

SPS13: 7:30-9:30 p.m. The Correct Explanation for the Working of the Straw Oboe

Poster – Gyaneshwaran Gomathinayagam, The Doon School, Dehradun, India 248001; gya@doonschool.com

Aditya Garg, The Doon School

Madhu Sudhan, FIITJEE Limited

The standard explanation for the working of the straw oboe is that it has an air column which is open at both ends, and so when the flaps vibrate, they set up stationary sound waves in the air column (open at both ends) which have resonant frequencies based on the length of the straw. So shorter the length of the straw, higher is the observed pitch of the sound waves. However, the measured sound frequencies for each length were found to be 15 times lower than the corresponding predicted resonant frequencies. This can be understood by considering the sound to be due to the flaps in the wedge vibrating at around 15 times lower frequency than the corresponding resonant frequency for the length of the straw. This 'correction factor' of 15 could depend on the material properties of the flap like the size, shape and stiffness of the flap.

W01: Learn Physics While Practicing Science: Introduction to ISLE

Sponsor: Committee on Research in Physics Education
Co-sponsor: Committee on Laboratories
Time: 8:00 a.m.-5:00 p.m. Saturday
Member Price: $87 Non-Member Price: $112
Location: S415 Eyring Science Center (ESC)

Eugenia Etkina, 10 Seminary Place, New Brunswick, NJ; eugenia.etkina@gse.rutgers.edu

David Brookes, Yuhfen Lin, Gorazd Planinsic

Participants will learn how to modify introductory physics courses at any level to help students acquire a good conceptual foundation, apply this knowledge in problem solving, and engage them in science practices. The framework for these modifications is Investigative Science Learning Environment (ISLE). We provide tested curriculum materials including: (a) The second edition of College Physics Textbook by Etkina, Planinsic and Van Heuvelen, the Physics Active Learning Guide and the Instructor Guide; (b) a website with over 200 videotaped experiments and questions for use in the classroom, laboratories, and homework; (c) a set of innovative labs in which students design their own experiments, and (d) curriculum materials that use LEDs to help students learn physics. During the workshop the participants will learn how to use the materials in college and high school physics courses to help their students learn physics by practicing it. We will focus on the connections of our materials with the NGSS and revised AP curriculum, specifically on the interplay of science practices and crosscutting concepts. Workshop participants may choose to obtain one graduate credit-hour for completing this workshop plus a few hours of additional work. If you are interested in this option, please send an email note to rhilborn@aapt.org.

W02: Physics Activities for the Life Sciences (PALS)

Sponsor: Committee on Research in Physics Education
Co-sponsor: Committee on Laboratories
Time: 8:00 a.m.-5:00 p.m. Saturday
Member Price: $85 Non-Member Price: $110
Location: C247 Eyring Science Center (ESC)

Duane Deardorff, University of North Carolina at Chapel Hill, Campus Box 3255, Chapel Hill, NC 27599; duane.deardorff@unc.edu
Alice Churukian, Colin Wallace, David Smith, Daniel Young

Physics instructors are increasingly being asked to reform their teaching practices and use evidence-based instructional strategies to actively and intellectually engage their students. In this workshop, participants will gain first-hand experience implementing multiple collaborative learning activities that have been specifically designed for use in introductory physics for life science (IPLS) courses. Examples will include content from mechanics, electricity, magnetism, and optics, with each activity grounded in real-world applications to biological phenomena. Participants will also gain a better understanding of student difficulties in IPLS-focused topics and be introduced to teaching methods aimed at addressing such issues.

W03: Developing and Implementing NGSS 3-D Physics Lessons

Sponsor: Committee on Physics in High Schools
Co-sponsor: Committee on Science Education for the Public
Time: 8:00 a.m.-5:00 p.m. Saturday
Member Price: $85 Non-Member Price: $110
Location: N153 Eyring Science Center (ESC)

Charlene Rydgren, P.O. Box 452, Malone, NY 12953; crydgren@gmail.com

The Next Generation Science Standards require students to use scientific and engineering practices and to apply crosscutting concepts to develop an understanding of disciplinary core ideas. How do we implement these shifts in our classroom? Participants will engage in a 3-Dimensional lesson followed by an analysis of the Science and Engineering Practices and Crosscutting Concepts involved in the lesson. The format of the NGSS will be explored; focusing on 3-Dimensional performance expectations. Time will be devoted to strategies for 3-D lesson design,story line development and assessment. Supplemental resources will be made available.

W04: High Altitude Ballooning

Sponsor: Committee on Educational Technologies
Co-sponsor: Committee on Apparatus
Time: 8:00 a.m.-5:00 p.m. Saturday
Member Price: $120 Non-Member Price: $145
Location: N127 Eyring Science Center (ESC)

Erick Agrimson, 2004 Randolph Ave., #4105, St. Paul, MN 55105; epagrimson@stkate.edu
James Flaten

Ever dream of doing science in space? High-altitude weather balloons can lift science experiments into the stratosphere, providing relatively low-cost and uncomplicated access to a space-like environment (and view)! Sending experiments to "near-space" is an unforgettable experience which can address a wide range of science and engineering standards. We can also discuss how one uses Ardunio based logging systems to collect data in the near space environment. This workshop will provide an introduction for those who wish to explore this exciting type of platform in their classroom. We will share ideas for college as well as pre-college projects and undergraduate collaborative research that can make use of this hands on experimental platform.

W05: Visualizing Contemporary Physics

Sponsor: Committee on Contemporary Physics
Co-sponsor: Committee on Educational Technologies
Time: 8:00 a.m.-5:00 p.m. Saturday
Member Price: $105 Non-Member Price: $130
Location: C445 Eyring Science Center (ESC)

Jay Wang, Physics, UMass Dartmouth; jwang@umassd.edu

Joel Klammer, Kenneth Cecire

The Workshop on Visualization will focus on the use of effective visualization in teaching and modeling in contemporary physics and related areas such as life sciences. It will offer activities and examples from experienced practitioners on how to create graphical and visual representation including illustrations and animations of physical processes to gain a better understanding and insight of concepts at introductory and advanced levels, including special relativity, visualizing quantum eigenstates, transverse and longitudinal waves, wave packet propagation, energy across disciplines, thermal physics, etc. The panel will discuss design and development using standard programs and tools such as VPython, Glowscript, Jupyter notebook, Matplotlib, IPywidgets, Ffmpeg, and POV-ray. Participants are expected to bring your own devices (laptops or tablets) and will be guided to work on practical, interactive hands-on activities, writing code from templates and building your own visualization modules.

W06: Quantum Mechanics with Mathematica

Sponsor: Committee on Educational Technologies
Co-sponsor: Committee on International Physics Education
Time: 8:00 a.m.-12:00 p.m. Saturday
Member Price: $60 Non-Member Price: $85
Location: N212 Eyring Science Center (ESC)

Dan Schroeder, Physics Department, Weber State University, Ogden, UT 84408-2508; dschroeder@weber.edu

Bring quantum mechanics to life! Instead of slogging through lengthy algebra to solve even the most idealized problems, your students could be using versatile numerical methods to find bound states and scattering probabilities for potentials of any shape. With Mathematica they can code a powerful algorithm in just a few lines, and instantly visualize the results using high-level graphics and animation functions. In this workshop you will learn to use Mathematica to: plot wavefunctions in one and two dimensions, using color hues to represent complex phases; find definite-energy wavefunctions for arbitrary potentials using the shooting method, a matrix method, and a relaxation method; solve the time-dependent Schrödinger equation using an explicit finite-difference algorithm; and animate the time evolution of wavefunctions. Most of these techniques are suitable for students in a sophomore-level modern physics course, and all are suitable for an upper-division quantum mechanics course. Prior experience with Mathematica will be helpful but is not required.

W07: Get the Facts Out: Changing the Conversation Around Teaching as a Profession

Sponsor: Committee on Teacher Preparation
Co-sponsor: Committee on Women in Physics
Time: 8:00 a.m.-12:00 p.m. Saturday
Member Price: $60 Non-Member Price: $85
Location: N106 Eyring Science Center (ESC)

Drew Isola, Colorado School of Mines, 1500 Illinois St., Golden, CO 80401; drew.isola@gmail.com

Wendy Adams

In this workshop we will share the Get the Facts Out campaign toolkit to support your efforts to change the conversation about STEM teaching careers in your department. The toolkit, based on pilot interventions that show positive results in shifting perceptions among students and faculty, and which have been shown to outperform traditional recruitment efforts, is designed to be customizable and adaptable to the local situation. The materials and strategies include: (1) both student-facing and faculty-facing resources and a how-to guide for running interactive events, including but not limited to slide decks, clicker questions, and handouts with national survey data on retention, job satisfaction, and student loan forgiveness; (2) sample informational handouts on teacher salaries, comparisons of teacher and faculty salaries, and retirement benefits, with instructions on how to customize these with local data; (3) brochures and posters that incorporate tested messaging strategies; and (4) 60-second narratives and single-sentence "bulleted messages" that can be used as conversation starters in emails or other resources you design. This work is supported by the National Science Foundation IUSE and Noyce Programs.

W08: Fun and Engaging Labs

Sponsor: Committee on Physics in High Schools
Time: 8:00 a.m.-12:00 p.m. Saturday
Member Price: $60 Non-Member Price: $85
Location: N131 Eyring Science Center (ESC)

Wendy Adams, Colorado School of Mines, 1500 Illinois St., Golden, CO 80401; wkadams@mines.edu

Duane Merrell

In this workshop we will share many labs that are suitable for both high school and introductory college physics. The labs are challenging but not too difficult and, leave plenty of room for creativity! We have found success by limiting the goals for the labs to: 1. Fun and engaging, 2. Built in student choice, 3. Related to this week's material. The labs are effective at engaging the students in problem solving and conceptual understanding. Merrell used this type of lab as a high school teacher and physics quickly became one of the most popular classes in the school. Adams, inspired by Merrell, has found that her college students no longer rush to leave, and in some cases stay to see how other groups do even after they've turned in their lab write up for the day! This workshop will allow you to try out these labs for yourself.

W09: PIRA Lecture Demonstrations I & II Condensed: Selections from the PIRA 200

Sponsor: Committee on Apparatus
Time: 8:00 a.m.-12:00 p.m. Saturday
Member Price: $95 Non-Member Price: $120
Location: C215 Eyring Science Center (ESC)

Dale Stile, Rm 58 Van Allen Hall, Dept. of Physics and Astronomy, Univ. of Iowa, Iowa City, IA 52242; dale-stille@uiowa.edu

Sam Sampere

During this half-day workshop, we will introduce you to the Physics Resource Instructional Association (PIRA) and the PIRA 200. Almost every demonstration one can think of has a catalog number within the Demonstration Classification System (DCS); we will introduce you to this system and the comprehensive bibliography that details journal articles and demonstration manuals for construction and use in the classroom. The PIRA 200 are the specific 200 most important and necessary demonstrations needed to teach an introductory physics course. We will also show a subset of approximately 50 demonstrations explaining use, construction, acquisition of materials, and answer any questions in this highly interactive and dynamic environment. Ideas for organizing and building your demonstration collection will be presented. We especially invite faculty members teaching introductory physics to attend. NOTE that this is a paperless workshop. All information and materials will be distributed on a USB thumb drive. A computer, tablet, or other device capable of reading a USB will be needed for note taking, or you can bring your own paper.

W10: Mobilizing the Forgotten Army: Equipping TAs with Inquiry-Based Instruction Methods

Sponsor: Committee on Laboratories
Time: 8:00 a.m.-12:00 p.m. Saturday
Member Price: $80 Non-Member Price: $105
Location: C255 Eyring Science Center (ESC)

Jordan Gerton, 115 South 1400 East, RM 201 Salt Lake City, UT 84112; jgerton@physics.utah.edu

Jackie Chini, Mike Schatz, Emily Alicea-Munoz

In this half-day workshop, participants will reflect on the teaching assistant (TA) professional development programs in their home departments, will articulate goals for improving and enhancing those programs, and will develop strategies for assessing progress toward those goals. Participants will also learn about some specific research-based approaches for helping TAs develop and practice instructional facilitation skills in different environments, including an immersive virtual/mixed-reality approach currently under development. Participants will leave with a personalized TA professional development improvement plan that includes intended outcomes, measures to assess those outcomes, and strategies to move the program towards the outcomes, as well as access to resources for continued refinement. This workshop will be facilitated by a team with several years of experience running a multi-day National TA Workshop for Physics & Chemistry departments, and will utilize some of those resources and processes. Faculty, graduate students, and undergraduates are all welcome and encouraged to attend – colleagues from the same department may wish to consider participating in this workshop as a team (although this is not required).

W11: Introductory Labs for Optical and Wave Physics

Sponsor: Committee on Laboratories
Co-sponsor: AAPT
Time: 8:00 a.m.-12:00 p.m. Saturday
Member Price: $72 Non-Member Price: $97
Location: C425 Eyring Science Center (ESC)

Kenn Lonnquist, 1875 Campus Delivery CSU Physics Kenn; kennlonnquist@gmail.com

Mary Ann Hickman Klassen

Whether your lab curriculum is ripe for an overhaul, well-established, or you are simply looking for exciting and innovative activities for the classroom, this workshop will provide new ideas to bring home to your institution. Presenters from colleges and universities across the United States will each demonstrate their approach to a favorite introductory lab exercise or two. This year's workshop will focus on labs for Optical and Wave Physics. Attendees will have the opportunity to work with each instructor and their apparatus, and will have an opportunity to browse the equipment freely. Links to documentation will be provided for each experiment, with lab manuals, sample data, equipment lists, and construction or purchase information. This workshop is appropriate primarily for college and university instructional laboratory developers, but all instructors are welcome.

W12: Understanding the Mathematical Constructs that Boggle New Physics Students

Sponsor: Committee on Physics in Two-Year Colleges
Co-sponsor: Committee on Physics in Undergraduate Education
Time: 8:00 a.m.-12:00 p.m. Saturday
Member Price: $70 Non-Member Price: $95
Location: N252 Eyring Science Center (ESC)

Trina Cannon, 6315 Rincon Way; cannonb75@gmail.com

Kathy Harper, Martha Lietz

Mathematical Constructs that boggle the mind of new physics students! Students entering physics often have preconceived notions regarding physics. More often that not, these notions are negative. Once instructions begin and assignments are given, negativity grows, and instructors are challenged by both students and administration to alleviate the rising tide! After years of working with these students we have a perspective that should alleviate this stress. We will explore the composite functions that are the source of anxiety. Then we will extend this to the content-rich problems. The composite functions are clues to the solution strategy for these problems that can precede engineering assignments. Finally, we will examine the "Working Backwards Tasks" from TIPERS. In many disciplines that includes mathematical operations, when we learn "to do", also learn to "un-do". These tasks allow students to reverse the solution strategy and begin to "chunck" the process as noted in cognitive science. This will be a powerful experience with brain power, physics scrutiny and exemplary clues for improving a critical component of all physics classes.

W13: Graph Out Loud

Sponsor: Committee on Physics in Two-Year Colleges
Time: 1:00 p.m.-5:00 p.m. Saturday
Member Price: $60 Non-Member Price: $85
Location: N362 Eyring Science Center (ESC)

Cheryl Davis, N313 ESC, Physics and Astronomy, Brigham Young University, Provo, UT 84602; davis@byu.edu; cheryl_davis@byu.edu

Robert C. Davis

Graphing builds conceptual intuition and is an enabling problem solving strategy, but it takes practice. This workshop will focus on graphical analysis as a method for small-team engagement in rich physics contexts. We will share (and help you develop) group-based graphing and diagramming activities for in-class use with whiteboards. The integration of graphing approaches with physics problem solving will also be discussed. We have used these activities in small and large introductory physics classroom environments where they engage students and provide a platform for delivering high quality conceptual guidance and feedback to students in real time. We will guide you in developing implementation plans for you to use in your own classroom.

W14: Using Universal Design for Learning to Prepare for Variation in Physics Learners' Needs, Abilities and Interests

Sponsor: Committee on Research in Physics Education
Co-sponsor: Committee on Professional Concerns
Time: 1:00 p.m.-5:00 p.m. Saturday
Member Price: $63 Non-Member Price: $87
Location: C255 Eyring Science Center (ESC)

Jackie Chini, 4111 Libra Dr., Orlando, FL 32816; jchini@ucf.edu

Erin Scanlon, Westley James

This workshop will introduce participants to the Universal Design for Learning (UDL) framework as a tool to design instruction and curricula that support variation in learners' needs, abilities and interests, with specific focus on students with disabilities. The UDL guidelines emphasize providing supports and options for how students receive information (representation), demonstrate their understanding (action and expression), and engage with the content (engagement). Research shows that popular physics curricula do not enact many UDL-aligned practices. Attendees will have the opportunity to: 1) reflect on their role in designing instruction that supports students with disabilities; 2) practice applying the guidelines to identify barriers in the learning environment and to design options and supports in sample written curricula and instructional scenarios; 3) reflect on their own written curricula and/or classroom practices and design UDL-aligned strategies to implement; and 4) contribute to a list of resources for continuing to plan and implement strategies to make their instruction more accessible. This workshop will be appropriate for high school teachers, college/university instructors, and curriculum developers. Workshop content will incorporate views of students with disabilities about student-centered active learning STEM courses.

W15: PICUP: Integrating Computation into Introductory Physics

Sponsor: Committee on Educational Technologies
Co-sponsor: Committee on Physics in Undergraduate Education
Time: 1:00 p.m.-5:00 p.m. Saturday
Member Price: $60 Non-Member Price: $85
Location: N252 Eyring Science Center (ESC)

Marie Lopez Del Puerto; lope0176@stthomas.edu

Larry Engelhardt, Kelly Roos, Danny Caballero

In this workshop we will discuss the importance of integrating computation into introductory courses in the physics curriculum and will guide participants in discussing and planning how they would integrate computation into their courses. The PICUP partnership has developed materials for a variety of physics courses in a variety of platforms including spreadsheets (Excel or other), Python/VPython, C/C++, Fortran, MATLAB/Octave, Java, and Mathematica. Participants will receive information on the computational materials that have been developed, will discuss ways to tailor the materials to their own classes, and will learn about opportunities that are available to receive additional support through the PICUP partnership. PLEASE BRING A LAPTOP COMPUTER WITH THE PLATFORM OF YOUR CHOICE INSTALLED. This workshop is funded by the National Science Foundation under DUE IUSE grants 1524128, 1524493, 1524963, 1525062, and 1525525. The participant will pay up front for the workshop during registration and receive a refund after the workshop is completed in the amount of $60. The total cost of the workshop to each participant is $20 for AAPT members and $45 for non-members of AAPT.

W16: LIGO & Interferometers

Sponsor: Committee on Apparatus
Co-sponsor: Committee on Contemporary Physics
Time: 1:00 p.m.-5:00 p.m. Saturday
Member Price: $100 Non-Member Price: $125
Location: S420 Eyring Science Center (ESC)

Dan Beeker, Physics Department, Indiana University, 727 E 3rd St., Bloomington, IN 47405; debeeker@indiana.edu

Ken Cecire, Ambere Strunk

Learn about how the LIGO experiment uses interferometry to detect gravitational waves and study the result. We will put together an interferometer (you get to take home) and do other hands-on activities with LIGO physics. Bring your laptop to work with LIGO data. Bring a web cam if you would like to analyze diffraction data using video.

W17: Using Astronomy Demonstration Videos

Sponsor: Committee on Space Science and Astronomy
Time: 1:00 p.m.-5:00 p.m. Saturday
Member Price: $30 Non-Member Price: $43
Location: N131 Eyring Science Center (ESC)

Kevin Lee, 244D Jorgensen Hall, University of Nebraska, Lincoln, NE 68588-0299; klee@unl.edu

Emily Welch

This project is developing a series of more than 40 videos centered on physical demonstrations that are ideal for use in introductory astronomy and physics courses. They can be utilized in the classroom, in homework and in distance education courses. Interactive materials accompany or are incorporated into many videos, consistent with the recommendations of educational research to maximize student learning from demonstrations. These videos are hosted on YouTube and on the Astronomy Education web site at the University of Nebraska, a site that is widely-used by astronomy educators. Workshop participants will be exposed to the underlying pedagogy of the videos and then experience them first in the role of the student and then in the role of instructor. This project is funded by NSF award #1245679. Participants are expected to bring their own laptop computer.

W18: Getting Your Paper Published

Sponsor: Committee on Physics in Undergraduate Education
Co-sponsor: Committee on International Physics Education
Time: 1:00 p.m.-5:00 p.m. Saturday
Member Price: $60 Non-Member Price: $85
Location: C261 Eyring Science Center (ESC)

David Jackson, Dept. of Physics, Dickinson College, Carlisle, PA 17013; jacksond@dickinson.edu

Gary White

Are you interested in publishing a physics paper, but are a bit intimidated by the process? If so, then this workshop is for you. In this workshop, we will discuss the entire process involved in turning an idea into a published paper. Attendees will learn about developing a compelling storyline, the importance of figures, doing background research, and understanding your audience. In addition, we will walk through the entire publication process, from initial submission through peer review to final publication, providing some basic tips on how to deal with each step of the process. Although this workshop will focus primarily on AAPT's journals (*The Physics Teacher* and the *American Journal of Physics*), most of what is learned will apply equally well to other journals.

W19: Breaking Glass with Sound Waves (Make & Take)

Sponsor: Committee on Apparatus
Time: 1:00 p.m.-5:00 p.m. Saturday
Member Price: $80 Non-Member Price: $105
Location: N106 Eyring Science Center (ESC)

Dave Kardelis, USU Eastern 451 E 400 N; dkardelis@gmail.com
Sam Sampere, Don Balanzat

Participants will make a device to break plate glass using sound. The device breaks glass in a much more controllable fashion and does not require the high volume needed to break a wine glass. Additionally if so inclined the device can be used to measure standing waves in the glass and effects or length, width and thickness. At the home institution the an power amplifier(stereo amp or PA amp) and a function generator will be required.

W20: Machine Learning in PER

Sponsor: Committee on Research in Physics Education
Co-sponsor: Committee on Educational Technologies
Time: 1:00 p.m.-5:00 p.m. Saturday
Member Price: $135 Non-Member Price: $160
Location: C460 Eyring Science Center (ESC)

John Aiken, Sem Sælands Vei 24 Uio/Fysisk Inistitutt; johnm.aiken@gmail.com

Rachel Henderson, Danny Caballero

Physics Education Research has long collected quantitative data sets. These data sets have been traditionally examined using descriptive statistics and classical analysis frameworks. Machine learning has expanded the traditional analysis toolbox by adding tools that are more adept at examining data commonly collected in PER (e.g., categorical data, text data, social network data). The University of Oslo/Michigan State University joint Learning Machines Lab (http://learningmachineslab.github.io) has created a collection of Jupyter notebooks that introduce researchers in DBER to machine learning. This workshop will bridge the gap between the traditional quantitative data sets collected by PER and new machine learning tools available in the python programming environment. Participants will be exposed to various modeling techniques (regression and classification) and will participate in a group research project using real PER data. Participants should bring a laptop with Anaconda Python 3.x installed.

W22: Teaching Innovation and Entrepreneurship in Physics: Helping Physics Students Change the World

Sponsor: Committee on Physics in Undergraduate Education
Time: 8:00 a.m.-5:00 p.m. Sunday
Member Price: $85 Non-Member Price: $110
Location: Science Building 136

Crystal Bailey, American Physical Society, One Physics Ellipse, College Park, MD 20740; bailey@aps.org

Bahram Roughani, Randy Tagg, Linda Barton, Jason Deibel, Wouter Deconinck, Doug Petkie, Doug Arion, Bill Briscoe

The physics education community has recently gained insights into, and made recommendations concerning, the skills and knowledge needed to best prepare physics students for future careers - in particular, careers in private sector and/or entrepreneurial environments (e.g. the Phys21 Report). We also know that the broad problem solving ability and deep understanding of natural principles afforded by a physics education makes physicists natural innovators: there is a real role to be played by physics graduates in solving difficult problems that address human need. Physics Innovation and Entrepreneurship (PIE) education is an approach to teaching the skills, knowledge, and mindset to help physics graduates pursue careers and become successful agents of change in the scientific workforce. This workshop will be broken into four sections focused on how PIE can address each set of learning goals outlined in the Phys21 report: physics-based knowledge, scientific and technical skills, communication skills, and professional and workplace skills. Participants will be asked to provide feedback on what they experienced, and learn how they can engage in this growing community.

W23: An Introduction to Data Science for Emerging Quantitative Researchers with R-Studio

Sponsor: Committee on Research in Physics Education
Co-sponsor: Committee on Graduate Education in Physics
Time: 8:00 a.m.-12:00 p.m. Sunday
Member Price: $60 Non-Member Price: $85
Location: Science Building 138

Jayson Nissen, 659 Sw Jefferson Ave. #2, Corvallis, OR 97333; jayson.nissen@maine.edu

Daryl McPadden, John Buncher, Geoff Potvin, Robert (Bud) Talbot

This workshop covers statistical tests for comparing two groups and a process for learning new statistical methods by applying these methods to common tasks in physics education research. The application, interpretation and limitations of common inferential tests will be emphasized by focusing on developing a conceptual understanding of variance in data, visualizations that account for variance, and the relationships between variance, effect sizes, and p-values. Participants will work in small groups with facilitators and participate in larger group discussions. They will compare scores on concept inventories and responses to a multiple-choice question using parametric tests for interval and ratio scale data and nonparametric tests for ordinal and nominal data. To facilitate these conversations, we will provide a working file in RStudio; however, participants do not need any prior experience with statistics or with RStudio. We invite more advanced RStudio users and quantitative researchers to participate and to support other participants. By focusing on the process for learning new statistical methods, participants will leave with skills and resources to conduct, evaluate, and report their own analyses.

W24: Designing Economical Outreach Kits for Physics

Sponsor: Committee on Apparatus
Co-sponsor: Committee on Science Education for the Public
Time: 8:00 a.m.-12:00 p.m. Sunday
Member Price: $80 Non-Member Price: $105
Location: Science Building 132

Stephen Irons, Yale University, Department of Physics, 217 Prospect Street, New Haven, CT 06520; stephen.irons@yale.edu

Paul Noel

In this workshop you will learn strategies to design, source and build economical physics-based outreach kits. In the first portion we will discuss: where to get ideas, where to purchase parts and materials and how to successfully distribute your kits. 3D printer part design using free software, will be described as well as how these parts can be successfully integrated into any project. Other maker space tools will be discussed as time permits. Resources for designing PCBs will be discussed as compact circuits can be integrated into a wide variety of projects. During the active portion, workshop participants will be introduced to some computer design applications and then assemble their choice of a kit, which will be provided. Kits may involve soldering, non-powered hand tools, and glue.

W25: Creating Sustainable Change in University Departments: Theory and Practice

Sponsor: Committee on Research in Physics Education
Co-sponsor: Committee on Professional Concerns
Time: 8:00 a.m.-12:00 p.m. Sunday
Member Price: $62 Non-Member Price: $87
Location: Pope Science 002

Joel Corbo, 860 35th Street, Boulder, CO 80303; joel.corbo@colorado.edu

Gina M. Quan

Creating sustainable change in university departments can be a difficult challenge to achieve. For the last several years, we have been creating Departmental Action Teams (DATs), which are teams of 4 to 8 faculty members, staff, and/or students that are created by a department and facilitated by our project team to achieve two goals: (1) to create sustainable change related to undergraduate education in the department by shifting departmental structures and culture and (2) to help DAT participants become change agents through developing facilitation and leadership skills. In this workshop, we will support participants in learning how to more effectively create change related to undergraduate education in their departments. Participants should expect both to learn theory for understanding change and to develop practical skills for enacting change. The workshop will be informed both by literature on organizational change, facilitation, and higher education and our team's own experience in working with about a dozen DATs at two universities.

W26: Fun, Engaging, Effective, Research-Validated Lab Activities and Demos for Introductory University, College and High School Physics

Sponsor: Committee on Research in Physics Education
Co-sponsor: Committee on Educational Technologies
Time: 8:00 a.m.-12:00 p.m. Sunday
Member Price: $75 Non-Member Price: $100
Location: Pope Science 001

David Sokoloff, Department of Physics, University of Oregon, 1371 E 13th Avenue, Eugene, OR 97403; sokoloff@uoregon.edu
Ronald K. Thornton

Participants in this workshop will have hands-on experience with research-validated active learning activities for the introductory laboratory—including RealTime Physics (RTP) labs using computer-based tools and video analysis—that have been used effectively in university, college and high school physics courses. They will also experience Interactive Lecture Demonstrations (ILDs)—a strategy for making lectures more active learning environments. These active learning approaches are fun, engaging and validated by physics education research (PER). Research results demonstrating the effectiveness of RTP and ILDs will be presented. Emphasis will be on activities in mechanics, electricity and magnetism and optics. The following will be distributed: Modules from the Third Edition of RTP, and the ILD book.

W27: Just-in-time Teaching

Sponsor: Committee on Educational Technologies
Time: 8:00 a.m.-12:00 p.m. Sunday
Member Price: $30 Non-Member Price: $45
Location: Pope Science 004

Andy Gavrin, IUPUI Dept of Physics, LD154 402 N. Blackford St. Indianapolis, IN 46202; agavrin@iupui.edu

For 20 years, faculty members in physics, math, engineering and many other fields have used Just-in-Time Teaching, also known as "JiTT." By creating a short time scale feedback loop between homework and the classroom, JiTT encourages students to be prepared for class, promotes active learning in the classroom, improves students' overall engagement with the course. JiTT also provides faculty with greater insight to their students' thinking and preparation, enabling them to make the most of classroom time. This workshop will introduce JiTT methods, and show how they can be implemented in a variety of educational settings. Participants will learn to implement JiTT using their LMS or free technology, and will be introduced to an online library of assignments that they can use or adapt. By the end of the session, participants will have several JiTT assignments usable in their own classes. We will also discuss tips and tricks for a successful implementation.

W28: Demo Kit in a Box: Sound and Waves

Sponsor: Committee on Science Education for the Public
Co-sponsor: Committee on Apparatus
Time: 8:00 a.m.-12:00 p.m. Sunday
Member Price: $95 Non-Member Price: $120
Location: Pope Science 108

Steve Lindaas, The University of Utah 115 South 1400 East Room 201 James Fletcher Building Salt Lake City, UT 84112-0830; lindaas@mnstate.edu

Adam Beehler

This workshop is packed with sound and wave demos and activities suitable for all ages. Are you looking for easy ways to infuse inquiry into your classroom? Don't have a demo manager? We will help you establish having several small demos conveniently packed into one box, ready for the classroom at any moment. You may bring your box to your class and use the demos to highlight lecture points, or use them when a student asks a question. Use a "Just-In-Time" teaching approach but with a demo twist! We will show you how to pack small demo kit boxes that pack a large instructional punch. Come hear the demos and ride the wave. Participants will leave with a lot of demos!

W29: A Primer on Computing with Python

Sponsor: Committee on Physics in Undergraduate Education
Co-sponsor: Committee on Educational Technologies
Time: 8:00 a.m.-12:00 p.m. Sunday
Member Price: $60 Non-Member Price: $85
Location: Science Building 060

David Jackson, Dept. of Physics, Dickinson College Carlisle, PA 17013; jacksond@dickinson.edu

Larry P. Engelhardt

Programming in Python is becoming quite popular as a means of introducing computational methods into the physics program. If you are curious as to what all the fuss is about but don't really know how to get started, then this workshop is for you. In this workshop attendees will install a working Python distribution and learn the basic tools needed for writing simple programs using Jupyter notebooks and the Spyder development environment. Some of the topics to be discussed include reading data from a file, plotting graphs, and curve fitting. Attendees will also learn to solve Newton's second law problems and create animations. In short, we want to give you the basic skills needed to help you feel comfortable programming in Python. We will also discuss ideas on how to incorporate computational exercises into your classes and introduce you to the PICUP website where you can explore and download dozens of peer-reviewed Exercise Sets that have been developed on a variety of physics topics. For maximum benefit, attendees should bring a laptop computer to this workshop. PICUP has been supported by the National Science Foundation under DUE IUSE grants 1524128, 1524493, 1524963, 1525062, and 1525525.

W30: Fostering Inclusivity in Physics: Resources, Strategies, and Interventions

Sponsor: Committee on Women in Physics
Co-sponsor: Committee on Diversity in Physics
Time: 8:00 a.m.-12:00 p.m. Sunday
Member Price: $60 Non-Member Price: $85
Location: Science Building 032A

Mike Vignal; vignalm@oregonstate.edu

MacKenzie Lenz, Kelby Hahn

This workshop aims to help physicists and physics educators practice creating inclusive environments in their classrooms, schools, and/or departments. The tools and strategies developed in this workshop are informed by intersectional feminism, feminist science studies, and physics education research. In the first half of this workshop, we explore different ways institutional and structural discrimination manifest in physics institutions and communities. We discuss ways to identify, anticipate, and mitigate these discriminations before they occur as well as strategies for handling situations as they arise. In the second half of the workshop, we practice identifying and intervening in instances of discrimination and bias. This practice helps participants become knowledgeable about and comfortable with addressing these issues as they arise in everyday situations.

W31: PTRA: Cartoon Physics

Sponsor: Committee on Physics in Pre-High School Education
Time: 8:00 a.m.-12:00 p.m. Sunday
Member Price: $70 Non-Member Price: $95
Location: Pope Science 107

Kenric Davis, 1508 Castle Creek Dr., Little Elm, TX 75068; kenric.davies@gmail.com

Looking for more engaging science examples for your elementary or middle school classroom? In this session, we will break down scenes from classic cartoons like

Coyote and Roadrunner, Speedy Gonzales, and other cartoon movies using physics concepts taught in the elementary and middle grades. Teachers will go through a few hands on experiments that their students can do to test whether or not the cartoon scenes showed good or bad physics. Teachers will also use the CER (Claim, Evidence, and Reasoning) method of developing good scientific explanations that are grade level appropriate. Participants will receive information on where to find each clip and hands on materials for easy use in the classroom.

W32: Designing and Building Informal Programs

Sponsor: Committee on Science Education for the Public
Time: 8:00 a.m.-12:00 p.m. Sunday
Member Price: $65 Non-Member Price: $90
Location: Pope Science 268

Mike Bennett, 440 UCB Boulder, CO 80309; mibe5762@jila.colorado.edu

Claudia Fracchiolla

This workshop will address three important aspects of designing and building informal physics education programs: values-driven development, thoughtful implementation, and evidence-based sustainability. The focus of the workshop will be on big-picture planning rather than specific tools, physics demonstrations, or apparati. First, attendees will develop their own broad plans for program design based upon the needs and goals of both their programs and their communities. Second, attendees will explore unique pathways for creating organizational partnerships and gain strategies for crucial program aspects such as volunteer recruitment and training. Third, attendees will learn about tools for maintaining a successful program in the long-term, with a focus on methods of evaluation, assessment, and discipline-based research. The workshop is highly interactive and participants will work with both the facilitators and each other, both giving and receiving feedback on the ideas and strategies shared. By the end of the workshop, attendees will have developed strong, evidence-based strategies for leveraging effective design, implementation, and assessment techniques toward sustainable informal education programs.

W34: Coding Integration in High School Physics and Physical Science

Sponsor: Committee on Physics in High Schools
Co-sponsor: Committee on Educational Technologies
Time: 8:00 a.m.-12:00 p.m. Sunday
Member Price: $30 Non-Member Price: $43
Location: Pope Science 102

Chris Orban, 191 W Woodruff Ave.; orban@physics.osu.edu

Richelle Teeling-Smith

Ever wondered how to integrate a little bit of coding into a high school physics class without overwhelming your students or taking up lots of class time? This hands on workshop will provide an overview of simple, conceptually-motivated exercises where students construct games like asteroids and angry birds using a free in-browser editor that works great on chromebooks or whatever devices you have. Following that we will show you how to use stemcoding.osu.edu which is a free "learning management system" that is designed to facilitate using coding activities in sizable classes. This framework also includes assessment questions designed to probe whether students are building their conceptual knowledge as they complete the activities. We will share with you a full set of lesson guides and solutions for over 17 different simple coding activities for high school physics and physical science, all of which produce PhET-like interactives. If you have enjoyed seeing coding tutorial videos on the STEMcoding youtube channel (http://youtube.com/c/STEMcoding) here is your chance to do a deep dive! The STEMcoding project is led by Prof. Chris Orban from Ohio State Physics and Prof. Richelle Teeling-Smith in the physics department at the University of Mt. Union. The STEMcoding project is supported in part by the AIP Meggers Project Award.

W35: Group-Worthy Tasks

Sponsor: Committee on Physics in High Schools
Co-sponsor: Committee on Teacher Preparation
Time: 8:00 a.m.-12:00 p.m. Sunday
Member Price: $60 Non-Member Price: $85
Location: Science Building 259

Kelly O'Shea, 40 Charlton Street, New York, NY 10014; kellyoshea@gmail.com
Marta Stoeckel

Students often learn and work in groups, and scientists also work in teams. How can we make sure that the tasks we give students are really group-worthy? In Designing Groupwork: Strategies for the Heterogeneous Classroom, a group-worthy task is defined as one that is open-ended, provides multiple entry points and multiple ways to demonstrate knowledge, and requires positive interdependence from students. Because group-worthy tasks emphasize the value of multiple abilities and a range of approaches to a problem, they provide the opportunity for all students to engage deeply and meaningfully with the content. These types of tasks also often meet many of the NGSS Science and Engineering Practices. In this workshop, we will discuss characteristics of group-worthy tasks and share tasks that the presenters have used. Participants will also have the opportunity to work on adapting and applying these ideas for their own classrooms. Although we hope that this workshop will be interesting to a wide audience, our target audience is high school teachers.

W36: New Resources for AP Physics

Sponsor: Committee on Physics in High Schools
Time: 8:00 a.m.-12:00 p.m. Sunday
Member Price: $60 Non-Member Price: $85
Location: Science Building 238

Tanya Sharpe, 3700 Crestwood Parkway, Duluth, GA 30096; LSharpe@collegeboard.org
Matthew Sckalor, Angela Jensvold, Michelle Strand, Tanya Sharpe, Amy Johnson

The AP Physics Symposium will support the AP Physics 1, AP Physics 2, AP Physics C – Mechanics and AP Physics C – Electricity and Magnetism courses and consist of three distinct sessions: 1) The Course, 2) The Exam, and 3) New Resources. Each session will provide participants with opportunities to share ideas and best practices, as well as learn of instructional strategies and approaches for enhanced teaching and learning. At the end of each session presenters and participants will engage in Q&A.

W37: Improving the Pedagogical Content Knowledge of Teaching Assistants and Instructors

Sponsor: Committee on Research in Physics Education
Co-sponsor: Committee on Teacher Preparation
Time: 1:00 p.m.-5:00 p.m. Sunday
Member Price: $60 Non-Member Price: $85
Location: Science Building 060

Alexandru Maries, 345 Clifton Court, Cincinnati OH 45221; mariesau@ucmail.uc.edu

Chandralekha Singh

Both graduate and undergraduate students have been playing an active role in educating the physics undergraduate students in physics, serving as Teaching Assistants (TAs) in undergraduate recitations and labs. These recitations and labs sometimes use research-based instructional strategies (e.g., group work and conceptual tutorials in recitation, inquiry-based labs), and TAs may not be familiar with or fully buy into this pedagogy. When working on conceptual tutorials for example, it is beneficial if the TAs are aware of common student alternate conceptions (e.g., motion at constant speed requires constant force), and this workshop will explore the literature on the extent to which TAs are aware of various alternate conceptions and discuss productive approaches to help TAs learn about introductory students' alternate conceptions. This workshop will help participants design an effective plan for their teaching assistant professional development that includes activities designed to help TAs become aware of students' alternate conceptions and become reflective teachers trying to understand how students are thinking.

W38: Getting Students to Think Critically in Intro Labs

Sponsor: Committee on Research in Physics Education
Co-sponsor: Committee on Laboratories
Time: 1:00 p.m.-5:00 p.m. Sunday
Member Price: $60 Non-Member Price: $85
Location: Pope Science 107

Natasha Holmes; ngholmes@cornell.edu

Emily M. Smith

In this hands-on, minds-on workshop, we'll explore new research-based strategies for getting students to think critically in intro physics labs. We'll explore methods of teaching scientific practices such as uncertainty and data analysis, modeling, and experimental design. We will focus on a strategy that uses cycles of comparisons and decision making to expose students to the creativity and excitement of physics experimentation, the nature of measurement, and more. We aim for participants to leave the workshop with tools, ideas, and structure to implement the approach in their own courses.

W39: Developing the Next Generation of Physics Assessments

Sponsor: Committee on Research in Physics Education
Co-sponsor: Committee on Teacher Preparation
Time: 1:00 p.m.-5:00 p.m. Sunday
Member Price: $60 Non-Member Price: $85
Location: Science Building 138

James Laverty, 1228 N. 17th St., Manhattan, KS 66506; laverty@ksu.edu

Want to write assessments that will give you more evidence about what your students are actually able to do with their physics knowledge? If so, then this is the workshop for you. Participants will learn how to use the Three-Dimensional Learning Assessment Protocol (3D-LAP; a research-based protocol) to develop in-class, homework, and exam problems that engage students in both the process and content of physics. This instrument was developed to help assessment authors at all levels generate questions that include scientific practices, crosscutting concepts, and disciplinary core ideas, the three dimensions used to develop the Next Generation Science Standards. Join us to learn how to create the next generation of physics assessments.

W41: Teaching Introductory Physics in an Earth & Space Science Context – Resources for Hands-on & Minds-on Instruction

Sponsor: Committee on Space Science and Astronomy
Time: 1:00 p.m.-5:00 p.m. Sunday
Member Price: $60 Non-Member Price: $85
Location: Pope Science 005

Shannon Willoughby; shannon.willoughby@montana.edu

Rebecca Vieyra

Join this fully reimbursable workshop to sample instructional materials appropriate for high school and introductory college physics and astronomy teachers who want to teach basic physics concepts using space science content and authentic data. Attendees will sample selected labs and tutorials developed and tested by physics education researchers through the NASA Space Science Education Consortium. These materials address topics that integrate Physics, Earth Science, and Space Science through extended, structured activities. Examples include (1) coronal mass ejection videos to understand both simple mechanics as well as acceleration of relativistic particles, (2) sunspot data to understand period and frequency, (3) eclipses to understand geometric optics, and (4) auroral currents to understand electromagnetism. This workshop is fully funded by a NASA Grant/Cooperative Agreement Number NNX16AR36A awarded to Temple University and the AAPT. Participants who complete the workshop will receive full reimbursement of their workshop registration fee.

W43: Teaching Physics towards Social Justice

Sponsor: Committee on Diversity in Physics
Co-sponsor: Committee on Science Education for the Public
Time: 1:00 p.m.-5:00 p.m. Sunday
Member Price: $65 Non-Member Price: $90
Location: Pope Science 001

Moses Rifkin, 8000 25th Ave. NE, Seattle, WA 98103; MRifkin@universityprep.org

Johan Tabora, Chris Gosling, Andrew Morrison, Danny Doucette, Abigail Daane, Adam Quall

Motivated by our shared desire to address under-representation in physics and support systemically non-dominant groups, we have created a flexible, modular curriculum designed to help physics instructors bring conversations about science and society into our classrooms. Topics include: under-representation in STEM, systemic racism, implicit bias, stereotype threat, and the myth of meritocracy in a physics context. Attendees will experience the curriculum first-hand, and learn how to implement it in their own classrooms.

W44: Intermediate and Advanced Labs

Sponsor: Committee on Laboratories
Co-sponsor: AAPT
Time: 1:00 p.m.-5:00 p.m. Sunday
Member Price: $85 Non-Member Price: $110
Location: Pope Science 016

Jeremiah Williams, 225 N. Fountain Ave., Physics Department, Wittenberg University, Springfield, OH 45504 ; jwilliams@wittenberg.edu

This workshop is appropriate for college and university instructional laboratory developers. At each of five stations, presenters will demonstrate an approach to an intermediate or advanced laboratory exercise. Each presenter will show and discuss the apparatus and techniques used. Attendees will cycle through the stations and have an opportunity to use each apparatus. Documentation will be provided for each experiment, with sample data, equipment lists, and construction or purchase information.

W45: Modifying Introductory Labs to Target Scientific Reasoning and Decision-Making Abilities

Sponsor: Committee on Physics in Two-Year Colleges
Co-sponsor: Committee on Laboratories
Time: 1:00 p.m.-5:00 p.m. Sunday
Member Price: $60 Non-Member Price: $85
Location: Pope Science 102

Kathleen Koening, University of Cincinnati, 417 Geo-Phys Building, 345 Clifton Ct., Cincinnati, OH 45221; koenigkn@ucmail.uc.edu

Krista E. Wood, Lei Bao

Participants will learn how to modify their introductory physics lab course to better support the development of reasoning abilities necessary for scientific inquiry and critical thinking. Using tested lab curriculum, participants will work through activities that model the facilitation of guided inquiry-based labs focused on designing and conducting controlled experiments, making appropriate decisions, engaging in data analysis, interpretation, and synthesis to construct meaningful evidence-based claims, and communication of outcomes. The curriculum meets the AAPT Lab Guidelines while explicitly targeting select scientific reasoning (SR) sub-skills. It was developed using a curricular framework based on these operationally defined SR sub-skills, includes deliberate skills-based practice through pre-lab hypothetical scenarios and in-class activities, and uses a progressive learning cycle scaffolded through Socrative dialogue. Participants will learn how to apply our SR-focused curricular framework to modify their existing labs, as well as how to include a variety of formative and summative assessments to measure the impact of the lab on developing targeted skills. Participants will receive all research-based lab materials and assessments that we currently use, along with future support for implementation at their home institutions.

W46: Astronomy Research Seminar Workshop

Sponsor: AAPT
Time: 1:00 p.m.-5:00 p.m. Sunday
Member Price: $60 Non-Member Price: $85
Location: Science Building 259

Russell M. Genet, California Polytechnic State University, Astronomy Instructor, Cuesta College Institute for Student Astronomical Research

Rachel Freed

This workshop prepares high school and college instructors to start their own Astronomy Research Seminar. A dozen high schools and colleges offer this seminar which has produced 150 published papers with over 500 coauthors. Teams prepare a research proposal, manage their own research, obtain and analyze original data, write a team paper, obtain an external review, submit their paper for publication, and give a public PowerPoint presentation—all in a single semester. Seminars are supported by the Small Telescope Astronomical Research Handbook, an open-source learning management system, and a community of experienced professional and amateur astronomers organized by the Institute for Student Astronomical Research (www.In4StAR.org). Being a coauthor improves a student's chance of obtaining a scholarship as a result of their demonstrated research experience and encourages STEM careers. Participants will receive a complimentary copy of the book, Small Telescope Astronomical Research Handbook. This book contains much of the information they will need to start their own Astronomy Research Seminar. Participants should save room in their luggage to take the 8.5x11" hardbound book home with them. PlaneWave Instruments is sponsoring this book for the workshop's participants.

W47: Teaching About Work and Energy

Sponsor: Committee on Teacher Preparation
Co-sponsor: Committee on Physics in High Schools
Time: 1:00 p.m.-5:00 p.m. Sunday
Member Price: $60 Non-Member Price: $85
Location: Science Building 032A

Gay Stewart, Department of Physics, West Virginia University; gbstewart@mail.wvu.edu

Energy and systems are fundamental, crosscutting science concepts, and physics is the place to help students develop a deeper conceptual understanding. However, students hear what we say, not what we mean! Trying to simplify our discussions of work and energy (particularly potential energy) can generate increased confusion. What could be a single approach to solving a wide variety of problems becomes compartmentalized into many special cases to be memorized. What we mean is so clear to those of us "in the club" that assessments are not always designed to elicit the incorrect models many students hold. In Learning and Understanding (2002), the National Research Council presented design principles vital to improving the effectiveness of AP and introductory college courses in the U.S. Focusing on key ideas and providing ample opportunities to explore them in depth is one recommendation perfectly served by a more careful approach to energy and systems. We will look at a few examples of how common wording can generate incorrect models, and then spend our time considering how to help our students develop a single coherent conceptual model that significantly impacts their ability to use more robust problem-solving approaches and to describe and model physical situations.

W48: Curriculum Swap: Creating, Sharing, and Improving Student-centered Physics Activities for Life Science Students

Sponsor: Committee on Physics in Two-Year Colleges
Time: 1:00 p.m.-5:00 p.m. Sunday
Member Price: $60 Non-Member Price: $85
Location: Science Building 132

Chandra Turpen & Sam McKagan, Department of Physics, University of Maryland, College Park; Chandra.Turpen@colorado.edu and

Adrian Madsen

Come join a community of faculty committed to innovative teaching within introductory college physics courses for life science students. Bring an instructional task that you are proud of to share with other highly engaged educators. Bring a second instructional task that has potential but that you've run into problems implementing. Solicit other educators' reactions to your student activities. Hear about innovative things that other highly engaged educators are doing. In this workshop, educators will discuss the logic behind why they organize their physics activities in the ways that they do. Learn how to use the Living Physics Portal (livingphysicsportal.org) to make your innovations accessible to other educators. By the end of the workshop, you will be prepared to contribute your own activities to the Portal for other educators to use and adapt. You will also hear about opportunities to continue engaging in community activities.

W49: STEP UP – Take Action to Engage Women in Physics

Sponsor: Committee on Women in Physics Co-sponsor: Committee on Physics in Two-Year Colleges
Time: 1:00 p.m.-5:00 p.m. Sunday
Member Price: $60 Non-Member Price: $85
Location: Pope Science 203

Robynne Lock and T. Blake Head , Texas AM University-Commerce ; robynne.lock@tamuc.edu

Support inclusive classroom practices in physics education through active strategies and discussions. Come to this workshop to learn how to be a part of a national campaign for high school physics teachers and their students, STEP UP 4 Women (Supporting Teachers to Encourage Pursuit of Undergraduate Physics for Women). During this workshop, learn about gender representation in physics in the U.S. and around the world, and engage in active strategies and two specific lessons that are demonstrated to enhance the physics identity of young women. If half of the high school physics teachers in the U.S. encourage just one more female student to pursue physics as a major, a historic shift will be initiated – female students will make up 50% of incoming physics majors. Undergraduate faculty have a special role to welcome and retain these young women. Whoever you might be, be a part of the change!

Session AA PER: Instructional Practices and TA/LA Training

Location: MH - Bryce **Sponsor:** AAPT **Time:** 8:30–10:30 a.m. **Date:** Monday, July 22 **Presider: TBD**

AA01: 8:30-8:40 a.m. Leading Departmentally Based Change Initiatives: The Science Education Initiative Handbook*

Contributed – Stephanie Chasteen, University of Colorado Boulder, 247 Regal St., Louisville, CO 80027; stephanie.chasteen@colorado.edu

Warren Code, University of British Columbia

Educational change efforts focused at the department level can be particularly powerful. Positive outcomes, however, are not automatic. This talk will share some of the big lessons-learned from the Science Education Initiatives (SEIs) designed by Carl Wieman, in which postdoctoral fellows were embedded directly within disciplinary departments as catalysts of change. Come see our messages for initiative leaders, departmental faculty, and embedded postdocs and instructors on effectively leading change through embedded experts within departments.

*The free, open-source SEI Handbook is available at https://pressbooks.bccampus.ca/seihandbook/.

AA02: 8:40-8:50 a.m. Teaching Assistant Reflections on Practice Sessions in a Mixed-reality Classroom Simulator

Contributed – Constance M. Doty, University of Central Florida, 4111 Libra Drive, Orlando, FL 32816; Constance.Doty@knights.ucf.edu

Tong Wan, Ashley A. Geraets, Erin K. H. Saitta, Jacquelyn J. Chini, University of Central Florida

Multiple STEM disciplines have adopted student-centered active learning laboratory activities as an alternative to traditional laboratories. However, the professional development received by GTAs that lead these courses has been reported to vary across STEM disciplines. In this study, practice teaching sessions in the mixed-reality simulator, TeachLivE, were integrated into the professional development for GTAs leading student-centered active learning introductory physics and chemistry laboratories. During their session, GTAs were given two opportunities to practice two teaching skills (normalize error and cold call) while leading a discussion with avatar-students. Between times in the simulator, GTAs were asked to reflect on their performance before trying again. Here, we discuss GTA reflections on their performance in the simulator focused on their opinions about how the simulator supported their practice with the teaching skills. In addition, we describe the relationship between their reflection and the actual implementation of teaching skills in their practice sessions.

AA03: 8:50-9:00 a.m. Characterizing Instructional Practices in Inquiry-Oriented Laboratories

Contributed – Tong Wan, University of Central Florida, 4111 Libra Drive, Orlando, FL 32816; tong.wan@ucf.edu

Constance M. Doty, Ashley A. Geraets, Erin K. H. Saitta, Jacquelyn J. Chini, University of Central Florida

While the discipline-based education community has been dedicated to developing inquiry-oriented labs, little research has investigated instructional practices of graduate teaching assistants (GTA), who are often the ones leading such laboratories. Thus, the goal of this study is to characterize GTAs' instructional practices in inquiry-oriented laboratories. Specifically, we focused on algebra-based introductory physics "mini-studios" (which combine student-centered recitation with inquiry-oriented lab) and an introductory general chemistry inquiry-oriented lab at the University of Central Florida. We used a classroom observation protocol adapted from the Laboratory Observation Protocol for Undergraduate STEM (LOPUS) to document both GTA and student behaviors. We present data to demonstrate different GTA instructional styles, including the extent to which GTAs use pedagogical strategies such as lecture and posing questions. We compare our identified instructional styles to those previously identified in a traditional general chemistry lab. These results provide insight for developing strategies for GTA professional development.

AA04: 9:00-9:10 a.m. Students' Sense of Belonging in Introductory Science Labs: Does GTA Training Matter?

Contributed – Caitlin Kepple, San Francisco State University, 1207 Broderick St., San Francisco, CA 94115-3906; ckepple@mail.sfsu.edu

Kim Coble, San Francisco State University

Over the past year, the Physics and Astronomy Department at San Francisco State University has implemented a pedagogical training course for incoming graduate teaching assistants (GTAs). While it has been widely accepted that students' sense of belonging in the classroom can be influenced by many factors, our focus is on those that may be created or impacted by the GTA. These factors may include students' interpersonal relationships in lab, perceived competence, or their science identity. We have collected both interview and survey data from new and returning GTAs, as well as a number of attitudinal surveys from students taking introductory physics and astronomy labs. Our goal is to identify potential key factors that may affect students' sense of belonging and ultimately provide insight for future lab instructors to help create an inclusive and accessible laboratory environment.

AA05: 9:10-9:20 a.m. Looking Back on Six Years of GTA Preparation

Contributed – Emily Alicea-Munoz, Georgia Institute of Technology, 837 State St., Atlanta, GA 30332; ealicea@gatech.edu

Six years ago, the School of Physics at Georgia Tech began a new graduate teaching assistant (GTA) preparation program that integrated physics content, pedagogy, and professional development strategies. To date, over 130 graduate students total, accounting for around 80% of the current grad student population, have participated in the program. Here we will talk about how the program came into being, how its curriculum has evolved over the years, a brief overview of its assessments, and what changes and expansions the program will have in the near future.

AA06: 9:20-9:30 a.m. Supporting the LA Model Weekly Preparation Session: A Tool for Practitioners*

Contributed – Mel Sabella, Chicago State University, 9501 S. King Drive, Chicago, IL 60628; msabella@csu.edu

Felicia Davenport, Fidel Amezcua, Andrea G. Van Duzor, Chicago State University

The Learning Assistant (LA) Model involves undergraduate students as peer support in STEM classrooms. Ideally, LAs meet weekly with the instructors of the classes they serve. The weekly sessions provide multiple benefits for the students in LA supported classes, the LAs, and the instructors. While the weekly preparation session has the least amount of structure in the LA Model and has the most variation from institution to institution and from instructor to instructor, it is an essential part of the model. Our work has focused on how we can better understand what is happening in the weekly preparation session and how we can better support instructors to (1) recognize the importance of the weekly preparation session and (2) effectively reflect on these sessions. This work has led to the development of a tool for the practitioner to support their thinking around these sessions.

* Supported by the National Science Foundation (DUE#1524829) and the Department of Education.

AA07: 9:30-9:40 a.m. Analyzing Fieldnotes to Characterize Teaching Approaches in Physics Help Sessions

Contributed – Laura A. Wood, Michigan State University, 220 Trowbridge Rd., East Lansing, MI 48824; laura.anne.wood@gmail.com

Vashti Sawtelle, Michigan State University

Students learn physics in many settings outside of the classroom. This work builds on research that examines how students interact with instructors in physics help session environments. In this presentation we will discuss data collected from an experience that is part of a cohort program at a large baccalaureate granting institution. This program is for students intending to major in natural sciences and is primarily made up of students of color. The program provides academic, advising, social, and professional support, including the opportunity to attend help sessions for particular classes. We collected fieldnotes in several of the physics sessions, focusing on the instructors and the student-instructor interactions, and paying attention to researcher questions that emerged across the sessions. In this talk we will describe how two different instructors' teaching styles emerged from our fieldnotes of these help sessions and how these styles impacted interactions with students.

AA08: 9:40-9:50 a.m. Characterizing Active Learning Environments in Physics: Preliminary Results

Contributed – Kelley Commeford, Drexel University, 7215 Emlen St., Philadelphia, PA 19119; kelley.commeford@gmail.com

Eric Brewe, Drexel University

Adrienne Traxler, Wright State University

There is broad evidence that active learning leads to improved student outcomes as compared with traditional lecture, but relatively little work has been done to distinguish outcomes between different types of active learning. Before differentiation can occur, we need a way to characterize the different active learning curricula. We have looked at six active learning curricula in physics, using the Classroom Observation Protocol for Undergraduate STEM (COPUS), as well as self-reported student social network data. Together, these data will show how classroom activities drive student social network development for each curriculum. In this talk, we will discuss preliminary findings.

AA09: 9:50-10:00 a.m. Graduate Teaching Assistants' Views of Broken-into-Parts Physics Problems

Contributed – Melanie L. Good, University of Pittsburgh, 2017 Noble St., Sharpsburg, PA 15215; melanie.l.good@gmail.com

Emily Marshman, Chandralekha Singh, University of Pittsburgh

Edit Yerushalmi, Weizmann Institute of Science

In this investigation, we examined TAs' views about introductory physics problem "types", i.e., different ways of posing the same underlying physics problem, within the context of a semester-long TA professional development course. Here, we focus on TAs' views about two broken-into-parts problems. TAs reported that they found broken-into-parts problems to be the most instructionally beneficial out of all the problem types and would use a broken-into-parts problem often and in a variety of ways stating the guidance such problems offer as a major pro. The instructional benefits of gradually removing the scaffolding support to help students develop self-reliance in solving problems appeared to be overlooked by most TAs. In particular, most TAs did not mention a long-term goal of helping students acquire more independence in problem-solving in written responses or in interviews.

AA10: 10:00-10:10 a.m. Preparing the Next Generation of Educators

Contributed – Alexandru Maries, University of Cincinnati, 345 Clifton Court, Cincinnati, OH 45221; mariesau@ucmail.uc.edu

Graduate students across the United States are currently playing an important role in the education of students as they often teach laboratories, recitations, and discussion sections. It is important to provide professional development for graduate teaching assistants (GTAs), not only because this will have a positive impact on students now, but also because it can have an impact on the students of tomorrow. In this talk I will first summarize the important takeaways from the literature on effective TA programs and discuss how this literature has helped shape a particular GTA professional development program. Finally, I will discuss results from over three years of implementing this program, in particular, by focusing on the pedagogical practices of the GTAs.

AA11: 10:10-10:20 a.m. Graduate Teaching Assistant Fidelity of Implementation in Introductory Physics Laboratories*

Contributed – Annalisa F. Smith-Joyner, East Carolina University ,1000 E 5th St., Mail Stop 552, Greenville, NC 27858; smithann14@students.ecu.edu

Feng Li, Steven F. Wolf, Joi P. Walker, East Carolina University

This study reports the fidelity of implementation by Graduate Teaching Assistants (GTAs) of the Argument-Driven Inquiry (ADI) instructional model in introductory physics laboratories. An ADI specific observation protocol was used to document the facilitation techniques of two GTAs during three investigations of a semester long course. This observation protocol considers each aspect of the ADI instructional model and therefore reveals fidelity of implementation. GTAs in general physics 1 and general physics 2 were observed during the first semester of course wide implementation. The results from the implementation of the observation protocol for two semesters of introductory physics will be discussed as well as implications for GTA facilitation for our facility.

*Supported by NSF DUE-1725655

Session AB Frontiers of Astronomy

Location: CC - Cascade D **Sponsor:** Committee on Space Science and Astronomy **Time:** 8:30–10:30 a.m. **Date:** Monday, July 22
Presider: Emily Welch

AB01: 8:30-9:00 a.m. Planets Around Other Stars Revealed by the Kepler Space Telescope

Invited – Darin A. Ragozzine, Brigham Young University, N482 ESC, Provo, UT 84602; darin_ragozzine@byu.edu

The discovery of planets around other stars like the Earth is a completion of the Copernican Revolution and an exciting development in astronomy. Questions that have been pondered for millenia can be addressed with the recent scientific discoveries of the Kepler Space Telescope. After describing the basic principles of the transit discovery method and how Kepler operated, I will provide an overview of the key results from the mission. Even though the primary mission concluded in 2013, these results are constantly evolving. In particular, I will explain the current state of the field (including some of my own research) in understanding: 1) the frequency of planets of different sizes and periods (including Earth-like planets), 2) the typical "architectures" of planetary systems, and 3) the composition of known planets.

AB02: 9:00-9:30 a.m. Early Science Results from the Transiting Exoplanet Survey Satellite (TESS)

Invited – Denise C. Stephens, Brigham Young University, N486 ESC, Provo, UT 84602; denise_stephens@byu.edu

The Transiting Exoplanet Survey Satellite (TESS) is NASA's first all-sky transiting exoplanet survey. Launched in May of 2018, TESS has spent its first year of observations scanning the southern sky and will switch to the northern sky this summer. During its lifetime, TESS will survey 200,000 of the brightest stars in the sky to try and detect small drops in light corresponding to the eclipse of the star by a transiting planet. Each candidate identified by TESS triggers an alert that is sent to the follow-up working groups, who then obtain observations from the ground to rule out false positive events. Data from all of the groups is shared, and used to determine physical parameters for the star and transiting object. In this talk I will discuss the basic goals of the mission, the process by which a detection by TESS ends up being confirmed as a extrasolar planet, and I will highlight some of the more interesting planet discoveries.

AB03: 9:30-10:00 a.m. Stars, Galaxies, and the History of the Universe: Two Decades (and Counting!) of Exploration with the Sloan Digital Sky Survey

Invited – Gail Zasowski, University of Utah ,115 S. 1400 E., Salt Lake City, UT 84112; gail.zasowski@gmail.com

The stars in the night sky have inspired questions about our place in the Universe throughout recorded history. The invention of the telescope showed us that the stars visible to the naked eye merely hint at the vast tapestry of stars within our own Galaxy. As telescope design has advanced, energy signatures invisible to the human senses have been revealed. We now know that there are billions of stars in our galaxy, billions of galaxies in our Universe, and nearly 14 billion years of cosmic evolution that have led to where and what we are today. Over the last 20 years, the Sloan Digital Sky Survey (SDSS) has had an unprecedented impact in its efforts to systematically study the stars, galaxies, and history of the Universe, and to make its data available for the world to use. I will describe some of the key insights that the SDSS has provided into the nature of our Universe, along with the big questions that we are excited to tackle next.

AB04: 10:00-10:30 a.m. Tension in the Cosmological Distance Scale

Invited – Joseph Jensen, Utah Valley University, 800 W University Pkwy., Orem, UT 84058-5999; jjensen@uvu.edu

Observational astronomers continue to improve the precision of their measurements of the local (i.e., current) expansion rate of the Universe, but the more precise those measurements get, the more they disagree with the model-based predictions derived from the properties of the early Universe. What started out as "tension" with the standard cold dark matter + dark energy model is looking more and more like disagreement. What could be wrong? Are there systematic errors in the distance ladder? Are there problems with the cosmological models? If the model assumptions are wrong there could be exciting new physics just around the corner.

Session AC Getting the Facts Out About STEM Teaching Professions

Location: CC - Cascade C **Sponsor:** Committee on Research in Physics Education **Co-Sponsor:** Committee on Teacher Preparation
Time: 8:30–10:30 a.m. **Date:** Monday, July 22 **Presider:** Monica Plisch

AC01: 8:30-9:00 a.m. Get the Facts Out: Changing the Conversation About Teaching*

Invited – Wendy K. Adams, Colorado School of Mines, 1700 Illinois St., Golden, CO 80401; wkadams@mines.edu

The Get the Facts Out campaign is a joint effort between four societies and the Colorado School of Mines to change the conversation about high school and middle school physics, chemistry, and math teaching careers. We have developed a toolkit which is designed to be customizable and adaptable to the local situation. The resources in the toolkit are based on pilot interventions that show positive results in shifting perceptions among students and faculty, and which have been shown to outperform traditional recruitment efforts. The materials include posters and brochures that incorporate tested messaging strategies as well as both student- and faculty-facing presentations that share national survey data on retention, job satisfaction, and student loan forgiveness as well as teacher salaries, and retirement benefits, with instructions on how to customize these with local data. In this presentation we will share these materials and strategies and the research behind them.

*This project is supported by NSF DUE-1821710.

AC02: 9:00-9:30 a.m. Want More Students Excited About Teaching? Be a Change Agent!

Invited – Gay B. Stewart, West Virginia University, PO Box 6315, Morgantown, WV 26506-6315; gbstewart@mail.wvu.edu

Misperceptions about high school teaching discourage STEM undergraduates from exploring teaching as a viable career option. The Get the Facts Out campaign toolkit is designed to support faculty efforts to change the conversation about STEM teaching careers in their departments. Funded by NSF grants 1821710 and 1821462, this project involves professional societies in physics, mathematics, and chemistry. In each field "Change Agents" have been chosen to help get the facts out. The author is one of those change agents in physics and will share information about what this looks like and why you should, and how you can, get involved.

AC03: 9:30-10:00 a.m. GFO to Guide Community College Students to HS STEM Teaching

Invited – Karen Magee-Sauer, Rowan University, Department of Physics & Astronomy, Glassboro, NJ 08028; sauer@rowan.edu

Community colleges provide access to higher education at affordable prices and have a highly diverse student population including many first-generation and low-income college students. Thus, recruiting community college students is a promising way to increase the diversity of future STEM teachers. As part of the "Get the Facts Out" project, a series of workshops were given for students/faculty/advisors/administrators at community colleges in the South Jersey region. The goals of the workshops were to ensure that community college students/faculty/advisors/administrators were aware of the high need, job satisfaction, benefits, loan forgiveness, and other aspects of High School STEM teaching as a career and understand how to access resources from the GFO toolkit. This presentation will describe activities and feedback from the workshops and offer advice to others on how to create a relationship with area community colleges to help recruit students to High School STEM Teaching and STEM majors

AC04: 10:00-10:30 a.m. Secondary Physics Teaching: Let's Look at the Facts

Invited – Duane Merrell, Brigham Young University, N-143 ESC, Provo, UT 84602; duane_merrell@byu.edu

Secondary teachers have great opportunities to do what they love—work with students that need great physics teachers. Many times students question entering the secondary teaching profession do not understand the reasons that so many teachers love their jobs. We will take a look at salary, benefits, job satisfaction, and some other intangible or hidden advantages of being a secondary physics teacher.

Session AD Physics of Digital Games

Location: CC - Cascade E **Sponsor:** Committee on Physics in Two-Year Colleges **Time:** 8:30–10:30 a.m. **Date:** Monday, July 22
Presider: TBA

AD01: 8:30-10:30 a.m. The Physics of Video Games: Interactive Modules for Beginner Programmers*

Invited – Richelle Teeling-Smith, The University of Mount Union, 1972 Clark Ave., Alliance, OH 44601; teelinri@mountunion.edu

Chris Orban, The Ohio State University

There is an ever-growing need to integrate computation into the physics curriculum. Incorporating new content into an introductory physics course is a challenging task that can be made much easier by utilizing avenues of student interest – specifically, digital games. We introduce a series of hour-long video game-like programming activities for classical mechanics and electricity and magnetism topics. These interactive modules resemble popular games such as "Asteroids", "Angry Birds", "Pong", and "Bonk.io" and require students to write and modify the code to control the physical behavior they see in the game. The 20+ activities are browser-based (requiring no software installation) and modular in nature so that they can be easily integrated into existing courses or labs. We will discuss our experiences in integrating these video game-like programming exercises into the introductory physics courses at Mount Union and OSU Marion, as well as in high school physics classes in Ohio.

*The STEMcoding Project is supported by the AIP Meggers Award and internal funding from OSU.

AD02: 8:30-10:30 a.m. Assessing the Value of Physics-Rich Digital Games and Coding Activities*

Invited – Chris Orban, 191 W Woodruff Ave., Physics, Columbus, OH 43210; orban@physics.osu.edu

Richelle Teeling-Smith, University of Mt. Union

The STEMcoding project has developed a number of "Physics of Video Games" that are fusion of PhET-like web interactives and traditional coding activities. A crucial question is whether activities that merge computer science content and physics instruction do anything more than build student's familiarity with computer science. I briefly overview efforts to assess the conceptual physics knowledge of students completing coding activities that produce physics-rich digital games. Our hypothesis is that these activities naturally encourage students to look more critically at the behavior of a physics-rich digital game than they would if the code behind an interactive were hidden. I also briefly discuss efforts to assess "computational thinking" which is an emerging field of research.

*The STEMcoding project is supported by an OSU internal grant and the AIP Meggers award

AD03: 8:30-10:30 a.m. Mechanics and Optics in Game Engines

Invited – Alejandro Garcia, San Jose State University, 1479 Sierra Ave., San Jose, CA 95126; Alejandro.Garcia@sjsu.edu*

Modern game engines, such as Unity and Frostbite, can use advanced physics simulations to create realistic, immersive worlds. This talk describes how such engines perform these calculations for two specific examples from the fields of mechanics and optics.

*Sponsored by Glenda Denicolo

AD04: 8:30-10:30 A.M. Disciplinarily Integrated Games: Manipulating Formal Representations as Core Game Mechanics

Invited – Douglas Clark, University of Calgary, 3015 Underhill Dr., NW Calgary, AB T2N 4E4, Canada; douglas.clark@ucalgary.ca*

Pratim Sengupta, University of Calgary

Interpreting, translating, and manipulating across formal representations is central to scientific practice and modeling (Pickering, 1995; Lehrer & Schauble, 2006a, 2006b; Duschl et al., 2007). We developed disciplinarily integrated games (DIGs) such that players' actions involve the iterative development and manipulation of formal representations as the core game mechanics (Clark, Sengupta, Brady, Martinez-Garza, & Killingsworth, 2015; Clark et al., 2016; Sengupta & Clark, 2016). The core design commitment in DIGs involves: (a) leveraging formal representations as the means of communicating challenges to players and (b) leveraging formal representations as the players' means of control within the game. In their strongest form, DIGs can help us structure meaningful connections between epistemic and representational forms across the semester, year, or multi-year curriculum to support the development of epistemic and representational practices that are central to the long-term development of scientific expertise in an authentic manner.

*Glenda Denicolo invited my talk

AD05: 8:30-10:30 a.m. Using Video Games to Build Models

Invited – Rhett Allain, Southeastern Louisiana University SLU, 10878 Hammond, LA 70402; rhettallain@gmail.com

If you want to discover new fundamental models in physics, you might need to build a very expensive experiment like a particle accelerator or a gravitational wave detector. However, there is a much cheaper option to practice model building - video games. Just like the real world, video games have their own fundamental rules that govern the motions of characters. By examining different levels in a game, it's possible to collect data and build models that reflect the nature of the physics in the video game. In this talk I will share some of my favorite examples of model building in physics games.

Session AE Assessment Strategies, Especially for Upper-division Physics

Location: MH - Birch **Sponsor:** Committee on Physics in Undergraduate Education **Co-Sponsor:** Committee on Research in Physics Education
Time: 8:30–10:20 a.m. **Date:** Monday, July 22 **Presider:** Andy Rundquist

AE01: 8:30-9:00 a.m. Assessment Practices for Accessibility, Rigor, and Sustainability: You Can Have All Three

Invited – Mylène DiPenta, 2-1226 J Jordan Rd., Canning, NS B0P 1H0 Canada; mylenedipenta@gmail.com

Is it possible increase rigor, authentic assessment, and accessibility at the same time? How can we support students' widely varying learning needs in ways that are sustainable for faculty? What assessment practices make success more possible for members of marginalized groups (including students who are one or more of , Black, people of color, women, queer, trans, disabled/having disabilities, etc.) while contributing to a healthier climate for all students? How do we help students develop the confidence that they can take control of their own learning and improvement? Will my students ever complete the assigned readings before class, and if they do, how do I prevent them from memorizing it as compartmentalized nonsense? I've been experimenting for 8 years with answering these questions, using a combination of Standards-Based Grading, format-independent rubrics, student-developed assessment, student-developed curriculum, Elder/Paul model critical thinking, Universal Design for Learning, peer review, and some basic techniques of conflict mediation. Come try these techniques first-hand using examples from an algebra-based circuits course. We will discuss the techniques' pros and cons, and explore underlying conditions that make them work, including "question generating exercises", a "curiosity tracking" spreadsheet, and the surprising role of definitions in students' understanding of causality. You will leave with a package of classroom-ready resources, including at least one that you have modified to suit your curriculum.

AE02: 9:00-9:30 a.m. An Evolving Approach to Assessment in Upper-level Labs

Invited – Melissa Eblen-Zayas, Carleton College, 1 North College St., Northfield, MN 55057; meblenza@carleton.edu

Upper-level labs often focus on hands-on activities and project-based work that are designed to enhance student understanding of the process of experimental work, in addition to developing core content knowledge. When I began teaching upper-level lab courses, my assessment of student learning primarily relied on traditional quizzes or final poster presentations or write-ups. However, these approaches didn't allow me to measure development of students' understanding of process in experimental work, because the assessments tended to focus on final outcomes. I will describe how I have revised assessment in my upper-level lab courses to include low stakes reflections and presentations as well as hands-on exams that better match my learning goals for these courses. In addition, I will outline questions that remain as I continue to re-examine my approach to assessment in upper-level labs.

AE03: 9:30-9:40 a.m. Piecewise Specifications-based Grading

Contributed – Joshua P. Veazey, Grand Valley State University, 1 Campus Drive, Allendale, MI 49401; veazeyj@gvsu.edu

Mastery-based grading systems (like specifications grading) are attractive to many instructors at the college level. They shift student focus from accumulating points to learning. These grading systems also accommodate logical revision policies that promote growth mindset. However, transitioning from points-based grading to a mastery grading system can seem daunting and prevent adoption. What's more, implementation in large-enrollment lecture courses may mean a large volume of revisions and reassessments that is unmanageable. In this talk I will discuss my experimentation with a piecewise approach to implementation in various ways across several introductory level courses. Specifications grading has been applied strategically to only some areas of these courses (e.g., labs, discussions, homework problems) to achieve some of the benefits while keeping the workload manageable. Feedback from students has suggested that even limited applications of specifications grading can impact the overall class culture in positive ways.

AE04: 9:40-9:50 a.m. Modeling and Assessing Scientific Reasoning

Contributed – Lei Bao, The Ohio State University, 191 W Woodruff Ave., Columbus, OH 43210; bao.15@osu.edu

Kathleen Koenig, University of Cincinnati

Yang Xiao, Shaona Zhou, South China Normal University

Jing Han, The Ohio State University

In STEM education, there has been increased emphasis on teaching goals that include not only the learning of content knowledge but also the development of scientific reasoning, which is a core ability supporting the workforce and global economy of the 21st century. Although there has been abundant research in the literature on various aspects of scientific reasoning, the research community has yet to reach a consensus on the definition, assessment, and development of scientific reasoning. The single popular assessment instrument on scientific reasoning has also been shown to have validity defects. Through a decade of extended research and development, a comprehensive modeling framework as well as a new assessment instrument on scientific reasoning have reached a releasing point. This presentation will introduce the modeling framework and the assessment instrument, which are now ready to be implemented in research and teaching. Future work and possible collaborations will also be discussed.

AE05: 9:50-10:00 a.m. Assessing the Mindsets of Physics Students through Intellectual Humility (IH)

Contributed – Meagan Sundstrom, University of Connecticut, 8 Queens Court, Walpole, MA 02081-3145; meagan.sundstrom@uconn.edu

Fabiana Cardetti, Jason Hancock, Manuela Wagner, University of Connecticut

Students often enter the physics classroom with intuitive conceptions about how one learns physics, drawn from real life experiences or former coursework, and they may be hesitant to revisit these mindsets as they encounter new learning environments. The nature of scientific inquiry in the classroom necessitates one's abilities to be open to hearing evidence that contradicts his or her personal opinion, to be willing to discard any original misconceptions in the face of such alternative evidence, and to identify and pay appropriate attention to one's academic limitations. Such a mindset is indicative of Intellectual Humility (IH), defined as "the owning of one's limitations." In this mixed methods study, we analyzed IH surveys, in-class activities and assignments, and qualitative data to assess the mindsets of introductory physics students through the lens of IH. We will discuss our main findings and relate them to students' in-class learning experiences.

AE06: 10:00-10:10 a.m. Percolating Down Bloom's Pyramid: Students Create their Own Exam Problems

Contributed – Ameya S. Kolarkar, Auburn University, 206 Allison Lab, Auburn, AL 36849; kolarkar@auburn.edu

Students were encouraged to create their own exam problems some of which would be used on their actual exams. It was noticed that – over the course of a semester – the students who participated demonstrated significantly better learning covering all the Bloom's levels in the process. We extended this process to the entire class (up to 70 students) and obtained similar results, and that students could think at higher levels than the rest, on average. We noticed that even though students' creating process mimicked the teacher's, the way they framed their questions differed in interesting ways. This "Creating" process also highlights their preconceptions that we, the teachers, may easily miss.

AE07: 10:10-10:20 a.m. An Effective Assessment of Students Learning Behavior Based on Internet and Cloud Technology

Contributed – Fuli Zhao, School of Physics, Sun Yat-sen University, 135, Xingangxi Road Guangzhou, 510275; stszfl@mail.sysu.edu.cn

Han SHEN, Raohui FENG, Xintu CUI, Daoxin YAO, School of Physics, Sun Yat-sen University

In order to improve the positive effect for the assessment of student learning behavior in the compulsory courses in fundamental physics, we developed an internet-based software to monitor the behavior of optical project design and evaluated the detail properties of the students' manipulation data to get the detail data sheet of the learning behavior. Furthermore, based on the cloud technology the real-time output of the students manipulation can be put into the statistics strategy and find whether the instruction is good or not in order to give evident support for teacher to modify the instructions afterwards. Such a real-time dynamic method has been carried out in SYSU for three years and we have obtained very positive feedback.

Session AF Sharing, Improving, and Researching Pedagogies and PER Resources, Using Data Analytics

Location: MH - Amphitheater **Sponsor:** Committee on Educational Technologies **Time:** 8:30–10:30 a.m. **Date:** Monday, July 22
Presider: KC Walsh

AF01: 8:30-9:00 a.m. Enabling the Digital Ecosystem Through Standards

Invited – Cary Brown, IMS Global Learning Consortium, 24315 Elliott Lane, Newhall, CA 91321-3546; cbrown@imsglobal.org

One of the significant challenges facing educational institutions, both technically as well as pedagogically, is the continued fractured and disparate nature of learning tools and platforms on campus. By encouraging the adoption of standards to ensure interoperability between these systems, we also facilitate the convergent flow of learning data to record stores and other repositories that provide the opportunity for meaningful learning data analytics. We'll review a number of the standards provided by IMS Global Learning Consortium, how they work together to provide a framework for interoperability in the next generation digital learning ecosystem, and look at new initiatives and next steps to achieve the promise of analytics to drive efficiencies and student success on campus.

AF02: 9:00-9:30 a.m. Using Analytics to Nudge Student Responsibility for Learning

Invited – John Fritz, University of Maryland, Baltimore County, 1000 Hilltop Circle, Baltimore, MD 21250-0001, fritz@umbc.edu*

For 10 years, the University of Maryland, Baltimore County (UMBC) has provided a Check My Activity (CMA) feedback tool allowing students to compare how active they are in the campus Learning Management System (LMS) compared to an anonymous summary of course peers earning the same, higher or lower grade on any assignment -- If instructors use the gradebook. Typically, students earning a D/F tend to use the LMS 40% less than more successful peers, but we've also seen that students who use the CMA are about 1.5-2 times more likely to earn a C or higher. In this talk, I will share how the CMA came about, lessons learned, and possible implications for course design. For a demo, see https://youtu.be/rpU1GdvS_yc. For a more detailed write-up, see https://doi.org/10.1002/he.20244 as well as related links about UMBC analytics at doit.umbc.edu/analytics.

*Invited by KC Walsh at Oregon State University

AF03: 9:30-9:40 a.m. Improving Equity and Inclusion in Physics Through the SEISMIC Project

Contributed – Nita Kedharnath, University of Michigan, 450 Church St., Ann Arbor, MI 48109; nitaked@umich.edu

SEISMIC, the Sloan Equity & Inclusion in STEM Introductory Courses project, aims to improve equity and inclusion in foundational STEM courses enrolling more than 60,000 new students per year. Bringing together 10 large, public research universities throughout the country, this three-year project will share data, execute parallel data analysis, and run coordinated experiments across the collaboration. SEISMIC creates an opportunity for STEM instructors, discipline-based education researchers, data analysts, staff in teaching and learning centers, and many other stakeholders in STEM education to share ideas, experiments, and data to help us improve our courses. Modeled on other large scientific collaborations, the SEISMIC project relies on a Scientific Working Group structure to achieve its goals. This talk will describe the activities of the Measurement Working Group, whose central goal is to characterize and make new measurements of equity and inclusion in introductory STEM courses using educational data from each member institution.

AF04: 9:40-9:50 a.m. The Metadata and Resource Quality Bottleneck

Contributed – Bruce A. Mason, University of Oklahoma, 440 W. Brooks St., Norman, OK 73019; bmason@ou.edu

The creation, organization, and application of information about content and resources in digital collections is the well-known "Metadata Bottleneck". This barrier has been a re-discovered by many groups and projects wishing to share their work or build collections of high-quality online resources. Providing detailed, quality information is particularly difficult in support of groups with very specific and arcane needs, such educators. This talk will review a few examples of information cataloging in digital library projects

AF05: 9:50-10:00 a.m. Data Driven Evidence-based Instructional Design Using Open Resources and Tools

Contributed – Kenneth C. Walsh, Oregon State University, 301 Weniger Hall, Oregon State University, Corvallis, OR 97331-8507; walshke@oregonstate.edu

Active learning sparked a flipped classroom movement at Oregon State University. Modular shared open resources and learning tools enabled ultimate control for instructors and equity for students. Click-stream tracking and learning objectives-based analysis opened up a whole new world of evidence-based instructional design possibilities. My journey from building a few lecture videos to using data analytics and predictive modeling has led me to create a curriculum embedded with the research tools necessary to close-the-loop on its efficacy. I will talk about the resources and tools we use, share initial results of what helps students learn in this environment, and where the project is headed.

AF06: 10:00-10:10 a.m. Modernizing PERs Analysis of the CLASS and Similar Assessments

Contributed – Ben Van Dusen, CSU Chico, 2354 Farmington Ave., Chico, CA 95929-0535; bvandusen@csuchico.edu

Jayson Nissen, CSU Chico

Many assessments in PER include questions with ordered categorical answers such as Likert-style questions. As a field, PER has used a range of methods to analyze this data. For example, when analyzing Colorado Learning Attitudes about Science Survey (CLASS) data, researchers typically collapse student responses into two categories, calculate average scores in each category, and then analyze the overall scores using linear regression models. In this talk, we will explore the limitations of transforming categorical data and including it in linear regressions. We offer proportional odds logistic regression as an alternative solution that does not require transforming the data nor violates the assumptions of the statistical model used. To illustrate the differences between these two methods, we will apply them both to the same set of CLASS data, explore the model outputs, and discuss how to interpret them.

AF07: 10:10-10:20 a.m. Describing Student Interaction with Interactive Simulations Using a Teacher Dashboard

Contributed – Diana B. Lopez Tavares, Instituto Politécnico Nacional, Calz Legaria 694, Mexico City, MEX 11500 Mexico; dianab_lopez@hotmail.com

Katherine Perkins, Michael Kauzmann, University of Colorado

Carlos Aguirre Velez, Instituto Politécnico Nacional

Student engagement with interactive simulations is affected by the prompts and activities teachers choose to couple with such simulations. In this work, we introduce a prototype dashboard to visualize and evaluate student interaction generated by simulation centered activities. We compare student interaction resulting from two different prompts using PhET's Energy Skate Park: Basics and Forces and Motion: Basics simulations. The first prompt invites students to find the variables that affect movement via challenge-style questions. The second prompt asks students to predict and observe movement given specific parameters and variables. The dashboard shows information such as the time spent in the activity and information about the controls used in the sim. Results show that activities based in challenges get that students explore with more sim's elements and they interact for longer time. We reflect on the differences in student how a teacher dashboard can guide instructional design.

AF08: 10:20-10:30 a.m. Using Analytics to Understand Affect and Content Knowledge

Contributed – Andrew D. Gavrin, IUPUI, Dept. of Physics, 402 N. Blackford St., LD154 Indianapolis, IN 46202; agavrin@iupui.edu

Patrick Kelley, IUPUI Dept. of Physics

In this talk, we will present examples of analytics used to understand student affect and content knowledge in an introductory calculus-based mechanics class. Enrollment in the course is 150–200 students each semester, and the setting is an urban public institution. We will discuss analytic data reflecting two distinct areas and originating from three data sources: content knowledge (homework, personal response system) and affect (an online forum). Our results suggest the potential for using these data sources to understand student behavior and improve instruction. Our results also highlight one of the difficulties of using this data. Because the data and analysis are complex, they are difficult to use, and even more difficult to merge, in real time. We will conclude with a discussion of our interactions with one of the application developers to begin moving towards a resolution of this problem.

Session AG K-12 PER

Location: MH - Cedar **Sponsor:** Committee on Research in Physics Education **Co-Sponsor:** Committee on Physics in High Schools
Time: 8:30–10:20 a.m. **Date:** Monday, July 22 **Presider:** TBA

AG01: 8:30-9:00 a.m. Content Knowledge for Teaching Energy: Construct and Assessment

Invited – Eugenia Etkina, Rutgers University, 10 Seminary Pl., New Brunswick, NJ 08901-1108; eugenia.etkina@gse.rutgers.edu

Lane Seeley, Seattle Pacific University

Stamatis Vokos, California Polytechnic State University

What is Content Knowledge for Teaching, how can we assess it, and what do we learn from this assessment? This talk will answer these questions in the domain of high school energy. We will report on a multi-year, multi-institutional effort to study physics teachers' knowledge for teaching energy. In particular, we describe the framework that we developed to clarify Content Knowledge for Teaching (CKT) construct in the context of high school energy learning and the process through which we developed, tested, and refined an on-line assessment that we administered to several hundred physics teachers and physics majors. The findings of the assessment are encouraging and surprising at the same time, especially in the area related to the role of subject matter knowledge in the content knowledge for teaching.

AG02: 9:00-9:30 a.m. Promoting High School Students' Physics Identity Through Explicit and Implicit Recognition

Invited – Jianlan Wang, Texas Tech University, 3008 18th St., Lubbock, TX 79409; jianlan.wang@ttu.edu

Zahra Hazari, Florida International University

Using the theoretical framework of physics identity and emotional scaffolding, we investigate the impact of two types of recognizing strategies, i.e. explicit (ER) and implicit recognizing (IR), on high school students' sense of recognition and physics identity. ER is teachers directly conveying their acknowledgment of students' qualities or abilities, such as acknowledging good work and expressing faith in student ability, and IR is teachers indirectly acknowledging students' qualities or abilities via assigning them a position or a task that demands those qualities or abilities, such as valuing student opinions and assigning a challenging task. We trace the physics identity development of 134 students from three high school physics classes in one year. Our findings indicate that the synergy with ER and IR strategies are used as well as the nature of the activities (i.e. attainable success) are critical features of effective teacher recognition that can be internalized by the student.

AG03: 9:30-9:40 a.m. A Learner-based Perspective on STEM Learning in AP Courses

Contributed – Albert Y. Bao, Dublin Jerome High School, 8300 Hyland-Croy Rd., Dublin, OH 43016; 20bao_albert@dublinstudents.net*

STEM fields are at the core of 21st Century Innovation. However very few American students pursue STEM disciplines as their future careers. In high school, AP STEM courses provide unique opportunities to improve students' awareness, interests, and access to STEM learning in the school environment. A positive experience in these AP courses can be a catalyst to shaping a student's career interests and preferences towards STEM fields. However, these courses are also the most challenging among all high school curricula, and the situation is even more complicated by the shortage of teachers skilled in STEM subjects. It is then important to help students

develop effective learning strategies for these courses. Through surveying high school students who have studied AP STEM courses, this research seeks to develop a student based perspective on best practices to effectively manage learning and achieve good performance.
*Sponsored by Lei Bao

AG04: 9:40-9:50 a.m. Effects of Investigative Learning on Student Attitudes, Confidence, and Motivation

Contributed – Danielle Bugge, Rutgers University, 10 Seminary Place, New Brunswick, NJ 08901; danielle.bugge@rutgers.edu

Eugenia Etkina, Rutgers University

During the 2015-2016, 2016-2017, and 2017-2018 school years, high school students learned physics through the Investigative Science Learning Environment (ISLE). Each year, the first-year honors physics students regularly designed experiments that engaged them in the science practices and focused on the development of various scientific abilities. Based on prior studies, we know that this sample of high school students is capable of achieving proficiency with the scientific abilities. However, does learning in a collaborative, investigative environment have an influence on student goals, attitudes, and confidence? During this three-year period, we collected pre and post surveys for first year honors physics students. We report on the study in which we analyze student responses and growth to questions associated with motivation to take a physics course, goal setting, comfort and confidence with scientific abilities, and attitudes via the E-CLASS survey.

AG05: 9:50-10:00 a.m. Coping with Reform: Epistemic Contradictions for Highly Successful Physics Students

Contributed – William E. Lindsay, University of Colorado Boulder, 320 JACKSON PL, APT C ,Golden, CO 80403; william.lindsay@colorado.edu

Khadijih Mitchell, Valerie Otero, University of Colorado Boulder

This physics education research study focuses on students who have been successful learning science in traditional classrooms when they interact with Next Generation Science Standards (NGSS) aligned instruction. For students who have developed positive identities as science learners within traditional contexts, the shifts in participation required to learn physics in a NGSS-aligned, reformed context may result in frustration, contradictions, and other affective outcomes. We explored this hypothesis using interviews and video observations collected in the classrooms of teachers implementing the Physics through Evidence, Empowerment through Reasoning (PEER) curricular suite. From this data, we constructed case studies outlining the experiences of four highly successful students engaging in scientific practices while learning physics for the first time. Findings indicate that case students experienced a host of epistemic contradictions and tensions that were challenging to navigate. Implications of these findings for physics teachers attempting NGSS implementation are discussed.

AG06: 10:00-10:10 a.m. Integrating Standards-based Grading into a First-Year HS Physics Course

Contributed – Debbie S. Andres, Paramus High School, 99 East Century Road, Paramus, NJ 07652; dandres@paramusschools.org

The Next Generation Science Standards (NGSS) call for teachers to incorporate science practices into the instruction of their students. How can we best assess our students' progress on targeted learning objectives? Teachers can use various assessment techniques to measure student proficiency such as Standards Based Grading (SBG). How can we use a SBG model while abiding by a school district's online grading policy? During the 2018-2019 academic year, I piloted a version of SBG in freshmen Physics Honors classes. Rather than receiving number grades on assessments, I gave students descriptors regarding their level of mastery on specific standards. Every marking period, the standards were given to students along with rubrics that helped them monitor their progress. The standards fell within three categories: Professional Expectations, STEM Practices, and Content Specific Standards. In this talk I will share the SBG model developed, strategies for implementation, and student feedback on this assessment strategy.

AG07: 10:10-10:20 a.m. Building NASA Rovers to Demonstrate Conservation of Energy

Contributed – Brandon Rodriguez, NASA Jet Propulsion Laboratory, 4800 Oak Grove Dr., Pasadena, CA 91101; brandon.rodriguez@jpl.nasa.gov

The Education Department at NASA's Jet Propulsion Laboratory has created numerous activities for K-12 schools to explore STEM through space science. Once such activity is the creation of small rubber band-powered vehicles for 'roving on Mars'. This activity, originally targeting middle school standards, was revised by high school physics teachers to address NGSS standards on the conservation of energy. Using cheap and simple supplies, students build vehicles and use kinematics and energy calculations to determine their velocity, kinetic/potential energy and friction to calculate the strength of their rubber bands. In this presentation we will look at student created models and the materials used to set the stage for student engagement.

Session AH Outreach for Underserved Populations

Location: MH - Arches **Sponsor:** Committee on Science Education for the Public **Co-Sponsor:** Committee on Space Science and Astronomy
Time: 8:30–10:20 a.m. **Date:** Monday, July 22 **Presider:** Jacquelyn Chini

AH01: 8:30-9:00 a.m. Refuges Exploring the Foundations of Undergraduate Education in Science (REFUGES)

Invited – Tino S. Nyawelo, University of Utah, Department of Physics & Astronomy, 115 South 1400 East, JFB # 201, Salt Lake City, UT 84112; tnyawelo@gmail.com

Approximately one-third of refugees who resettle in the U.S. are youth. Although the refugees come from a variety of backgrounds and nationalities, they have similar, challenging experiences when resettling in the U.S. Refugee youth often encounter difficulties related to language barriers, cultural adjustments, and a history of interrupted schooling is a primary cause of the low rate of high school completion and college matriculation among refugee students across the U.S. Without positive intervention, many of these youth are at risk of dropping out of school and engaging in illegal activities. This presentation will describe Refuges Exploring the Foundations of Undergraduate Education in Science (REFUGES), a Utah-based, STEM-focused afterschool program that supports new American and refugee students in achieving college readiness, and is designed to change these statistics through two program components: 1) an afterschool program for refugee and immigrant students (grades 7-12) that provides academic support, hands-on science enrichment, and social services such as family counseling, health and wellness workshops, and recreational activities; and 2) a bridge program for incoming University of Utah students from marginalized populations to adjust to college life, course work and research. During the summer, participating students live on campus for seven weeks and complete two courses that count towards University of Utah undergraduate degree requirements and prepare students for success in STEM. It also offers research lab placement positions to students during students' freshmen years. This experience launches interaction with peers, graduate students and faculty and helps students develop a network of colleagues who will help them throughout their academic careers.

AH02: 9:00-9:30 a.m. Fidgeting with Fabrication: Students with ADHD Making Tools to Focus

Invited – Alexandria K. Hansen, Fresno State University, 2555 E. San Ramon Avenue, M/S SB73, Fresno, CA 93740-8034; akhansen@csufresno.edu

Students with learning disabilities often have unique needs that require innovative approaches to ensure accessibility in the classroom and beyond. This talk will describe a design-based research project that worked with a small group of middle school students who were diagnosed with Attention-Deficit/Hyperactivity Disorder (ADHD). Students were tasked with designing and fabricating a personalized fidget tool—a small hand-held object to use in a classroom with the goal of increasing focus—by following the process of engineering design described in the Next Generation Science Standards (NGSS). Students teamed with a local science museum to access tools and expertise. Analysis of student interviews and recorded design sessions revealed that students accurately defined the problem and design constraints. Further, despite issues in measurement precision, students successfully optimized their design solution over time through multiple rounds of revision. Implications for educators and researchers interested in better supporting students with disabilities will be shared.

AH03: 9:30-10:00 a.m. Engaging People with Disabilities in the Practices of Science

Invited – Ron Skinner, MOXI, The Wolf Museum of Exploration + Innovation, 125 State St., Santa Barbara, CA 93101; Ron.Skinner@MOXI.org

By focusing science outreach goals on engaging a diverse audience in the practices of science and incorporating multiple means of engagement, representation, and expression, outreach activities can be designed for equal access by all learners, including people with physical or developmental disabilities. Accessibility has been a focal point in the development of MOXI, The Wolf Museum of Exploration + Innovation, a new interactive science center in Santa Barbara, CA. Practice-Based Learning and Universal Design for Learning have informed the design and implementation of our physics-focused exhibits and educational programs. Creating learning experiences that are open-ended and multi-sensory and incorporating Practice-Based Facilitation to engage learners in the practices of science has broadened our audience to include learning opportunities for any and all people.

AH04: 10:00-10:10 a.m. A Service Learning Project for Introductory Physics Students

Contributed – Nicholas B. Conklin, Gannon University, 109 University Sq., Erie, PA 16541; conklin003@gannon.edu

Service learning is a type of experiential education that applies the knowledge and skills learned in the classroom to meet a community need. The requirements of a service learning project, compared to simple community service, are alignment with the learning objectives of a course or program, demonstrated student self-reflection, and assessment of learning, often contributing to a final course grade. While many physics programs engage in extensive outreach, service learning at the course level remains somewhat uncommon. For the past two years at Gannon University, a service learning project has been implemented in the second-semester, calculus-based, honors introductory course. After visiting the local children's museum situated in downtown Erie, PA, students designed their own projects based on the course content. They then built exhibits and developed activities in cooperation with the museum staff. Details on how the project was implemented and assessed will be presented.

AH05: 10:10-10:20 a.m. Cross-Disciplinary Strategies for Engaging Broader Audiences in Science Advocacy

Contributed – Ann Wise, Phi Beta Kappa Society, 1606 New Hampshire Ave., NW Washington, DC 20009; awise@pbk.org*

S. Raj Chaudhury, University of South Alabama

The Phi Beta Kappa Society (PBK), the nation's oldest and most prestigious academic honor society, is a leading voice championing liberal arts and sciences education, fostering freedom of thought, and recognizing academic excellence. Physics plays a prominent role in the Society's cross-disciplinary efforts. We explore PBK's strategies for embedding science advocacy into public-facing events and identifying unlikely community champions to voice their support through its National Arts & Sciences Initiative. We will share tactics, tips, and resources that have proven effective for embedding advocacy into programming. We explore : can we cultivate unlikely champions to voice support for the liberal arts and sciences after attending a public facing event? Is there a way to broaden science advocacy audiences (socio-economically, politically, geographically, etc.) to counter entry barriers? Can we find a balance between giving audiences what they want and making sure this engagement achieves its objectives?

*Sponsored by S. Chaudhury

Session AI Introductory Physics for the Life Sciences (IPLS)

Location: MH - Canyon **Sponsor:** Committee on Physics in Undergraduate Education **Co-Sponsor:** Committee on Physics in High Schools
Time: 8:30–10:30 a.m. **Date:** Monday, July 22 **Presider:** Juan Burciaga

AI01: 8:30-9:00 a.m. The Lasting Impact of IPLS

Invited – Benjamin D. Geller, Swarthmore College, 500 College Ave., Swarthmore, PA 19081; bgeller1@swarthmore.edu

Chandra Turpen, University of Maryland, College Park

Catherine H. Crouch, Swarthmore College

There are multiple ways in which students' experiences in an IPLS classroom might impact their future learning. IPLS students may be better prepared to use physical reasoning skills in their later biology classes, or they may develop the enduring attitude that physics has relevance and significance for their work in the life sciences. In this talk I will describe the challenges and initial successes from the first two years of an exploratory study aimed at identifying the ways in which students exhibit IPLS skills and attitudes in their later biology coursework. I will describe the methodological challenges inherent in a longitudinal study that traverses multiple disciplines, and the ways in which we have addressed these challenges. I will draw on student written work in biology courses, and student interviews focusing on both reasoning and attitudes, to highlight how IPLS can have a lasting impact on the life science student experience.

AI02: 9:00-9:30 a.m. Students' Attitudes Toward Physics After Biomedically Relevant Instruction*

Invited – Elliot Mylott, University of Portland, 5000 N. Willamette Blvd., Portland, OR 97203; mylott@up.edu

Warren Christensen, North Dakota State University

Ralf Widenhorn, Portland State University

Many pre-health students are required to take introductory physics as undergraduates, though they often struggle to see the relationship between medicine and what they learn in these courses. We developed instructional material that presents physics in a biomedical context. Our research explored whether students' opinions on the relevance of physics to medicine was impacted by the biomedically focused physics instruction. Shifts in attitudes were assessed using the Colorado Learning Attitudes about Science Survey (CLASS), original course surveys, and student interviews. Specific questions from the real-world connection and personal interest sections of the CLASS were rewritten to have a focus on the connection to biomedical content. The results show that students' attitudes were affected by the reforms in multiple ways including students' ability to contextualize physical phenomenon through biomedical applications. The results also suggest that questions from the standard CLASS might not capture the connection students are making between physics and biomedicine.

*This work was supported by a grant (DUE-1431447) from the National Science Foundation

AI03: 9:30-10:00 a.m. Assessing the Briggs Life Science Studio (BLiSS) Physics Course

Invited – Vashti A. Sawtelle, Michigan State University, 567 Wilson Rd., East Lansing, MI 48824-2320; vashtis@msu.edu

Abhilash Nair, Michigan State University

At Michigan State University, we have designed an integrated lab-lecture (studio style) introduction physics course that meets the needs of life science students. Our design of the Briggs Life Science Studio (BLiSS) physics course emphasizes (1) connecting the disciplines of physics, biology, and chemistry through designing authentic tasks for students, (2) incorporating computational simulations that model complex biological phenomenon, and (3) building positive relationships for life science students with physics. A challenge that many Introductory Physics for the Life Sciences (IPLS) curriculum designers have faced is how to assess these curricular transformations when the transformation is more than an activity but less than an entire course. In this presentation we will focus on the assessment tools and strategies that we use to examine the outcomes of the BLiSS course design. We will address how design-based research informs our assessment of transformations at the curricular thread grain-size.

AI04: 10:00-10:30 a.m. An Introductory Medical Physics Class Designed for Life Sciences Majors

Poster – Antoinette Stone, University of California, Merced, 6695 Tiffany CMN, Livermore, CA 94551; tstone3@ucmerced.edu

The new general education class series at UC Merced is designed to guide first-year students in scholarly inquiry by providing opportunities to explore a specific topic, encouraging engagement with campus resources, supporting the development of research questions, and presenting original ideas through multiple forms of communication. A newly designed medical physics class formatted with this structure introduces students to physics principles used in the analysis, diagnosis and treatment of selected human disease processes. It offers a multidisciplinary approach for analyzing the role of physics in medicine. The course has great appeal to life science and pre-med majors and draws heavily from basic imaging physics, introducing topics such as x-ray production; the interaction of radiation with matter; nuclear medicine applications; computerized axial tomography scanning (CAT); positron emission tomography scanning (PET) and magnetic resonance imaging (MRI). This poster reports on the structure of several physics-in-medicine activities that are embedded in the course material.

AI05: 10:00-10:30 a.m. Checking for Interdisciplinary Alignment: A Critical Assessment of General Physics

Poster – Ian T. Descamps, Pomona College, 1600 Arthur Ave., Missoula, MT 59801; ian.descamps@pomona.edu

Benjamin Pollard, University of Colorado Boulder, and JILA

Elijah Quetin, Thomas Moore, Pomona College

Students take physics courses for different reasons, expect different things from our courses, and have varying relationships to physics. At Pomona College, General Physics is not a pathway into the major but rather teaches calculus-based physics to nonphysics students, often for major, graduate school, or career requirements. Our assessment explores the alignment between the goals of different stakeholders – students, the physics department, and the other invested departments – and course outcomes. Surveys, including the Colorado Learning Attitudes about Science Survey (CLASS) and Classroom Test of Scientific Reasoning (CTSR), and qualitative interviews were used to solicit feedback. Preliminary results indicate a moderate shift toward more expertlike responses on the CLASS and a slight increase in CTSR scores. Interviews with professors focused on the role of General Physics: how to cultivate stronger interdisciplinary ties; interviews with students focused on the experience of General Physics: what does, what doesn't, and what could work well.

AI06: 10:00-10:30 a.m. Development of Personalized, Adaptive, and Interactive Course for Introductory Physics

Poster – Ralf Widenhorn, Portland State University, 1719 SW 10th Ave., Rm 134, Portland, OR 97201-3203; ralfw@pdx.edu

Priya Jamkhedkar, Portland State University

We present the development of a personalized, adaptive and interactive course for the algebra-based introductory physics course taught at Portland State University. Large class sizes with diverse skills in mathematics, problem-solving, conceptual reasoning, and learning styles of the student population pose challenges to instructors teaching introductory physics classes. The need to provide support in terms of mathematics remediation, improvement in problem-solving, understanding of concepts to students who work at different paces led us to look for a platform providing these features. We summarize the design of such a course using CogBooks as an adaptive platform with many support features including concept-checks, simulations, problems with intermediate steps, drawing tools and in-class activities to promote active and engaged learning. We will present early results from the first implementation of the curriculum and discuss future improvements to the course.

AI07: 10:00-10:30 a.m. Explaining Radiation Sickness Requires Zoom Scale Reasoning*

Poster – Andy P. Johnson, Black Hills State University, 610 Nellie Ln., Spearfish, SD 57783; andy.johnson@bhsu.edu

The Inquiry into Radioactivity (IiR) project has been studying and developing radiation literacy among undergraduate students. IiR's research-based tools and strategies enable most students to understand fundamental ideas about ionizing radiation. To explain radiation – induced cancer and acute radiation sickness, students must trace a chain of causality from interactions with electrons (at the subatomic scale) through ionization, molecular damage, chromosome or cell damage, and finally to the organism scale. Such "zoom scale reasoning" is powerful but not easy. This poster will describe some of the reasons why zoom scale thinking is particularly challenging, and present evidence that IiR has collected on the types of difficulties that students show.

*This work was supported by National Science Foundation grant DUE 0942699

AI08: 10:00-10:30 a.m. Implementation and Adaptation of Evidence-Based IPLS Laboratories

Poster – Jason M. May, University of Utah, 1212 W 200 N, Apt. D111, Centerville, UT 84014-3549; jason.may@utah.edu

Jordan M. Gerton, Claudia De Grandi, Lauren Barth-Cohen, Brianna Montoya, University of Maryland

In 2017, the University of Utah began implementing National Experiment in Undergraduate Science Education (NEXUS) Introductory Physics for Life Sciences (IPLS) laboratory courses. This project began with a fairly direct implementation of NEXUS-IPLS curricular and instructional resources, which led to multiple and ongoing adaptations based on our instructional environment and resources. The motivations of the iterative reform are multifaceted, based on: a) necessities created by our unique student population, b) college/departmental requirements, and c) research-designed data collection from students via surveys, interviews, and student artifact analysis. This iterative design has resulted in successive shifts of instruction and curriculum to strengthen the promotion of student-driven research-focused collaboration and physical and biological experimentation. Here, we provide an overview of the NEXUS curriculum, our IPLS iterative reforms, and qualitative evidence from student artifacts for the rationale and efficacy for our reforms.

AI09: 10:00-10:30 a.m. Nurturing Inquiry

Poster – Nancy L. Beverly, Mercy College, 555 Broadway, Dobbs Ferry, NY 10522-1186; nbeverly@mercy.edu

In the project-based course at Mercy College, students consistently explore their own inquiries about the life phenomena of interest to them, sustaining that inquiry with modeling and quantitative analysis to make inferences regarding the phenomena. They pose their own questions, get their own data, and solve their own problems in mini-project homework assignments that lead to a semester-long project. Strategies to nurture this inquiry include starting with a larger, human inquiry for which a personal motivation is required. Narrowing this larger inquiry to the possible underlying physical mechanisms is key. Framing the inquiry in terms of comparison eases making quantitative analysis meaningful.

AI10: 10:00-10:30 a.m. Parallel Pedagogy: Teaching Mechanics Concepts Simultaneously

Poster – Owen Staveland, California Polytechnic State University, the new science building, 180-608, San Luis Obispo, CA 93407; owen@staveland.com

Dean A. Stocker. University of Cincinnati Blue Ash College

Pete Schwartz. California Polytechnic State University

Using "Parallel pedagogy" we introduce the concepts of momentum, energy, dynamics, and kinematics on the first day and develop depth and complexity throughout the semester. This pedagogy has shown promising results in conceptual, algebra-based, and calculus-based physics. Every example begins by considering each concept, steering students away from "formula hunting" and toward a concept-driven approach to problem solving. We have found that students have accepted this new system well, shifted toward expert thinking based on CLASS results, and solve problems and perform on the FCI on par with or better than conventionally-taught classes. Students also self-report at the end of the class that they enjoy physics more than they thought they would.

AI11: 10:00-10:30 a.m. Planning IPLS Course Development: Considerations for Different Life Science Majors

Poster – Andrew J. Mason, University of Central Arkansas, Department of Physics and Astronomy, Conway, AR 72035-0001; ajmason@uca.edu

We discuss recent considerations for course development in introductory physics for the life sciences (IPLS) at a primarily undergraduate institution. Previous research found that a bifurcation – in terms of attitudes towards physics, conceptual reasoning of force and motion, and overall course performance – exists within the life science major student population that predominates the host institution's introductory algebra-based physics course, specifically between majors within the biology department and majors within the health sciences college. We examine possible ways forward for addressing IPLS courses that would be respectively suitable for the two different course populations. We also discuss considerations of additional data, e.g. students' perceptions of how course topics applied to their respective majors.

AI12: 10:00-10:30 a.m. Shifts in Student Attitudes in IPLS Labs

Poster – Claudia De Grandi, University of Utah, Physics & Astronomy, 115 South 1400 East #201, Salt Lake City, UT 84112-0830; degrandi@physics.utah.edu

Jason M. May, Jordan M. Gerton, Lauren Barth-Cohen, University of Utah

There has been a shift in undergraduate labs towards emphases on the explorative and collaborative dimensions of science. Following this trend, the University of Utah has recently adopted a revised format of the National Experiment in Undergraduate Science Education (NEXUS) IPLS Introductory Labs. Here we focus on data from the second semester of this lab sequence. Specifically, we have collected student responses to an end-of-semester anonymous surveys that addresses mindset, attitude towards challenges and group work. We report the survey results and observations for two semesters of implementations of the lab. In particular, we observed positive shifts in student attitudes towards two main components of the course: learning from/in the process independently from simply getting a final answer, and learning to work efficiently in different groups. These results inform how to effectively promote engagement of life-science students in introductory physics labs and student-initiated connections between physics and life-sciences.

AI13: 10:00-10:30 a.m. Student Surveys and Mindset Interventions: Analysis from Reformed IPLS Labs

Poster – Jason M. May, University of Utah, 1212 W 200 N Apt. D111, Centerville, UT 84014-3549; jason.may@utah.edu

Jordan M. Gerton, Claudia De Grandi, Lauren Barth-Cohen, University of Utah

Brianna Montoya, University of Maryland

Instructors at the University of Utah have collected data from students in modified NEXUS-IPLS reformed laboratory courses via validated surveys (CLASS, E-CLASS) and instructor-designed surveys. Preliminary analysis shows that students completed the course with no changes or positive changes to perceptions of physics courses and physics-based knowledge. These results provide evidence that redesigned IPLS lab courses, such as at the University of Utah, do not diminish students' attitudes and beliefs about physics, as compared to such outcomes from traditional physics labs. These results are consistent with findings from other IPLS course reforms. We hypothesize that, in addition to the completed IPLS reforms, student completion of mindset-focused interventions, designed by the Failure as a Part of Learning: A Mindset Education network (FLAMEnet), have contributed to these results. This poster presents the results of two post-pilot semesters of student surveys (CLASS and E-CLASS), one semester of instructor-designed surveys, and FLAMEnet interventions.

AI14: 10:00-10:30 a.m. The Science of Energy

Poster – Donald G. Franklin, Retired, 35 East Main Street, South Hampton, GA 30228-2932; donfranklin8@gmail.com

Using 3 ebooks, you can have a course for students that covers all of the sciences, with Energy as the main topic. Energy of Biology, Energy of Chemistry, Energy of Earth and Space, Energy of Physics. This will prepare all students not just those taking a selected AP course.

Session AJ The History of the Last Few Decades of Computation in Physics Education

Location: MH - Aspen **Sponsor:** Committee on Educational Technologies **Time:** 8:30–10:30 a.m. **Date:** Monday, July 22

Presider: Larry Engelhardt

We will hear the stories of how the computational tools and resources that we use for physics education today came to be, told by the pioneers who developed them.

AJ01: 8:30-10:30 a.m. Five Decades of Computers in Physics Education

Panel – Bruce Sherwood, University of North Texas, 3341 Clubview Drive, Argyle, TX 76226; bruce.sherwood@gmail.com

Over the decades there has been an oscillation of emphasis on students writing programs themselves and students running educational programs written by faculty for student use. I wrote my first computer program in 1962 and my first educational physics program in 1969, in the graphics-oriented PLATO computer-based education system. PLATO had a powerful programming language, TUTOR, that showed it was possible to design a programming language that enabled people without high-level programming expertise to be able to write programs that do remarkable things. I've been involved in the development of such programming environments ever since, culminating in GlowScript VPython (2014). I will discuss historical links between ease of programming and the feasibility of engaging physics students in modeling physical systems by writing programs themselves. Ease of programming can also facilitate writing educational programs for students to use.

AJ02: 8:30-10:30 a.m. Early Computational Physics Leading to a Software Company

Panel – David L. Vernier, Vernier Software & Technology, 13979 SW Millikan Way, Beaverton, OR 97005; dvernier@vernier.com

As a high school physics teacher in the late 1970s, I was lucky to have access to some early microcomputers with graphic displays. I quickly discovered that they were very helpful in my physics teaching. One of my first useful programs was a projectile-motion program. It was a BASIC computational physics program and I encouraged students to modify the code, changing various parameters, including the drag coefficients. This program and a program simulating satellite motion eventually became commercial Apple II programs and led to the start of Vernier Software. Lately we have mostly concentrated on data-collection software, but I will explain how we have continued to encourage students and teachers to write their own programs for reading our sensors.

AJ03: 8:30-10:30 a.m. Computer-based Physics Education at Davidson College and Beyond

Panel – Wolfgang Christian, Davidson College, 167 Catalina Dr., Mooresville, NC 28117; wochristian@davidson.edu

Over the past 25 years, the Davidson College Physics Department has produced some of the most widely used interactive computer-based curricular materials for the teaching of introductory and advanced physics courses. Our curricular development began with our involvement in the Pascal-based MUPPET and CUPS projects and the distribution of interactive material during the dawn of the Internet using a WebPhysics server running on a NeXT computer. This early work led to the hosting of computational physics conferences and later the publication of Physlet and Open Source Physics based curricular material by commercial publishers and by the AAPT-ComPADRE National Science Digital Library. It continues with the development of Python Jupyter notebooks and JavaScript apps for mobile devices. This talk describes the academic environment and the many collaborations that made this development possible at a small liberal arts college.

AJ04: 8:30-10:30 a.m. Lessons Learned in Sharing Computational Resources for Physics Education

Panel – Bruce Mason, University of Oklahoma, 440 W. Brooks St., Norman, OK 73019; bmason@ou.edu

Many of the best efforts to develop, test, and use resources for integrating computation into the physics curriculum have included the difficult chore of sharing and encouraging adoption by other instructors. Many different avenues of dissemination have been used: journal articles, workshops, conferences, online repositories, startup companies, and commercial partnerships. Some efforts have been successful while others have come and gone. All have faced issues of training, debugging, and technology change. This talk will highlight some notable examples, past and present, of including computation in physics education, with the hope of providing some lessons for the future.

Session AK Topical Discussion & Social for Students

Location: CC - Cascade A/B **Sponsor:** Committee on Research in Physics Education **Co-Sponsor:** Committee on Graduate Education in Physics
Time: 8:30–10:30 a.m. **Date:** Monday, July 22 **Presider:** Danny Doucette

This session is the primary opportunity for student members of the PER community to meet and discuss common issues. While this session is aimed toward graduate students, we welcome undergraduates who are interested in studying PER or curious about life as a graduate student!

Session AL PTRA: Make, Play, Do to Learn

Location: CC - Ballroom B **Sponsor:** Committee on Physics in Pre-High School Education **Co-Sponsor:** Committee on Physics in High Schools
Time: 8:30–10:30 a.m. **Date:** Monday, July 22 **Presider:** Nin Kaye

This session is sponsored by the Pre-High School Committee and hosted by PTRAs. Come and get a variety of ideas for things you can make for a small investment of money and time. Students can make many of these items. These can be used to teach physics concepts at a variety of levels. Each item will have the instructions available and is linked to the NGSS.

AL01: 8:30-10:30 a.m. Literature-based Make, Play & Do to Learn Activities

Contributed – William E. Reitz, retired, 2921 Kent Rd., Silver Lake, OH 44224; wreitz@neo.rr.com

A range of physical science topics will be explored using activities inspired by Graphic Novels and YA(Young Adult) literature. Participants will be able "Make, Play & Do" the activities at their own pace. They will also be able to interact with the literature driving those activities. This is one of several sets of activities other presenters will offer in the "Make, Play & Do to Learn" session.

AL02: 8:30-10:30 a.m. Scribble Bots

Contributed – Alice Flarend, Bellwood-Antis HS, 209 W 15th Ave., Altoona, PA 16601; aflarend@gmail.com

We will make small bots from common materials including plastic cups, markers and motors, and experiment with them to control their motion. They are also an engaging way to practice distance and velocity measurements, even in 2-D!

AL03: 8:30-10:30 a.m. Using Paper Dice to Practice Calculating Newton's Law of Gravity

Contributed – Bree B. Dreyfuss, Amador Valley High School, 1155 Santa Rita Rd., Pleasanton, CA 94566; BreeBarnettDreyfuss@gmail.com

While learning about Newton's law of gravitation physics students often struggle with the inverse square in the equation. Computational practice of orbiting objects in the solar system can be dry and repetitive. Using paper dice with planet information and calculation prompts students can practice using the equation and Kepler's laws. Students roll two dice that have the mass, radius, and distance to the Sun to randomly select two objects, such as Jupiter and Mercury. Students also roll a calculation die with prompts about what to calculate such as the force of gravity between the two, what the orbital speed would be if they one were to orbit, etc. A set of copies of the dice will be available for teachers to keep.

AL04: 8:30-10:30 a.m. Ball Bounce Lab Using Argument Driven Inquiry

Contributed – Ann Robinson, The University of West Georgia, 293 Paces Lakes Ridge, Dallas, GA 30157; arobinso@westga.edu

(Adaptation from Teaching Physics for the First Time by Jan Mader and Mary Winn) Problem: How does dropping a ball from a certain height affect the height it bounces? How is the time of free fall related to the distance fallen? (Grades 5-12)

AL05: 8:30-10:30 a.m. Demonstrate 5 Physics Concepts Using this DIY Straw Sprinkler

Contributed – Gyaneshwaran Gomathinayagam, The Doon School, Dehradun, UTTARAKHAND 248001 India; gya@doonschool.com

Aditya Garg ,The Doon School

The Straw Sprinkler can be assembled easily in minutes using just a couple of straws, a water hose and a bucket of water. This innovation was made by modifying the famous Action-Reaction Straw Propeller (found in Arvind Gupta's youtube channel and Think Tac website) to use water instead of air as the working fluid. To provide a continuous flow of water of adjustable velocity, a siphon is connected to a bucket kept on a raised platform whose height can be varied to vary the velocity of water. It can be used to demonstrate the Laws of Conservation of Energy and Angular Momentum, Newton's second and third laws, and uniform circular motion in horizontal or vertical plane. The hole size, number of holes, height of water reservoir, and angle of hole can also be varied to study their effect on the angular velocity of the straw sprinkler.
https://youtu.be/YJEFROW5sBI

Session AM PTRA: Physics of Sound

Location: CC - Ballroom A **Sponsor:** Committee on Physics in Pre-High School Education **Co-Sponsor:** Committee on Physics in High Schools
Time: 8:30–10:30 a.m. **Date:** Monday, July 22 **Presider:** Ann Robinson

Sounds have identifiable characteristics, and the basic idea that all sounds result from vibrating objects is the focus for this interactive presentation. Sounds are produced with a variety of common objects at stations set up using rulers, tuning forks, straws, and toys. These stations will also have a variety of game-like activities involving participants locating sounds from unseen sources, learning about decibels, and calculating the speed of sound. Many of the activities will feature some of "Heck's Physics" as a tribute to Richard Heckthorn and presented by PTRA.

Session AN International Perspectives for Laboratories

Location: MH - Juniper **Sponsor:** Committee on Laboratories **Co-Sponsor:** Committee on International Physics Education
Time: 8:30–10:30 a.m. **Date:** Monday, July 22 **Presider:** Benjamin Pollard

AN01: 8:30-9:00 a.m. Physics Lab in Brazil: Do As I Say, Not As I Do?

Invited – Katemari Rosa, Federal University of Bahia, Instituto de Fisica-UFBA - Rua Barão de Jeremoabo s/n, Salvador, BA 40170-115 Brasil; katemari@gmail.com

Most people agree that laboratory courses are important in physics education. Numerous physics education research (PER) investigations and results help us understand the relationships between engaging in experimental practices, learning physics, and being enculturated into physics. However, when we go into the "real world" of high school physics labs, practices may differ greatly from what we have learned about how they should be. The same happens when we enter physics lab classes at the university. At least that is what I have been experiencing in Brazil, and that is what I will be sharing in this presentation. I will discuss the practices of high school physics teachers in Brazil as well as higher education physics faculty when it comes to labs. One of the results we will see is that Brazilian lab classes are very structured, lack technology, and may not foster deeper learning of physics concepts.

AN02: 9:00-9:30 a.m. Development of Stand-alone Lab Courses in China

Invited – Yongkang Le Fudan, University No. 220, Handan Road, Shanghai, 200433 China; leyk@fudan.edu.cn

In order to host several thousand students in science, engineering and medicine each year, including several hundred students majoring physics, lab courses in Chinese universities are overwhelmingly stand-alone. Most universities provide fundamental, comprehensive, and advanced lab courses. Some also provide research-oriented lab course or open-projects training. With the increasing attraction of the International Young Physicists' Tournament, open projects have been adopted by more and more universities. Supported by increasing investment into undergraduate education from the government, universities are improving their infrastructure for lab training. At the same time, the lab community realizes that the outcomes are impacted by two key factors: competence of the lab faculty and the need to update lab contents. Nationwide competition among lab supervisors and related training programs were organized recently. Newly developed labs tend to cover more topics, such as vacuum physics, mass spectrometer and plasma physics. In this presentation, I will discuss these and other aspects of physics labs in China, using Fudan University as an example.

AN03: 9:30-10:00 a.m. Physics Laboratory Experiences at the University of Nigeria

Invited – Finbarr Odo, University of Nigeria, Nsukka Nsukka, 410101 Nigeria; finbarr.odo@unn.edu.ng*

Laboratory teaching is an essential component of teaching physics and other sciences at all levels. However, research findings on laboratory education in Nigerian universities have revealed a rapid dwindling of students' interest in laboratory courses. In this presentation, I will draw on 10 years of experience teaching physics laboratory courses at the University of Nigeria, and four years training other physics educators through the West African International Summer School for Young Astronomers (WAISSYA) to discuss the challenges faced by both teachers and learners of laboratory physics courses, and the creative teaching strategies developed by teachers for effective teaching of physics laboratory classes at the University of Nigeria and WAISSYA. Based on my experiences over these years, I recommend that in conducting lab courses, emphasis ought to be placed on what students can learn from the experience rather than the mere actions they perform in conducting the laboratory courses.

*Sponsored by Dimitri Dounas-Frazer

AN04: 10:00-10:30 a.m. Introductory Physics Laboratories in the South African Context

Invited – Nuraan Majiet, University of Cape Town, Rondebosch, Cape Town, Non U.S. 7700 South Africa; mjtnur001@myuct.ac.za

First-year physics students at the University of Cape Town come from a wide range of socio-economic backgrounds. This is reflected in levels of educational preparedness for first year physics, in particular where experimentation is concerned. The introductory physics laboratory needs to be suitably accommodating of students' prior experience. The Physics and Astronomy Education Research (Phaser) Group at UCT has over a period of several years undertaken an array of studies investigating different areas of laboratory work with a view to informing the curriculum. In the same way that framing theory problems can lead to answer-making rather than sense-making, framing the lab can lead to "follow the instructions," answer-making or sense-making. Therefore, framing the lab such that students can make sense of the overall purpose of the activity resulting in meaningful engagement both during the experiment and in the reporting of it, has been a key focus of our research.

Session AO PER: Diversity, Equity and Inclusion: Designing Curriculum for Inclusion

Location: MH - Zion **Sponsor:** AAPT/PER **Time:** 9–10 a.m. **Date:** Monday, July 22 **Presider:** TBA

A004: 9:00-9:10 a.m. Introductory Physics Students' Insights for Improving Physics Culture

Contributed – Acacia Arielle, South Seattle College, 6000 16th Ave. SW, Seattle, WA 98106; aarielle562@southseattle.edu

Kai S. Bretl, Abigail R. Daane, South Seattle College

Amad Ross, Columbia University

Women and people of color are underrepresented in classrooms and the field of physics. We can work to address this disparity by empowering students to change the physics culture within their own spheres of influence. Students in introductory, calculus-based physics classes from both two- and four-year institutions participated in lessons from the Underrepresentation Curriculum, a freely available curriculum designed to bring social justice conversations to the classroom. Post unit, students brainstormed ideas about how to raise awareness of, and ultimately remove, this inequity. We coded students' responses grouping analogous key words and phrases. Our analysis showed that students from both institutions generated similar sets of propositions. Their responses included having intentional conversations about equity issues and actively learning about their own biases. By following students' suggestions, we can create a more inclusive and diverse physics community.

A005: 9:10-9:20 a.m. Underrepresentation Curriculum for Teachers: Physics Lessons on Equity and Society

Contributed – Moses Rifkin, University Prep 8000 25th Ave. NE, Seattle, WA 98115; mrifkin@universityprep.org

Chris Gosling, McGill University

Abigail Daane, South Seattle College

Johan Tabora, University of Illinois-Chicago

Danny Doucette, University of Pittsburgh

The Underrepresentation Curriculum is a freely available, adjustable curriculum designed to support STEM teachers in bringing conversations about equity, identity, society, and justice into their classrooms. Since its launch a year ago, it has been enthusiastically received by physics teachers across the country. In this presentation, we will share aspects that have been particularly successful in our own implementation and among the users. We will share different approaches and advice from instructors who have taught a unit in their own classrooms.

A006: 9:20-9:30 a.m. Underrepresentation Curriculum: Pilot Surveys to Identify Growth

Contributed – Chris Gosling, McGill University, 27 Rockledge Ln., Saranac Lake, NY 12983; christopher.gosling@mail.mcgill.ca

Abigail Daane, South Seattle College

Moses Rifkin, University Prep

Johan Tabora, University of Illinois-Chicago

Danny Doucette, University of Pittsburgh

Several instructors over the past few years have implemented the Underrepresentation Curriculum, a freely available, adjustable curriculum designed to bring conversations about equity, identity, society, and justice into the classroom. Anecdotally, the curriculum has been successful. However, as its use becomes more widespread, we have begun to work towards better articulating the nature and scale of students' learning as we revise the curriculum. We will share a preliminary analysis of student responses to pre- and post- survey questions regarding students' views of physics and their awareness of the intersection of society and science. These results will be incorporated in the curriculum to improve students' learning experiences.

A007: 9:30-9:40 a.m. Physics is Objective - or is it?

Contributed – Abigail R. Daane, South Seattle College, 6000 16th Ave. SW, Seattle, WA 98106; abigail.daane@seattlecolleges.edu

Chris Gosling, McGill University

Moses Rifkin, University Prep

Johan Tabora, University of Illinois-Chicago

Danny Doucette, University of Pittsburgh

Physics is widely perceived as an objective field. Students often echo that perception of physics as bias-free and not subject to human influence. In reality, a host of humans determine the focus of research, the projects that receive funding, and what is published. Using the Underrepresentation Curriculum, a freely available resource designed to bring conversations about equity to the classroom, students explore the question "is physics subjective or objective?" In this presentation, we share students' ideas about the nature of physics and how those ideas may influence their orientation to the scientific community. We posit that the illumination of subjectivity in hard sciences can be a powerful tool for motivating classroom conversations of social justice.

A008: 9:40-9:50 a.m. Voices in the Classroom

Contributed – Ruth Saunders, Humboldt State University, Science A, Laurel St, Lau Arcata, CA 95521; rbs177@humboldt.edu

This talk describes my efforts to enhance the diversity of student voices in the classroom. I have implemented strategies to give students more opportunities to have their voices 'heard' in the classroom.

A009: 9:50-10:00 a.m. The Physics Class as a Source of Empowerment and Self-advocacy

Contributed – Khadijih Nur Mitchell, University of Colorado Boulder, 249 UCB Boulder, CO 80309; Khmi8716@colorado.edu

Valerie Otero, University of Colorado Boulder

Physics is often perceived as a gatekeeper rather than as an opportunity for empowerment. We report on physics education research involving a physics class using the Physics through Evidence, Empowerment through Reasoning (PEER) curriculum suite. Through the process of inducing principles from data (inductive methods), and supporting claims with evidence, students learned to advocate for themselves as they used evidence and consensus, rather than the teacher and text, to sanction knowledge claims. Qualitative and quantitative findings will be used to support preliminary claims of how physics courses can be a source of empowerment for many students from groups traditionally underrepresented in the field.

David Jackson to Receive the AAPT 2019 David Halliday and Robert Resnick Award for Excellence in Undergraduate Physics Teaching —

Helping Students Have Meaningful Learning Experiences In Physics

David Jackson
Dickinson College

As physics instructors, we all want our students to learn some physics. But how can we best accomplish this task? Over the past several decades, a significant amount of research has gone into trying to answer this question. Two lessons that have come out of this research are: (i) that lectures are much less effective than any of us would like to believe, and (ii) that getting students actively engaged in the material is essential for effective learning. So why is it that some students can still learn in a lecture environment while others will fail to learn in a course that uses active-engagement techniques? Clearly, a lecture environment does not promote active learning, but that does not mean a student cannot be actively engaged in such a course. Conversely, even the best active-engagement strategies are doomed to fail if a student is inherently disinterested in the material. Ultimately, I think the best we can do is to try to provide meaningful hands-on experiences to our students, and then guide them through the steps needed to develop an understanding of the situation. In this talk, I will give several examples of how I try to provide such experiences to my students.

AAPT PHYSICS EDUCATION

Monday July 22
11:00–11:30 a.m.

CC - Ballroom C

Session BA Share-a-thon: Active Learning for the 2-Year College

Location: CC - Cascade A/B **Sponsor:** Committee on Physics in Two-Year Colleges **Co-Sponsor:** Committee on Physics in High Schools
Time: 1:30–3:30 p.m. **Date:** Monday, July 22 **Presider:** Theo Gotis

BA01: 1:30-3:30 p.m. Comparing the Cook Book and Non-Cook Book Lab Activities in an Active Learning Environment

Contributed – Azita Seyed Fadaei, South Seattle Community College, 1527 15th Ave., Apt 408, Seattle, WA 98122; seiedf@yahoo.com

We have compared the effects of cookbook-based lab activities with the impacts of doing lab inquiry based on a small introductory engineering physics course. Performance in lab activities that did and did not require the cookbook procedure were compared using a final questionnaire from the participating students in that course. The population of students who did the lab in each scenario was the same because they enrolled in the same course. In the course we planned five lab activities of three different types. The first type that we call Cook Book activities were prepared and then completed by students. The second type of activities, which we call Non- Cook Book were inquiry-based and orally guide. The final activity type was called Both and was a combination of two other activities. We analyzed the results of the activities-related questionnaire.

Session BB Best Practices in Educational Technology

Location: CC - Cascade D **Sponsor:** Committee on Educational Technologies **Time:** 1:30–3:30 p.m. **Date:** Monday, July 22
Presider: Shahida Dar

BB01: 1:30-3:30 p.m. Implementing Video Games and Augmented/Virtual Reality in the Classroom

Invited – David Rosengrant, University of South Florida, St. Petersburg, 140 7th Avenue South, Coquina 201, St. Petersburg, FL 33701; rosengrant@mail.usf.edu

Technology is changing the way we teach our students. Thus, it is imperative that we also change how we teach our future science and physics teachers to incorporate this new technology. Video games serve as a natural motivator for many students as they are already interested in them. The engines must be realistic in order to make them believable. This provides us with a great opportunity to use them as a teaching tool if done properly. Augmented reality allows our students the ability to maintain a hands on environment while incorporating virtual technologies. Virtual reality gives us unprecedented freedom to make any topic or any concept come alive in our classroom. This presentation focuses on the success and opportunities as well as student responses to these technologies in the author's science courses as well as strategies and resources for participants to adopt with their instruction.

BB02: 1:30-3:30 p.m. Using Volumetric and Holographic Display in Visualizing Scientific Concepts

Invited – Mojgan Haghanikar, SUNY Polytechnic Institute, Seymour Rd., Utica, NY 11201-7028; holomatloob@yahoo.com

The rapid advancements in three-dimensional digital imaging, virtual and augmented reality, have allowed extensive possibilities to elucidate scientific communication. Growing body of research (Hegarty, 2014)* in psychometrics and science education literature has reported the high correlation between learners' spatial abilities and success in the sciences. A significant number of abstract concepts in physics, chemistry, math, astronomy, and biology are three-dimensional entities. However, the challenges are not limited to the obscurity of the third dimension. Communicating science is troublesome whenever the speed of transition, scale or time frame is beyond the realm of our perceptions and our daily life experiences. The recent advancements in mixed reality technologies, hold vast potential to enhance the visualization and interactions to promote learning scientific processes. The unique characteristics of mixed reality technologies such as 3D interactive allowance, the physical and virtual world merger and the flexibility to connect various layers of information are the most promising features to enhance scientific communication. In this presentation, I will present sample demos and will also discuss the possible grounds for collaboration, in sketching a new platform for scientific communication, for instance, new strategies for outreach and dissemination of research findings, hybrid classes, and remote labs.

*Hegarty, M. (2014). Spatial thinking in undergraduate science education. Spatial Cognition & Computation, 14, 142–167.

BB03: 1:30-3:30 p.m. Integration of Computational Modeling: Formative Assessment

Invited – Ruth Chabay, University of North Texas, 3341 Clubview Drive, Argyle, TX 76226; rwchabay@gmail.com

The integration of computational modeling into physics courses at the introductory level and beyond offers various possible educational benefits. However, in order to make sure that we are actually meeting our own instructional goals, we need to assess what students have actually learned and to identify areas where our instruction can be improved. Large computational projects are not necessarily the most informative means of such formative assessment. How can we articulate clear goals for student learning and create tasks specifically targeted at assessing these goals?

BB04: 1:30-3:30 p.m. Leading Students to Create a Technology-Focused Portfolio

Invited – Aaron Titus, High Point University, One University Parkway, High Point, NC 27286; atitus@highpoint.edu

The Department of Physics at High Point University has three primary strategies to prepare all undergraduate physics majors for contemporary scientific practices in both industry and graduate school. (1) Every physics course incorporates both computational physics and experimental physics. (2) Each intermediate physics course requires students to do a semester project. (3) All students do guided research, starting in their first year. As a result, students have a plethora of experiences writing code, starting with the use of VPython in the first-year introductory physics course, which includes computational modeling. In this presentation, I will highlight their computational experiences and will describe how students make a professional technology-focused, public portfolio of their work.

BB05: 1:30-3:30 p.m. Teaching Kinematics with Drones and Videoanalytics

Invited – Lars Möhring, University of Cologne, Albertus Magnus Platz, Cologne, NRW 50931 Germany; moehrlars@gmail.com

Andre Bresges University of Cologne

Knowing the position of an object by having access to it's starting point, velocity, and acceleration is one of the main problems in kinematics. Teaching kinematics in real-life context often utilizes the behavior of cars, ships, or trains. With the advancement in technology autonomous drones or UAV become more and more part of our everyday life. The reduction in scale and price leads to new possibilities for studying their behavior in 3-dimensional space. Our drones are hexacopters programmable in SCRATCH via any mobile device. This enables a predict-observe-explain cycle promoting a combination of content knowledge, measuring and observation, programming skills and physical modelling. We present our teaching practice as well as empirical data of the learning outcome, measured with the Force Concept Inventory.

Session BC Supporting Accessibility in Physics Education

Location: CC - Cascade C **Sponsor:** Committee on Diversity in Physics **Co-Sponsor:** Committee on Professional Concerns
Time: 1:30–3:30 p.m. **Date:** Monday, July 22 **Presider:** TBA

The STEM Inclusion Study AAPT Organization Report (2017) found that disability status was a significant factor in many measures of AAPT members' experiences or observations of marginalization and devaluation in the workplace. In this invited panel session, panelists will give short presentations about their efforts to combat ableism and support accessibility in science education. Ableism refers to interpersonal, institutional, ideological, or internalized factors that negatively impact people with disabilities. Examples include discriminatory interactions, inaccessible classroom layouts, or stereotypes. Accessibility refers to the design of learning environments and materials by and for people with disabilities. After the presentations, there will be an hour-long question-and-answer period, during which the audience can participate in a dialogue with the panelists about implications for physics education.

BC01: 1:30-3:30 p.m. Strategies for Creating an Inclusive Classroom for Deaf or Hard-of-hearing Students

Panel – David Spiecker, Rochester Institute of Technology, 1 Lomb Memorial Dr., Rochester, NY 14623; desnca@rit.edu

In a typical classroom, artificial barriers can be created that prevent deaf or hard-of-hearing students from being included. By considering how those barriers are created in the first place, several strategies can be utilized to remove barriers and create an inclusive classroom for everyone in it. The strategies utilized address effective communication, accessibility of information, and cultural sensitivity.

BC02: 1:30-3:30 p.m. Inclusive Teaching Strategies Can Increase Accessibility in Physics Education

Panel – Jacquelyn J. Chini, University of Central Florida, 4111 Libra Drive - PSB 430, Orlando, FL 32816; jchini@ucf.edu

Westley James, Jillian Schreffler, Eleazar Vasquez III, Erin Scanlon, University of Central Florida

The physics education research community has a strong tradition of working to match pedagogical strategies to students' needs. In recent years, we have examined the student population typically included in our research studies and have identified differences in areas such as math preparation between the populations in our studies and the population of students taking undergraduate physics courses. Continuing in this vein, we investigated successful student-centered active learning strategies and curricula with an accessibility lens to examine the extent to which our community's focus on improving student learning has either explicitly or implicitly considered students with disabilities. Additionally, we have surveyed instructors about their views and self-reported use of inclusive teaching strategies. We will share examples of how inclusive teaching strategies, often based on the framework of Universal Design for Learning, can be used to make physics education more accessible to students with disabilities.

BC03: 1:30-3:30 p.m. ACS-CWD: Providing Resources and Support for the Scientific Community

Panel – Debra A. Feakes, University of Indianapolis, 1400 E Hanna Ave., Indianapolis, IN 46227; feakesd@uindy.edu

The mission of the American Chemical Society (ACS) Chemists with Disabilities (CWD) committee is to "promote educational and professional opportunities in the chemical sciences and in fields requiring knowledge of chemistry for persons with disabilities. The committee will champion the capabilities of those persons to educators, employers, and peers." Composed of 19 members and 10 associate members, the committee represents higher education, the chemical industry, and government agencies. Through the volunteer efforts of its members, the committee creates, compiles, and distributes resources to promote and advance the full participation of people with disabilities and serves as a resource to the scientific community. The resources and opportunities provided by this committee, particularly with regards to the education of individuals with disabilities, will be presented.

BC05: 1:30-3:30 p.m. The Third Decade of Efforts Helping Blind Students Learn Science

Panel – George M. Bodner, Purdue University, Department of Chemistry, West Lafayette, IN 47907; gmbodner@purdue.edu

This paper will examine efforts going back almost 25 years to help students who are blind or low-vision (BLV) successfully complete high school and college-level courses in chemistry and, to a lesser extent, physics. Genesis for this project occurred when the dean asked what he thought was a rhetorical question: "You wouldn't let a blind student take general chemistry, would you?" He was shocked when my response was: "Why not?" Our work has taken a three-pronged approach. At the institutional level, we helped create a campus-wide Tactile Access to Education for Visually Impaired Srtudents (TAEVIS) program. As chemical educators, we developed adaptive technology approaches to help students who are blind take an active role in collecting data in the laboratory. As practitioners of discipline-based educational research, we have completed three PhD dissertations devoted to understanding and overcoming problems BLV students encounter in the lecture and lab portions of science courses.

BC06: 1:30-3:30 p.m. Disability Justice + Queer Justice: Integrated accessibility approaches in the classroom

Panel – Melissa Kelley Colibrí, San Diego Pride, 3620 30th Street, San Diego, CA 92103; melissa@sdpride.org

This interactive session will introduce participants to the key issues of accessibility in the classroom for students with disabilities and students who experience intersectional oppressions. Participants will leave with practical tools and resources to make their classroom more accessible, the ability to address accessibility through the intersecting lenses of economic, disability, racial, queer and gender justice, and the skills to work with their disability service organizations to enhance accessibility services in their classrooms. They will also be introduced to inclusive language for all students.

Session BD The Graduate Physics Education Experience

Location: MH - Bryce **Sponsor:** Committee on Graduate Education in Physics **Co-Sponsor:** Committee on Physics in Undergraduate Education
Time: 1:30–3:30 p.m. **Date:** Monday, July 22 **Presider:** Deepa Chari

BD01: 1:30-2:00 p.m. Examining Prospective Graduate Students' Views on Barriers and Motivations Towards Physics Graduate School*

Invited – Geoff Potvin, Florida International University, 11200 SW 8th St., Miami, FL 33199; gpotvin@fiu.edu

Deepa Chari Florida International University

Diversity in graduate physics remains a persistent problem, and there are many factors that may hold back efforts to improve the situation. In prior work, we considered how faculty members' values in admissions decisions may limit the diversity of accepted graduate students. In this talk, we instead examine the perceptions of prospective graduate students (upper division undergraduate physics majors) on potential barriers to graduate school and their motivations towards the pursuit of a graduate degree. This is accomplished through an analysis of a recent, nationally-representative survey of over 1000 undergraduate physics majors in the U.S. The results indicate specific factors that may be limiting the opportunities for the diversification of graduate physics by dissuading students from even applying.

*This work was supported in part by NSF Grant No. 1143070.

BD02: 2:00-2:30 p.m. The Intersection of Content, Student, and Institution in Graduate Physics

Invited – Christopher Porter, The Ohio State University, 191 W. Woodruff Ave., Columbus, OH 43210; porter.284@osu.edu

Andrew F. Heckler, Sara Mueller, Amber Simmons, The Ohio State University

There are many reasons to study graduate-level physics education. These include the 55% 10-year completion rate, and the chronic underrepresentation of certain groups. One might add to that the overall poor performance on conceptual assessments in the handful of studies that have looked at graduate physics education. Such concerning outcomes cannot be entirely attributed to any one part of the physics graduate experience; rather the students, content, and institution should all be viewed as important parts. In this talk, we will review recent efforts to examine each of these areas. Specifically, we will discuss attitudinal and motivational factors measured in physics graduate students, factors that are known to be linked to retention in undergraduate STEM. We will also address a number of content misunderstandings that persist through the end of core course instruction. We will briefly discuss programmatic differences between several participating departments and how these might affect students.

BD03: 2:30-3:00 p.m. Effective Professional Development for Graduate Teaching Assistants

Invited – Alexandru Maries, University of Cincinnati, 345 Clifton Court, Cincinnati, OH 45220; mariesau@ucmail.uc.edu

Graduate students across the United States are currently playing an important role in the education of students as they often teach laboratories, recitations, and discussion sections. It is important to provide professional development for graduate teaching assistants (GTAs), not only because this will have a positive impact on students now, but also because it can have an impact on the students of tomorrow. GTA professional development can also provide an opportunity to improve graduate students' sense of belonging by recognizing them as partners in furthering the educational mission of the department and using their feedback to improve teaching and learning. This talk will discuss productive approaches to designing an effective GTA professional development program that helps improve GTAs' pedagogical content knowledge as well as their sense of belonging.

BD04: 3:00-3:30 p.m. Physics PhD Student Social Networks and Experiences

Invited – Alexis Knaub, Department of Physics and Astronomy, Michigan State University, East Lansing, MI 48824; avknaub@gmail.com

Graduate school is a social endeavor where students form ties with faculty, staff, and fellow students for many reasons including research, coursework, and social support. Using social network analysis, the community structures of physics doctoral students in one department were studied. Different purposes (e.g., purely social, research) for each network were examined. The networks were studied with respect to a variety of demographic variables. Interviews delved into how the students viewed their networks and whether they felt supported. Findings indicate that despite having social ties to others within the department and not having any particularly dire negative social experiences, the doctoral students in this study felt as though they are not a part of a community and may not seek out support that they need.

Session BE: Current Materials for Program Self-Study & External Review, And Effective Practices for Physics Programs

Location: MH - Birch
Sponsor: Committee on Physics in Undergraduate Education **Time:** 1:30–3:30 p.m. **Date:** Monday, July 22 **Presider:** Ernie Behringer

Current AAPT materials bearing on program self-study and external review are discussed together with a new guide of Effective Practices for Physics Programs being developed by APS with community input.

BE01: 1:30-3:30 p.m. Guidelines for Self-Study: A Tool for Reflective Discovery and Management

Panel – Juan Burciaga, Department of Physics, Colorado College, 14 E. Cache La Poudre, Colorado Springs, CO 80903-3243; jburciaga@coloradocollege.edu

Departmental self-study, whether as part of an ongoing monitoring of the program or as part of preparing for an external review, is a powerful tool for both the department and for individual faculty. The "Guidelines for Self-Study and External Evaluation of Undergraduate Physics Programs" published in 2005 by AAPT form the basis for a comprehensive guided-inquiry into the goals of the department, the programs and curriculum within the department, and developing a profile of both the student and faculty communities. The talk will focus on introducing the guidelines and developing a perspective on the role of self-study in the life of the physics department and individual faculty.

BE02: 1:30-3:30 p.m. Using the AAPT Recommendations Documents for Program Review and Improvement

Panel – Joseph Kozminski, Lewis University, Department of Physics, One University Pkwy., Romeoville, IL 60446-2200; kozminjo@lewisu.edu

The AAPT has recently put out Recommendations for the Undergraduate Physics Laboratory Curriculum and Recommendations for Computational Physics in the Undergraduate Physics Curriculum. These recommendations focus on developing important skills and competencies, useful for graduate research and jobs in the STEM sector and many other employment sectors, in a scaffolded way throughout the undergraduate curriculum. The recommendations are general enough to be implemented at any institution and within a variety of curriculum frameworks. These documents give departments a way to evaluate their current programming and make changes to the laboratory and computational physics components of their curricula. They also provide guidelines that external reviewers can use to assess the laboratory and computational physics components of the program under review. This talk will provide an overview of these recommendations and how they might be used for department self-assessment or in an external program review.

BE03: 1:30-3:30 p.m. Guide to Program Review: Effective Practices for Physics Programs (EP3)

Panel – Theodore Hodapp, American Physical Society, 1 Physics Ellipse, College Park, MD 20740-3844; hodapp@aps.org

Program review is a reality for all colleges and universities. Whether this is regional accreditation, periodic external program review, or the department seeking certification or accreditation, there is a substantial amount of work required. The joint APS / AAPT guide: Effective Practices for Physics Programs (EP3), is a community-based effort to help physics programs conduct meaningful self-assessments, and respond to regional accreditation in ways that will maximize the value from the time spent by the department in developing and conducting these assessments. The guide will provide an opportunity for the department to transform the chore of self-assessment into a culture of continuous improvement, informed by evidence-based practices. It will include strategies for chairs to implement reforms, information on assessment practices, and a set of resources informing all aspects of a physics program. EP3 will train departmental reviewers to use these strategies and design principles in external program reviews.

BE04: 1:30-3:30 p.m. Effective Practices for Physics Programs: The EP3 Guide and Communities

Panel – David Craig, LeMoyne College, Department of Physics, Syracuse, NY 13214; craigda@lemoyne.edu

The EP3 Project is bringing together research and information about practices for building successful and effective physics programs from experts across the American physics community. The Guide it is creating will encompass recruiting and retention, research-based pedagogy, careers in physics, student research, considerations of equity, inclusion, and diversity, assessment of student learning, and program review, among many other areas. Sponsored by APS and AAPT, the Guide will be a living document and resource, not a report, with an ongoing commitment to maintaining and updating its content as the research evolves and the community learns and grows. The EP3 Project will also support the physics community in adoption and use of the Guide through workshops and online communities dedicated to helping physics departments achieve specific goals and objectives. This contribution will describe the Guide and its outreach and support initiatives.

Session BF PTRA: Paper Drag Racers in Your Classroom

Location: MH - Amphitheater **Sponsor:** Committee on Physics in Pre-High School Education **Co-Sponsor:** Committee on Physics in High Schools **Time:** 1:30–3:30 p.m. **Date:** Monday, July 22 **Presider:** Tommi Holsenbeck

Physics is NOT a Drag!! (new title) But it can be a drag race. Making paper drag racers is an engaging way to involve students at several grade levels in understanding principles of motion. Designing the inexpensive cars involves students in engineering a design to go fast (or go a certain distance) and covers concepts such as force, speed, impulse, graphing, and acceleration.

Session BH Lessons Learned: Let's Listen To Women and International Persons' Experiences

Location: MH - Arches **Sponsor:** Committee on Women in Physics **Co-Sponsor:** Committee on International Physics Education **Time:** 1:30–3:30 p.m. **Date:** Monday, July 22 **Presider:** MacKenzie Estelle Lenz

The panelists offer a multitude of perspectives on being a woman or international person in physics. Panelists will speak of their individual experiences, physics careers, as well as their attendance to and participation in conferences similar to AAPT.

BH02: A Venezuelan Perspective on International PER

Panel – Claudia Fracchiolla, University College Dublin, Belfield, Dublin, 4 Ireland; claudia.fracchiolla@ucd.ie

Different cultures have different perceptions of what inclusiveness and diversity mean. Europe, for example, could be considered culturally diverse. However, not necessarily racially diverse. When I first moved to the U.S. I had already lived, studied, and done research in five other countries, including my home country Venezuela. But it was not until then that I understood why discussions of inclusiveness and diversity were so important. I soon realized I was part of a minority. It was a hard awakening. Today, after working in three continents and multiple countries, I am more appreciative of others' perspective, which I believe have make my research stronger and inspired me to become an advocate for these issues

Speakers:

Tong Wan, 4060 New Broad Cir, APT 110, Oviedo, FL 32765

Carolina Alvarado, CSU Chico, 400 West St., Chico, CA 95929-0535

Session BI PER: Diversity, Equity, and Inclusion: Gender Differences

Location: MH - Zion **Sponsor:** AAPT/PER
Time: 1:30–2:50 p.m. **Date:** Monday, July 22 **Presider:** TBA

BI01: 1:30-1:40 p.m. Exploring FCI Misconceptions by Gender Using Modified Module Analysis

Contributed – James E. Wells, W.M. Keck Science Department of CMC, Scripps, and Pitzer Colleges, 925 N. Mills Ave., Claremont, CA 91711-5916; jwells@kecksci.claremont.edu

Rachel Henderson, Michigan State University

John Stewart, West Virginia University

Adrienne Traxler, Wright State University

In recent work by Traxler, et al., several items on the Force Concept Inventory (FCI) were identified as being unfair toward either female or male students. To determine whether these unfair items represent coherent misconceptions that vary by gender, we applied a modified version of the Module Analysis for Multiple Choice Responses created by Brewe, et al. to a dataset of over 4000 students. In our Modified Module Analysis, the correlation between each incorrect response serves as the edge strength in a network of wrong answers. A clustering algorithm found highly connected, incorrect-response modules indicating coherent misconceptions. Female and male students have slightly different misconceptions, but they do not incorporate the unfair items. Most modules represented true misconceptions; others connected consistent, but incorrect, responses from blocked sets of questions, indicating that the traditional scoring system of the FCI may underestimate a student's conceptual understanding of the material.

BI02: 1:40-1:50 p.m. Gender Differences in Self-efficacy States in High School Physics

Contributed – Jayson M. Nissen, California State University - Chico, 659 SW Jefferson Ave. Apt 2, Corvallis, OR 97333; jayson.nissen@gmail.com

Self-efficacy, the belief in one's ability to succeed in learning tasks, predicts learning and success in education broadly and physics specifically. While self-efficacy increases for students in most introductory science and mathematics courses, self-efficacy consistently decreases for women in physics courses. This study investigated gender differences in the self-efficacy high school students experienced in physics, other math and science classes, and other classes. Data for the study came from the Sloan Survey of Youth and Social Development and included data from 1,332 students at 12 different schools collected between 1993 and 1997. Comparisons of self-efficacy across gender and activity identified a large gender difference in self-efficacy experienced in physics and only in physics. These results add to the growing evidence that female students' physics self-efficacy tends to decrease after taking physics courses.

BI03: 1:50-2:00 p.m. An Examination of Gender Differences in Self-efficacy and Academic Performance in Different STEM Domains

Contributed – Kyle Whitcomb, University of Pittsburgh, 3941 O'Hara St., Pittsburgh, PA 15260; kmw136@pitt.edu

Z. Yasemin Kalender, Timothy J. Nokes-Malach, Christian D. Schunn, Chandralekha Singh, University of Pittsburgh

Prior research has shown that self-efficacy can be a critical factor in student learning and performance in STEM. Although past research has documented self-efficacy differences between females and males students in some STEM disciplines, relatively little work has compared these relations across disciplines. In order to better understand these relations and how self-efficacy and academic achievement are related, we analyzed engineering student grades since 2009 and the self-reported self-efficacy of these students since 2012 to examine gender differences in both self-efficacy and course grades. We discuss some interesting and alarming domain-dependent trends found in the relationship between these two measures. We thank the National Science Foundation for support.

BI04: 2:00-2:10 p.m. How Is Perception of Being Recognized by Others as Someone Good at Physics Related to Female and Male Students' Physics Identities?

Contributed –Timothy Nokes-Malach, University of Pittsburgh, 3939 O'Hara Avenue, Pittsburgh, PA 15260-3583; nokes@pitt.edu

Yasemin Kalender, Emily Marshman, Christian Schunn, Chandralekha Singh, University of Pittsburgh

Prior research on underrepresentation of women in physics has focused on gender differences in various attitudes and beliefs students have towards physics. One open area of investigation is the foundation of students' identities in physics, a particularly powerful driver of career decisions. We present an investigation involving approximately 500 students in introductory level calculus-based physics courses, a context in which less than one third of the students are women. The analysis tested a new physics identity framework, specifically examining whether the relation between gender and physics identity was mediated by motivational factors such as self-efficacy, interest, and perceived recognition.

BI05: 2:10-2:20 p.m. Understanding Motivational Characteristics of Students Who Repeat Algebra-based Introductory Physics Courses

Contributed – Yangqiuting Li, University of Pittsburgh, 3941 Ohara Street, Pittsburgh, PA 15260; clsingh@pitt.edu

Yasemin Kalender, Christian Schunn, Tim Nokes-Malach, Chandralekha Singh, University of Pittsburgh

In introductory algebra-based physics courses at the University of Pittsburgh, the majority of students are on pre-health professional track who aspire to become future health professionals. Two introductory physics courses are mandatory for students with these types of ambitions and many students who do not perform to their satisfaction the first time repeat these physics courses. We present an investigation in which we compared the motivational characteristics of male and female students who repeated an introductory algebra-based physics course across different racial and ethnic minority groups. These findings can be beneficial in providing appropriate advising and support to help all students excel in algebra-based physics courses.

BI06: 2:20-2:30 p.m. Understanding Motivational Characteristics of Students Who Repeat Calculus-based Introductory Level Physics Courses

Contributed – Sonja Cwik, University of Pittsburgh, 3941 Ohara st., Pittsburgh, PA 15260; clsingh@pitt.edu

Yasemin Kalender,Christian Schunn, Tim Nokes-Malach, Chandralekha Sing,h University of Pittsburgh

College level introductory physics courses are often perceived as weed-out courses by students. In introductory calculus-based physics courses, the self-doubt that many first-year college students, especially women or racial and ethnic minority students, experience can cause them to perform even worse than they otherwise would. Moreover, students who repeat introductory-level physics courses in college due to various reasons can experience an even higher level of self-doubt. We present an investigation in which we compared the motivational characteristics of male and female students who repeated an introductory calculus-based physics course across different racial and ethnic minority groups in order to develop interventions that can help all students learn physics.

BI07: 2:30-2:40 p.m. Physics Self-Belief Among Secondary School Students

Contributed – Elizabeth N. Parisi, The College of New Jersey, 2000 Pennington Road, Ewing, NJ 08628; parisie1@tcnj.edu

Giovanna Masia, Cynthia Reynolds, AJ Richards, The College of New Jersey

There is a dramatic underrepresentation of ethnic minorities and women within physics. The reasons for this underrepresentation are not fully understood. To explore this, we have surveyed high school physics students in order to investigate the relationship between a student's physics self-belief, their likeliness to pursue a career in physics, and their sense of belonging within physics. In our analysis we paid special attention to how a student's demographic data affected these variables. In this presentation, we will detail the trends we found between the students' self-belief, their sense of belonging, their likelihood to pursue a career in physics, and their demographics.

BI08: 2:40-2:50 p.m. Investigating the Role of Prior Preparation and Self-Efficacy on Female and Male Students' Introductory Physics Learning Outcomes

Contributed – Z. Yasemin Kalender, University of Pittsburgh, 2000 Wendover Apt 3, Pittsburgh, PA 15217; zyk2@pitt.edu

Emily Marshman, Community College of Allegheny

Christian D. Schunn,Timothy J. Nokes-Malach, Chandralekha Singh, University of Pittsburgh

Research suggests that self-efficacy is a central factor predicting students' engagement, participation, and retention in STEM. Physics is one STEM field in which women are severely under-represented and prior research suggests that women often underperform on conceptual assessments and exams. Women also tend to report lower self-efficacy than men in physics. We studied female and male students' self-efficacy and its relation to learning outcomes in introductory physics courses. We report the extent to which self-efficacy mediates learning outcomes for male and female students controlling for students' prior academic preparation.

Session BJ PER: Student Understanding about Mathematics in Physics

Location: CC - Ballroom A **Sponsor:** AAPT/PER **Time:** 1:30–2:40 p.m. **Date:** Monday, July 22 **Presider:** TBA

BJ01: 1:30-1:40 p.m. Nature of Students' Mathematical Difficulties in Introductory Physics Courses*

Contributed – David E. Meltzer, Arizona State University, College of Integrative Sciences and Arts, Wanner Hall, Mesa, AZ 85212-6207; david.meltzer@asu.edu

Dakota H. King, Arizona State University

We report findings from our three-year investigation into mathematical difficulties encountered by students in introductory physics courses. We have administered over 4000 written diagnostic tests in dozens of different algebra- and calculus-based physics courses on two different campuses at Arizona State University, and carried out over 60 individual problem-solving interviews. We find that regardless of course (i.e., algebra- or calculus-based), campus, or semester (spring or fall), that (1) difficulties with basic mathematical operations (algebra, trigonometry, graphing, geometry) are widespread, with average error rates ranging from 20-70%; (2) performance on problems using symbols for constants is consistently and significantly worse than on problems using numbers; and (3) during problem-solving interviews, students self-correct approximately 50% of all errors with only minimal prompting.

*Supported in part by NSF DUE #1504986

BJ02: 1:40-1:50 p.m. Exploring Student Difficulties in Mathematics Used in Introductory Physics*

Contributed – Dakota H. King, Arizona State University, 1519 East Hale Street, Mesa, AZ 85203; dakota.h.king@asu.edu

David E. Meltzer, Arizona State University

To study students' mathematical difficulties in introductory university physics courses, we continue to administer written diagnostics, as well as conduct one-on-one problem-solving interviews. After reviewing many interviews and thousands of diagnostics over the past three years, we have found that many students in both algebra- and calculus-based courses have significant difficulties in solving high-school-level (and lower) mathematics problems. Some of these problems include basic trigonometry and algebra posed both in numeric and symbolic form ("numeric" and "symbolic" refer to the nature of the constant coefficients and/or given information). We will report our most recent findings on these test problems, but will focus on new items including basic fraction manipulation and symbolic algebra involving Greek letters.

*Supported in part by NSF DUE #1504986

BJ03: 1:50-2:00 p.m. Mathematical Sense Making as a Lens for Understanding Student Reasoning

Contributed – Julian D. Gifford, University of Colorado Boulder, 390 UCB Boulder, CO 80302; julian.gifford@colorado.edu

Jessica R. Hoehn, Noah D. Finkelstein, University of Colorado Boulder

Mathematical formalisms are pervasive in physics, and coordinating between these mathematical formalisms and a conceptual understanding of the physical system is an important aspect of sense making. We add to existing frameworks for Mathematical Sense Making (MSM) by positing two broad categories for how physics students engage with mathematical formalisms: MSM-Math and MSM-Physics, which differ primarily in the object of focus (what students are trying to "figure out"). Here, we demonstrate the utility of these constructs by analyzing student responses to a question regarding the photoelectric effect that requires students to draw on both mathematical (symbolic and graphical) representations and a conceptual understanding. Using this framework we unpack the physical and mathematical reasoning involved in this process, and discuss how MSM can be used as a lens to help us understand student reasoning and develop curricula that support such reasoning.

BJ04: 2:00-2:10 p.m. Assigning Physical Significance to Elements in Mathematical Expressions*

Contributed – Abolaji R. Akinyemi, University of Maine - Orono, 18 Gym Drive, Orono, ME 04469; abolaji.akinyemi@maine.edu

John R. Thompson, University of Maine- Orono

Michael E. Loverude, California State University - Fullerton

One expected student outcome of physics instruction is a set of quantitative reasoning skills that includes evaluation of problem solutions, whether expressions or

numerical results. We developed and administered tasks to physics students that probe their use of validity checks of symbolic expressions. In one task, students were given a figure and an expression for the electric field due to three point charges of equal magnitude, and asked how they would check whether the expression was reasonable. We administered written tasks to 174 introductory students and 18 students in junior electricity and magnetism; 10 introductory students were interviewed. In addition to strategies we have previously described, we noticed that many students connect individual terms in the expression to their physical significance (e.g., tying one term to a specific point charge). We explore the significance of these responses and present some evidence of similar reasoning in unrelated tasks in mechanics.

*Supported in part by NSF Grant PHY-1405726.

BJ05: 2:10-2:20 p.m. The Ratio Table: A Tool for Making Meaning of Ratios, and Units Involving "Per"

Contributed – Philip B. Southey, Stellenbosch University, Physics Department, Merensky Building, Stellenbosch, WC 7600 South Africa; philsouthey@gmail.com

Arnold Arons described an inadequate understanding of ratios as "one of the most serious impediments to the study of science." Yet, ample math and physics education research demonstrates that STEM university students struggle with ratios. Our pilot study investigates a technique for both (a) working algebraically with ratios, and (b) making physical sense of ratios and units involving "per." For example, students are familiar with the notion of "meters per second," but many do not attribute meaning to the notion of "seconds per meter." This pre-/post-test pilot study is based on a questionnaire developed by Kanim et al., and demonstrates that a brief introduction of "the ratio table" can have a significant positive impact on students' understanding.

BJ06: 2:20-2:30 p.m. Comparing Covariational Reasoning of Experts in Physics and in Mathematics

Contributed – Charlotte Zimmerman, University of Washington, 3910 15th Ave. NE, Seattle, WA 98195-1560; zimmermc@uw.edu

Alexis Olsho, Suzanne White Brahmia, University of Washington

Andrew Boudreaux, Western Washington University

Trevor Smith, Rowan University

Interpreting how quantities change with respect to each other (covariational reasoning) is a habit of mind of physics experts, and integral in physics students' quantitative literacy. Understanding gaps between instructor mental habits and the mathematical preparation of students informs instructional innovations targeting mathematical reasoning in physics. Covariational reasoning has been studied extensively in mathematics education research, giving rise to a framework of its characteristics and a recent study examining expert covarational thinking in mathematics graduate students during think-out-loud interviews (1,2). Motivated by preliminary results suggesting differences in physics and mathematics experts' covariational reasoning, I will present results from an analogous study conducted with physics graduate students.

(1) Carlson, Marilyn, et al. "Applying Covariational Reasoning While Modeling Dynamic Events: A Framework and a Study." Journal for Research in Mathematics Education, vol. 33, no. 5, 2002, pp. 352–378 (2) Hobson and Moore. "Exploring Experts' Covariational Reasoning." RUME Proceedings, 2017, pp. 666-672.

BJ07: 2:30-2:40 P.M. Examining Consistency of Student Errors in Vector Operations Using Networks

Contributed – Nekeisha Johnson, New Mexico Institute of Mining and Technology, 106 Groton Rd., Tyngsboro, MA 01879-2308; nekeisha.a.johnson@gmail.com

John B. Buncher, North Dakota State University

Student difficulties with vector addition and subtraction have been documented extensively in the literature. We examine the consistency of students' incorrect responses in a multiple-choice assessment of adding and subtracting one- and two-dimensional vectors, represented as arrows. Students in a large-enrollment algebra-based sequence responded to an online assessment at the end of the course. The results of this assessment were analyzed using Module Analysis for Multiple Choice Responses, a type of network analysis which constructs groups of responses typically chosen together. Examining the groups of responses allows us to see if the kinds of mistakes students make are consistent across problems with similar features. We will present evidence that students make similar types of mistakes across questions of the same type, but that the type of mistake depends on the features of the question.

Session BK PICUP: Reports on the Growing Computational Physics Education Revolution

Location: MH - Canyon **Sponsor:** Committee on Physics in Undergraduate Education **Co-Sponsor**: Committee on Research in Physics Education **Time:** 1:30–3:30 p.m. **Date:** Monday, July 22 **Presider:** Marcos D. Caballero

BK01: 1:30-2:00 p.m. Incorporating Computation into UCLA Physics Curriculum: Progress and Challenges

Invited – Joshua Samani, UCLA Physics & Astronomy, BOX 951547, 1-707K Los Angeles, CA 90095; jsamani@physics.ucla.edu

Computational physics instruction has been incorporated into the UCLA Physics curriculum in labs and upper-division courses, but many challenges remain in making sure this computational curriculum is coherent and achieves desired objectives for the major. We review these challenges and the progress that has been made toward meeting them.

BK02: 2:00-2:30 p.m. I'm Not Teaching You Programming

Invited – Todd Zimmerman, 410 10th Ave. E, Menomonie, WI 54751; zimmermant@uwstout.edu

One of the complaints students have when computation is introduced in courses is to ask why they need to learn programming in a physics course. This is just one of the hurdles faced when trying to add a computational component to physics courses. I'll discuss how PICUP has helped me overcome many of these challenges and talk about the successes and failures my colleagues and I had trying to integrate computation into the physics curriculum.

BK03: 2:30-2:40 p.m. Computation in the Physics Classroom: A Census of Instructor Beliefs

Contributed – Thomas Finzell, University of Michigan, 8795 SPINNAKER WAY, APT. C1, Ypsilanti, MI 48197; finzellt@umich.edu

Sameer Barretto, Timothy Mckay, University of Michigan

Marcos D. Caballero, Michigan State University

Computation has become ubiquitous in physics; however, at most college-level institutions, it is underrepresented in physics instruction. We conducted approximately 20 interviews with faculty, instructors, and graduate students, to learn about their beliefs regarding the utility of computation in the physics classroom. We report on the themes gleaned from these interviews.

BK04: 2:40-2:50 p.m. Teaching Computational Physics for the First Time (and Surviving)

Contributed – David P. Jackson, Dickinson College, Dept. of Physics, Carlisle, PA 17013; jacksond@dickinson.edu

The physics department at Dickinson College has been discussing how to implement computational physics into our curriculum for a very long time. Unfortunately, because of differing levels of expertise using different computing platforms, we could never fully agree on a coherent plan of action. The result is that our program lacks any significant focus on computational techniques. After attending a PICUP workshop in the summer of 2018, I decided to take the plunge and teach a computational physics course even though we had no agreed upon departmental plan. The idea was simply to get a computational course in place and then to discuss how best to implement computational physics into our curriculum after the fact. In this talk I will present a brief overview of my experience and the response of the students and my department.

BK05: 2:50-3:00 p.m. Using VPython with Engineering Students in Matter and Interactions

Contributed – Jack A. Dostal, Wake Forest University, PO Box 7507, Winston Salem, NC 27109; dostalja@wfu.edu

During the past year, my first-semester calculus-based physics class used the Matter and Interactions curriculum. I worked closely with a small class of 13 students composed primarily of prospective engineering majors in the second semester of their freshman year. I will describe my efforts to incorporate computation into the course via VPython coding. In addition, I will describe some of the conclusions I have drawn about effective (and ineffective) ways to engage students who have a broad range of coding backgrounds.

BK06: 3:00-3:10 p.m. Costs and Benefits of a Functional Programming Language in Physics Teaching

Contributed – Scott N. Walck, Lebanon Valley College, 101 N College Ave., Annville, PA 17003; walck@lvc.edu

Functional programming languages, such as Haskell, have a reputation for being difficult to learn and use. There is some truth to this, but functional languages are difficult to learn in the same way that physics is difficult to learn; both invite and sometimes require a structured thinking. The thinking required to use Haskell matches surprisingly well with that required for physics. The benefit is that, once learned, functional language allows one to focus less on the computer's needs and more on the structure of physics. We show an example of a PICUP exercise implemented in Haskell to see the benefits. The presenter will also speak from his experience about the costs.

BK07: 3:10-3:20 p.m. Simplified Analysis of Phase Transitions in Thermodynamics

Contributed – Jay J. Wang, UMass Dartmouth, 285 Old Westport Rd., North Dartmouth, MA 02747-2300; jwang@umassd.edu

Nick J. Moniz, UMass Dartmouth

Understanding critical phenomena in physical systems such as thermodynamic phase transitions is important in the study of physics, but often such topics pose challenges including advanced mathematics hindering the discussion of them at earlier stages of the curriculum. In this presentation we discuss simplified analysis of two problems in thermodynamics in terms of the Lambert W function, including the mean field approximation of the Ising model and Bose-Einstein condensation (BEC). Utilizing appropriate simplifying approximations, we find a closed-form mean-field solution to the Ising model, and an approximate but quantitative dependence of the chemical potential on temperature in BEC in terms of the special W function. This analytic approach illuminates the essential physics in a clear and direct manner, allows for visualization with VPython (see http://www.faculty.umassd.edu/j.wang/), complements but does not require full numerical computation in the standard treatment of these problems, and highlights the use of special functions as a powerful toolkit in the physicist's arsenal.

BK08: 3:20-3:30 p.m. Integrating Computation in High School and Early College Physics*

Contributed – Chris Orban, The Ohio State University, 191 W Woodruff Ave., Columbus, OH 43210; orban@physics.osu.edu

Richelle Teeling-Smith, University of Mt. Union

Over the last year, the STEMcoding project has released a number of new coding activities and video tutorials designed to integrate computation into high school and non-major college physics courses. This includes three new activities for hourofcode.com, and many others for the STEMcoding youtube channel (http://youtube.com/c/STEMcoding) and the PICUP site. Importantly, our youtube videos feature women and underrepresented groups in order to let students see people who look like them coding, doing physics, and having a good time. We discuss our experiences using this content in classrooms, camps, and hackathons and we comment on approaches to assess "computational thinking" at this level.

*The STEMcoding project is supported by an OSU internal grant and the AIP Meggers Award.

Session BL Interactive Lecture Demonstrations: A Research-Validated Active Learning Strategy for Lectures – Including Clickers and Video Analysis

Location: CC - Ballroom B **Sponsor:** Committee on Research in Physics Education **Co-Sponsor:** Committee on Educational Technologies **Time:** 1:30–2:40 p.m. **Date:** Monday, July 22 **Presider:** David Sokoloff

BL01: 1:30-2:00 p.m. Interactive Lecture Demonstrations: Whats New? ILDs Using Clickers and Video Analysis

Invited – David Sokoloff, Department of Physics, University of Oregon, Eugene, OR 97403; sokoloff@uoregon.edu

Ronald Thornton, Tufts University

The results of physics education research and the availability of computer-based tools have led to the development of the active learning materials for the introductory physics course. Some of these materials are designed for hands-on learning in the lab, for example the student-centered laboratory curriculum, RealTime Physics [(1), (2)]. One reason for the success of these materials is that they encourage students to take an active part in their learning. This interactive session will demonstrate through active audience participation materials designed to implement active learning in lecture, Interactive Lecture Demonstrations (ILDs) [(3)] including those using clickers and video analysis.

1. David R. Sokoloff, Ronald K. Thornton and Priscilla W. Laws, "RealTime Physics: Active Learning Labs Transforming the Introductory Laboratory," Eur. J. of Phys., 28 (2007), S83-S94., 2. David R. Sokoloff, Ronald K. Thornton and Priscilla W. Laws, RealTime Physics: Active Learning Laboratories, 3rd Edition (Hoboken, NJ, John Wiley and Sons, 2011). 3. David R. Sokoloff and Ronald K. Thornton, Interactive Lecture Demonstrations (Wiley, Hoboken, NJ, 2004).

BL02: 2:00-2:30 p.m. Interactive Lecture Demonstrations: Effectiveness in Teaching Concepts

Invited – Ronald K. Thornton, Tufts University, Medford, MA 02155; ronald.thornton@tufts.edu

David Sokoloff, University of Oregon

The effectiveness of Interactive Lecture Demonstrations (ILDs) in teaching physics concepts has been studied using physics education research based, multiple-choice conceptual evaluations. [(1), (2)] Results of such studies will be presented, including studies with clicker ILDs. These results should be encouraging to those who wish to improve conceptual learning in their introductory physics course.

1. David R. Sokoloff and Ronald K. Thornton, "Using Interactive Lecture Demonstrations to Create an Active Learning Environment," Phys. Teach. 35: 6, 340 (1997),
2. David R. Sokoloff, "Active Learning of Introductory Light and Optics," Phys. Teach. 54: 1, 18 (2016).

BL03: 2:30-2:40 p.m. Interactive Lecture Demonstrations as a Computer Supported Collaborative Learning Activity

Contributed – Shiladitya Raj Chaudhury, University of South Alabama, Innovation in Learning Center, Mobile, AL 36688; schaudhury@southalabama.edu

Active learning designs that leverage the affordances of information and computer technologies (ICT) can vary tremendously in how they engage students – individuals, small groups or whole class. Interactive lecture demonstrations (ILDs) are well known in the PER literature for their impact on improving student conceptual understanding through instructor-led activities which engage the whole class (Thornton and Sokoloff, 1997). From the field of Computer Supported Collaborative Learning (CSCL), we adapt the idea that all active learning designs incorporate two concepts -- enactment scripts and orchestration. The script for doing ILDs is well known, but expert orchestration only comes about with practice. In this presentation we present the script and orchestration considerations for a typical kinematics ILD using the PhET Moving Man simulation to generate real time data. We also present a visualization of the flow of an ILD through creation of an 'orchestration graph' following the model of Pierre Dillenbourg.

BL04: 2:40-2:50 p.m. What Clicks in a Clicker Classroom

Contributed – Jacqueline Y. Bao, The Ohio State University, 191 W Woodruff Ave., Columbus, OH 43210; bao.224@osu.edu

Shaona Zhou, South China Normal University

Joseph Fritchman, The Ohio State University

Clickers have been widely used as a tool for promoting active learning in a classroom. Ample research has also shown the effectiveness of clickers on student learning in a wide range of STEM courses. This research takes a behavioral approach to study the variations of students' learning behaviors in clicker and non-clicker classrooms in order to understand the mechanisms underlying the learning effectiveness of clicker usage. Building on a web-based clicker app, this study investigates how students' attentions in lecture classes are influenced by the use of clickers and how variations on attention impact learning outcomes. Results from a controlled experiment in a mid-sized lecture classroom will be presented, which show the impacts from clicker usage on students' attention and learning performance. The outcomes of this study can provide useful empirical evidence to help modeling the cognitive learning mechanisms underlying clicker based active learning approaches.

Session BM Building Lobby Science Exhibits

Location: MH - Juniper **Sponsor:** Committee on Science Education for the Public **Co-Sponsor:** Committee on Apparatus
Time: 1:30–3:00 p.m. **Date:** Monday, July 22 **Presider:** Brian Pyper

BM01: 1:30-2:00 p.m. The History of the Universe in a Building Lobby Exhibit

Invited – Brian A. Pyper, BYU-Idaho, 116 Romney Science Building, Rexburg, ID 83460-0520; pyperb@byui.edu

BYU-I's Romney Physical Sciences Building hosts an exhibit in the front lobby that features explanatory and museum-style materials that take the visitor along the hallway from the Big Bang to the present. The exhibit is open to the public and local school groups, admissions tours and college science classes use the exhibit to teach about the various stages of the history of the Earth. I'll discuss the features of the display and its development and maintenance.

BM02: 2:00-2:30 p.m. A Solar Spectroscope Exhibit at Utah Valley University

Invited – Steven Wasserbaech, Utah Valley University, 800 W University Pkwy, MS 179 Orem, UT 84058; wasserst@uvu.edu

We are building an instrument to project onto a screen a 2-meter-long spectrum made from "live" sunlight. The device will have sufficient resolution to show numerous absorption lines. This permanent exhibit in a science building at Utah Valley University will offer visitors the opportunity to learn more about light, the sun, atoms, energy levels, optics, and more.

BM03: 2:30-3:00 p.m. Lobby Science

Invited – Clark Snelgrove, Brigham Young University, C135 Eyring Science Center, Provo, UT 84602; crsnel@byu.edu

The Eyring Science Center on the Brigham Young University campus has been the focus of science research and education since 1952. The lobby is filled with many displays and hands-on activities designed to engage students and visitors in scientific discovery. The lobby displays must survive the wild hordes of budding scientist that use them daily. I will discuss our philosophy and the work required to produce new displays and to update existing displays. I will also discuss how signs that describe the display can be designed to better engage the public and enrich the learning experience.

Session BN Hot & Cold Physics Demos

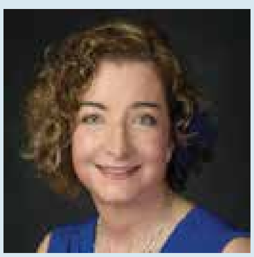
Location: MH - Aspen **Sponsor:** Committee on Apparatus **Co-Sponsor:** Committee on Teacher Preparation
Time: 1:30–2:30 p.m. **Date:** Monday, July 22 **Presider:** Duane Merrell

Workshop: Chasing Objectivity, Failing at Diversity: Physics and its Discontents, Simone Kolysh

1:30–3:30 p.m. **MH - Elm**

Less than 5% of Physics PhD degrees are granted to Black, Latinx, and Indigenous people and less than 20% are granted to women. In this workshop, we address how STEM fields like Physics are failing to attract and sustain diverse populations of students. Part of the problem rests with measures like the GRE that are not predictive of PhD success or completion and part of the problem rests with academia, which refuses to acknowledge that chasing objectivity and science for science's sake usually fails to acknowledge issues of diversity and equity and structural inequality. First, I want to talk about whether objectivity and neutrality are productive concepts. Next, I want to work through what is left out when students (including undergraduates) only receive a STEM education without learning about society at large or how science and academia are deeply flawed human institutions with a lot of racism, sexism, homophobia, transphobia, and so on. Finally, I want to workshop about how we get at truth as scientists and which epistemologies are privileged over others in a white Western world. In that discussion, I will include expanding our theoretical frameworks, research methods, and interdisciplinarity.

PLENARY: Correlated Electrons: The Dark Energy of Quantum Materials



Laura Greene
MagLab Chief Scientist

The nearly 80-year-old correlated electron problems remain largely unsolved; with one stunning success being BCS electron-phonon mediated conventional superconductivity. There are dozens of families of superconductors that are unconventional including the high-Tc cuprates, iron-based, and heavy fermion superconductors. Although these materials are disparate in many properties, some of their fundamental properties are strikingly similar, including their ubiquitous phase diagram; with intriguing correlated-electron phases above the superconducting transition. These remain among the greatest unsolved problems in physics today; and a fun analogy stressing this will be presented.

AAPT PHYSICS EDUCATION

Monday July 22
4:00–5:00 p.m.
CC - Ballroom C

Laura Greene: Leadership Skills and Networking for Women Workshop

MH - Elm
Date: Monday, July 22
Time: 5:15 –6:45 p.m.

Women scientists take on leadership roles everyday, in the classroom, in their department or institution and in their professional organizations. This workshop is designed to give participants the basic concepts of leadership, describe some research on leadership qualities that lead to success and failure, provide techniques and strategies for career advancement into leadership roles, and assist in developing and maintaining strong leadership networks. Topics also include effective communication styles for women, projecting confidence and credibility through voice, image and body language, dealing with difficult conversations and questions, using powerful rather than weak words, and effective scientific presentations. Role-playing activities provide practice in using learned strategies and practices.

Session CA: Other Paper

Location: CC - Cascade E **Sponsor:** AAPT **Time:** 5:15–6:45 p.m. **Date:** Monday, July 22 **Presider:** TBD

CA01: 5:15-5:25 p.m. Research on Chinese College Students' Learning Attitudes to Physics Experiments

Contributed – Yunlin Chen, East China Normal University, 3663N. Zhongshan Rd., Shanghai, China 200062; 369570663@qq.com

Physics experiments, as the core section of the physics education, have already become the main contents of higher education. And students' attitudes to physics experiments play a significant role in physics teaching and learning. So this research focuses on the learning attitudes of Chinese college students toward physics experiments. The research objects are college students who had a physics experiment course in East China Normal University in Shanghai, China. And the measurement tool is the Colorado Learning Attitudes about Science Survey for Experimental Physics (E-CLASS). The original E-CLASS was translated into Mandarin through a rigorous process. We found that students' learning attitudes to physics experiments were ordinary in general and they varied from different factors.

CA02: 5:25-5:35 p.m. Measurement of Kinetic Friction with Different Velocity Using Timoshenko Oscillator

Contributed – Yangming Li, Southeast University, No.2, Southeast University Road, Jiangning District Nanjing, Jiangsu 211189 China; 898201834@qq.com

Yichen Gao Southeast University

A Timoshenko oscillator, which consists of a plate with periodic motion with the combined influence between gravity and kinetic friction on its rotating supports, is built to illustrate the relation between the frequency of the vibration and the coefficient of kinetic friction. Our experiment allows us to explore the friction's low in relatively high velocity regime. Our experimental results show that the Coulomb's law of kinetic friction is only valid under the situation of small relative velocities and the kinetic friction becomes smaller when the velocity is increased. Usually the measurement of coefficient of kinetic friction is done at a low relative velocity, but our experiment allow us to explore the friction's low in higher relative velocities.

CA03: 5:35-5:45 p.m. Light Rings Around Water Jet

Contributed – Liu Ziyi, Southeast University, No.2, Southeast University Road, Nanjing, Jiangsu Province, China Nanjing, Jiangning 211189 China; 1289752649@qq.com

When a water jet freely falls onto a rigid horizontal plane and the contact point is illuminated by a laser beam, rings of light around the jet will appear. Based on Plateau-Rayleigh instability theory, the equation of corrugated stability can be established. According to the theory of equivalent surface light source, we are able to explain the cause of light rings. Through experiment, it is proved that there is equal relationship among the distance of two light rings, double of the width of one light ring and the wavelength of the ripple. However, if the plane is tilted, water column with stable corrugated structure becomes asymmetry. Due to the Plateau-Rayleigh instability, if the inclination of the plane is not very big, water column with stable corrugated structure can still exist. On the other hand, when the plane is steep enough, the corrugated structure becomes unstable and the light rings become invisible. As a result, relevant theory and experiment can be established. On account of the difference in the distance between the contact point and the water outlet, there are different wave numbers and wavelengths distributing at different angles. If the contact point is illuminated by a laser beam, tilted light rings around the jet can be observed. Consequently, relevant theory can satisfy a more extensive observation effect.

CA04: 5:45-5:55 p.m. The Dynamics of the Motion of Looping Pendulum

Contributed – Ding Zimin, Southeast University, No.2, Southeast University Road, Nanjing, Jiangsu Province, China Nanjing, 211189 China; 3523971828@qq.com

A looping pendulum consists of a horizontal rod and a string connected to a heavy load and a light load. The string is put over the horizontal rod and the light load is pulled down so that the heavy load is lift up. After the light load is released, it will sweep around the rod, keeping the heavy load from falling to the ground. Our experiment allows us to explore the relationship between the falling distance and the mass of the heavy load. And the trajectory of the light load can also be figured out. Our experimental and theoretical results show that the falling distance of the heavy load increase with the increase of the mass of the heavy load. The trajectory of the light load is the combination of two different Archimedes curves.

CA05: 5:55-6:05 p.m. Relation between Water Temperature and Its Sounds.

Contributed – Yu Hangyuan, Southeast University, No.2, Southeast University Road, Nanjing, Jiangsu Province, China Nanjing, 211189 China, 731638463@qq.com

The research is aimed to find out whether there is a relation between water temperature and its sounds. In this article, we will discuss how the temperature of water influences viscosity and in turn the frequency of sound that water makes when it is poured down under fixed conditions--water is poured down at a fixed speed and angle. Several experiments are made to figure out the relationship among temperature, viscosity and sound frequency, ruling out the effects of density at the same time. During the experiment, we also use certain ways to wipe out irrelevant sounds made by air and container. In the research, we find an apparent rise of frequency as temperature increases. And we are looking forward to getting a more explicit correspondence between them as to get water's temperature if its frequency is given.

CA06: 6:05-6:15 p.m. Investigation on New Teachers' Categorization of Kinematics and Mechanics Problems

Contributed – Jingyao Chen, East China Normal University, 3663N. Zhongshan Rd. Shanghai, China 200062; 791526344@qq.com

Novices and experts choose different strategies to categorize the physics problems, which reflects their different expertise in problem solving. Since the students' categorization is affected by their teachers, we conducted a study to investigate the physics teachers' method of categorization. Over 50 Chinese teachers from different schools were involved in our study. In general, the teachers can categorize problems of kinematics and mechanics into suitable categories based on the underlying principles.

CA07: 6:15-6:25 p.m. Students' Conceptual Understanding of Quantum Physics

Contributed – Siyou Wang, East China Normal University, Room 309, Building 1, Liuxing Garden Community, Renmin No.2 Village, Chengxiang Town, Taicang County Suzhou, Jiangsu 215400 China; 616489444@qq.com

Nowadays, Quantum Physics is a heated topic among almost all sectors of the international community. However, many college students, especially those non-physics majors, are not familiar with the physics terms and concepts appearing in hot movies and other forms of entertainment, which is a phenomenon worthy of attention. In order to know the degree of students' understanding of the concepts of Quantum Physics, we conducted investigations in different ways, such as giving out questionnaires and so on. After analyzing the results, we found that faced with the given concepts, most of the students majoring in arts responded with incomprehension, while the science majors showed a superficial understanding of them. The conclusion we've made, to some extent, can provide a reference for college teachers to adjust their teaching approach in order to improve students' understanding of the related concepts.

CA08: 6:25-6:35 p.m. Top Ten Women in the History of Physics

Contributed – James J. Lincoln, PhysicsVideos.com PO Box 11032 Newport Beach, CA 92658-5016 LincolnPhysics@gmail.com

Although there have been many accomplished female physicists, their contributions are not as well-known as their male counterparts. We physics teachers often lecture on their contributions and discoveries without realizing who we are referencing. In this talk, I spotlight 10 women from the history of physics and explain the physics behind their specific contributions to the field. In this work I have decided to focus specifically on physicists, as opposed to astronomers, in order to bring into the light the less well-known and raise awareness of these women to inspire a new generation of physicists.

CA09: 6:35-6:45 p.m. Counting Stars – A Citizen Science Mass-Experiment on Light Pollution

Contributed – Urban Eriksson, National Resource Center for Physics Education, Sölvegatan 14 Lund, Skåne 221 00 Sweden; urban.eriksson@fysik.lu.se

Street lamps, illuminated signs, buildings, cars – lights at night improve safety and make cities more attractive, but have also been shown to have negative effects for humans and animals. Scientific studies have shown that scattered artificial light —light pollution—have unexpected and worrying effects on the biology of many organisms, ecosystems, and on human health. In the Star-Spotting Experiment, hundreds of thousands of pupils, scouts, and members of the public in Sweden and other European countries are being invited to contribute to scientific research about light pollution. The experiment builds on the fact that the more light there is, the fewer stars you see. Hence, we encourage people to count stars where they live, using a simple method, and report via an App. We present results on 1) peoples' awareness of the night sky, 2) how this method compares to other measures of light pollution, 3) possible consequences for society.
https://forskarfredag.se/star-spotting-experiment-sweden/

Session CB: PER: Interdisciplinary Studies

Location: CC - Cascade D **Sponsor:** AAPT **Time:** 5:15–6:05 p.m. **Date:** Monday, July 22 **Presider:** TBD

CB01: 5:15-5:25 p.m. Assessing the Longitudinal Impact of IPLS on Student Reasoning

Contributed – Nathaniel Peters, Hopkins School, 500 College Ave., Swarthmore, PA 19081; npeters@hopkins.edu

Aqil MacMood, Catherine H. Crouch, Benjamin D. Geller, Swarthmore College

Haley Gerardi, Lake Forest High School

Although we have found that students in our Introductory Physics for Life Science (IPLS) course describe physics as more relevant to their primary interests than do their counterparts in a traditional introductory physics environment, we do not yet know whether these students subsequently apply the physics they have learned in later biology coursework. That is, we have yet to determine whether IPLS courses better prepare life science students to use physical reasoning in other contexts. In this talk, we describe preliminary findings from the first two years of an exploratory study comparing the reasoning exhibited by IPLS and non-IPLS students enrolled in upper level biology courses. We analyze student written work obtained from these biology courses, and data collected from think-aloud interviews of students enrolled in them. We describe the ways in which different physics backgrounds appear to influence student reasoning, and the challenges inherent in a longitudinal interdisciplinary study.

CB02: 5:25-5:35 p.m. Exploring the Impact of IPLS on Student Learning in Neurobiology

Contributed – Aqil MacMood, Swarthmore College, 500 College Ave., Swarthmore, PA 19081; amacmoo1@swarthmore.edu

Nathaniel Peters, Hopkins School

Haley Gerardi, Lake Forest High School

Catherine H. Crouch, Benjamin D. Geller, Swarthmore College

In this second of two paired talks exploring the longitudinal impact of Introductory Physics for Life Science (IPLS), we examine whether and how student experiences in an upper level Neurobiology course are impacted by their prior exposure to relevant physics. In particular, we look at the ways in which students connect an IPLS treatment of membrane potential and nerve signal propagation to the treatment of similar topics in the Neurobiology course. As a substantial portion of the second-semester IPLS course at Swarthmore is devoted to these topics, the Neurobiology course is a particularly relevant place to look for whether students apply what they learn in IPLS to a biology setting. We report on initial findings from an analysis of student work obtained in both the IPLS and Neurobiology courses.

CB03: 5:35-5:45 p.m. The Role of IPLS in Shaping Long-term Attitudes Toward Physics

Contributed – Haley Gerardi, Lake Forest High School, 4001 North Sagamore Drive, Milford, DE 19963; haley.gerardi.324@gmail.com

Chandra Turpen, University of Maryland, College Park

Catherine H. Crouch, Benjamin D. Geller, Swarthmore College

While there is evidence that life science students enrolled in Introductory Physics for Life Science (IPLS) courses find physics to be more engaging and relevant to their primary interests than do their counterparts in more traditional introductory physics environments, we do not yet know whether those attitudes and affective responses persist. By studying the attitudes toward physics and interdisciplinarity learning of life science students both during and after their IPLS experience, we hope to unpack how enduring these attitudes actually are. In this talk we describe the results of preliminary efforts to assess this durability. We report on data obtained from surveys, journaling prompts, and interviews conducted with students in both the IPLS course and in subsequent upper level biology courses.

CB04: 5:45-5:55 p.m. Interdisciplinary Energy Theme Integrated Across the Science Curriculum

Contributed – Nancy L. Donaldson, Rockhurst University; 1100 Rockhurst Rd.; Kansas City, MO 64110 ;nancy.donaldson@rockhurst.edu

Lisa K. Felzien, Michael C. Marvin, Joanna J. Cielocha, Rockhurst University

An ongoing need exists for the creation of interdisciplinary working groups in the sciences and the development of pedagogical approaches to content themes that integrate different scientific disciplines. This talk introduces a collaborative effort by physics, biology and chemistry faculty at Rockhurst University on the development of content and pedagogical curriculum supporting the central theme of energy conservation and transfer taught in various lower and upper level science courses. Our main goal was to design conceptual, visual models that addressed our energy topic and provided related, challenging, active-learning experiences that students could

integrate across the science curriculum. We used an assessment-first approach in which we designed models with our student outcomes in mind and then created course approaches around our assessment tools. Early indications suggest that students are challenged by and appreciative of these learning approaches, especially when more advanced models are developed in upper division Physics of Medicine curriculum.

CB05: 5:55-6:05 p.m. Topic Clustering in PER Abstracts Using Computational Linguistics

Contributed – Aurora J. Meyer, Kansas State University, Manhattan, KS 66502; oscarbelle810@gmail.com

Eleanor C. Sayre Kansas State University

Since the mid 1990s, there have been over 26,000 abstracts submitted to AAPT national conferences and PERC, and sorting abstracts into sessions by hand for each National Meeting has become difficult. We use computational linguistics methods to cluster abstracts by topic. We investigate which topics are interesting to PERers over time, as shown in their abstracts, and track changes to the community and its membership. In this talk, we present major clusters and their changes over time for both AAPT and PERC abstracts. We suggest how these methods can be used to sort papers for f`uture AAPT conferences, alleviating some of the strain on human paper sorters.

Session CC: Physics Majors: Pre High School to Doctorate

Location: CC - Cascade C **Sponsor:** AAPT **Time:** 5:15–6:45 p.m. **Date:** Monday, July 22 **Presider:** TBD

CC01: 5:15-5:25 p.m. Probing Introductory Astronomy Students' Notions of Sizes and Distances

Contributed – Tshiamiso Makwela, University of Cape Town, Rondebosch Cape Town, 7700 South Africa; mkwtsh014@myuct.ac.za

Alexander Sivitilli, Dale Taylor, Sarah Blyth, Saalih Allie, University of Cape Town

Size and distance are important in astronomy teaching and learning, as these are key concepts to understanding basic astronomy. In 2014 an instrument, Introductory Astronomy Questionnaire (IAQ)[1] was constructed at UCT, South Africa. The IAQ was a broad questionnaire, which looked at students' understanding of basic ideas of astronomy. The IAQ was then translated into Norwegian (NIAQ)[2] and was given to pre- service teachers and middle school students in Norway. Both studies [1][2] yielded similar poor results in terms of students' views regarding size and distance. In order to deepen our understanding of students ideas with regard to size and distance, we constructed a short instrument to probe these aspects. We selected and modified ranking task questions from the IAQ. We then administered this instrument (IAQ_R), as a pre and post test. We discuss the modifications to the ranking task as well as preliminary results of this study.

[1] Rajpaul, Vinesh, Saalih Allie, and Sarah Louise Blyth. 2014. "Introductory Astronomy Course at the University of Cape Town: Probing Student Perspectives." Physical Review Special Topics - Physics Education Research 10 (2). [2] Lindstrøm, Christine, Vinesh Rajpaul, Morten Brendehaug, and Megan C. Engel. 2016. "Perspectives on Astronomy: Probing Norwegian Pre-Service Teachers and Middle School Students," 1–4.

CC02: 5:25-5:35 p.m. Teaching Physics to Career Students: Curriculum Redesign and Project-based Approach

Contributed – Philomena N. Agu, Jordan Career Center, 5807 Candlecreek Drive, Richmond, TX 77469; jolugabe@usa.net

The Jordan Career Center is a high school turned into a career hub for 11th and 12 graders from nine different high schools. A student spends a half day at the school training in a chosen career, math and science only. The demands to simulate a learning environment similar to hands-on experiences in career classes and to allow some students to build their mathematics skills necessitated a change in the sequence of physics topics and embedding of projects in teaching and learning physics concepts. Typically, I teach mechanics first, but with the redesign, I begin with the concept of constant speed and proceed to waves, electricity, magnetism, thermodynamics, mechanics, atomic and nuclear physics. The students build cars, optical and musical instruments, conductivity testers, and roller coaster in addition to conducting experiments and demonstrations. Overall, the students find the class interesting and are motivated to learn; their grades in physics improved.

CC03: 5:35-5:45 p.m. Engineering Explorations: Integrating Physics and Engineering Activities into Classrooms

Contributed – Alexandria Muller, University of California- Santa Barbara, 735 Elkus Walk Apt., 105 Goleta, CA 93117-4126; Almuller@ucsb.edu*

Jasmine Marckwordt, Danielle Harlow, University of California-Santa Barbara

Ron Skinner MOXI, The Wolf Museum of Exploration + Innovation

In an effort to encourage critical thinking and problem solving, the Next Generation Science Standards have incorporated engineering standards for the first time. Unfortunately, teachers are under prepared and have little comfort to introduce these unfamiliar complex topics into their classrooms. The University of California at Santa Barbara and MOXI, The Wolf Museum of Exploration + Innovation partnered up to tackle this problem and bring physics-related engineering activities to teachers through the MOXI Engineering Explorations program. Our task is to develop nine engineering programs over the next three years. These programs will include museum-based field trip activities and grade-appropriate physics and engineering activities that teachers can implement in their classrooms before and after their field trip. This talk will discuss the development and implementation of the first three sets of activities which focused on air pressure and balanced forces, transmission of light and infrared radiation, and resonance frequencies.

*Sponsored by Dr. Danielle Harlow

CC04: 5:45-5:55 p.m. Setting the Tone on Day One: Lessons from Psychology

Contributed – Kristine Lui, Montgomery College, 20200 Observation Dr., Germantown, MD 20876; klui@montgomerycollege.edu

Many students are still resistant to non-traditional methods of teaching. Selling the idea of having students' "brains on" during class (aka active-learning) seems to occupy many instructors. First impressions do make a big impact, thus it is important to do more than read through the syllabus on the first day of class. Relying on research from psychology, I will outline some strategies that have helped me set the right tone on the first day of class.

CC05: 5:55-6:05 p.m. The Core Literacy Investigation of Shanghai Physics Examination Questions

Contributed – Haomin Zhang, East China Normal University, Room 1001, zhenping road, putuo district, Shanghai, China Shanghai; zhm166166@126.com

In recent years, China's college entrance examination reform is constantly being optimized and promoted, and Shanghai has been at the forefront of reform. In order to put forward a set of evaluation dimensions and standards that can reflect students' academic performance and physical quality, we optimized the performance of each secondary index on the basis of the national curriculum standards, and developed a specific framework of core literacy. Then, we selected some test questions from the past college entrance examination and conducted a survey in the form of questionnaire and interview for physics teachers. Through the analysis of the results, we found some problems and rules of core literacy and teachers' daily teaching: 8 of the 15 core literacy are difficult to examine in traditional examinations, and teachers are also trying to help students develop these abilities in daily teaching.

CC06: 6:05-6:15 p.m. AP Physics Results and their Implications for Diversity in Physics*

Contributed –Andrew G. Duffy, Boston University, Department of Physics, 590 Commonwealth Ave., Boston, MA 02215; aduffy@bu.edu

The importance of diversity in the physics community has, in recent years, become widely recognized. The College Board publishes data that breaks down AP results along racial and ethnic lines. An important connection between the previous two sentences is that the demographic information from the College Board, pertaining to the AP Physics exams, indicates that the exact groups that we would like to attract to the physics community are, in general, doing rather poorly on AP Physics. Visualizations of this data will be presented in this talk, in hopes of starting some useful discussions about what to do about the issue.

*Funded by NSF grant DRL 1720914.

CC07: 6:15-6:25 p.m. Investigating How Middle School Students View Different Science Disciplines

Contributed – Cynthia Reynolds, The College of New Jersey, 2000 Pennington Road, Ewing, NJ 08628; reynolc5@tcnj.edu

Giovanna Masia, Elizabeth Parisi, AJ Richards, The College of New Jersey

In previous research we found that a large fraction of secondary level students expressed that they disliked physics while also saying they had never been taught about the subject. We also found that students struggled to correctly identify what physics IS, and frequently conflated physics with chemistry or other branches of science. To understand this phenomenon, we have chosen to investigate how students develop their attitudes and beliefs about physics and other sciences. We administered a survey to 5th-8th grade students that revealed how they conceptualize different branches of science. In this presentation we will detail our findings and discuss whether or not students have an accurate understanding of the content encompassed by the different branches of science. We will also discuss how that understanding impacts a student's perception of working in that field.

CC08: 6:25-6:35 p.m. Making Quantum Computing More Accessible Through Interactive Activities

Contributed – Jasmine Marckwordt, UCSB 783 Acacia Walk, Apt H, Goleta, CA 93117; jasminegrace11@gmail.com*

Alexandria Muller, Danielle Harlow, UCSB

Randall Landsberg, Diana Franklin, University of Chicago

Quantum computers, which depend on quantum properties to solve complex problems, have the potential to transform the way we solve problems as diverse as data encryption, finding cures for cancer, and solving world hunger. The goals of the NSF-funded research project EPiQC include activities and resources to help the public develop ideas related to quantum computing. As part of this goal, we developed interactive activities to introduce ideas that will help the public grapple with ideas that will build a foundation for thinking about quantum computing. These activities are appropriate for museums, science nights, and other outreach events that serve an audience of varied ages and backgrounds. These activities developed through designed-based research by an interdisciplinary team that includes computer scientists, education researchers, and museum staff. Iterative development of each activity was informed by the trials with visitors of various ages and educational backgrounds at an interactive science center.

*Sponsored by Danielle Harlow

Location: CC - Ballroom C **Sponsor:** AAPT **Time:** 5:15–6:25 p.m. **Date:** Monday, July 22 **Presider:** TBD

CD01: 5:15-5:25 p.m. A Controlled Study of Stereoscopic Virtual Reality in Freshman Electrostatics

Contributed –Christopher D. Porter, The Ohio State University, 191 W. Woodruff Ave., Columbus, OH 43210; porter.284@osu.edu

Chris Orban, The Ohio State University (Marion)

Joseph Smith, Amber Simmons, The Ohio State University

Nick Young, Michigan State University

Smartphone-based stereoscopic VR is a relatively new tool for teaching heavily three-dimensional concepts. Amazing content is available in a variety of areas including physics. But very little has been done to test whether learning gains can be improved by using smartphone-based VR in place of more traditional media. We have designed short VR training sessions and have studied the utility of this training in the context of Gauss's Law and electrostatics in a cohort of students in calculus-based introductory physics at the Ohio State University. We compare performance on pre-post tests between students trained using VR, those trained using a video of the VR content, and those trained using static 2D images as in a traditional text. Based on preliminary results, we modified the treatment to include an introduction to the VR learning space. We discuss the effects of preliminary acclimation on the effectiveness of later training.

CD02: 5:25-5:35 p.m. Safety and Medical Context in a Ionizing Radiation Lab Curriculum

Contributed – Jan Beks, Utrecht University, Eyckenstein 46 Vleuten, 3452 JE Netherlands; jan.beks@gmail.com

Ad Mooldijk, Rob van Rijn, Utrecht University

The Ionizing Radiation Lab (ISP) based at the University of Utrecht has provided visits with three mobile ionizing radiation labs to secondary schools for almost five decades now. From a selection of 22 lab experiments, students learn about ionizing radiation. All experiments contain context about safety regarding ionizing radiation and students continuously have to implement safety rules. We will describe and discuss the safety aspect with its eye-openers, and exposure awareness. Some years ago content in the Dutch Physics Ionizing Radiation curriculum started to move towards medical context. Why do hospitals choose generators to provide the radioactive substances in nuclear medicine? What is the exposure while an X-ray is taken? We will describe some particular experiments and discuss (i) how the experiments support the Dutch Physics curriculum, and (ii) how the experiments support medical context.

CD03: 5:35-5:45 p.m. Using Machine Learning to Understand Physics Graduate School Admissions

Contributed – Nicholas T. Young, Michigan State University, 567 Wilson Road, East Lansing, MI 48824; youngn18@msu.edu

Marcos D. Caballero, Michigan State University, University of Oslo

Among all of the first-year graduate students enrolled in doctoral-granting physics departments, the percentage of women and underrepresented minorities has remained unchanged for the past 20 years. The current graduate program admissions process can create challenges for achieving diversity goals in physics. In this presentation, we will investigate how the various aspects of a prospective student's application to a physics doctoral program affect the likelihood the applicant will be admitted. Admissions data was collected from a large, Midwestern public research university that has a decentralized admissions process and included applicants' undergraduate GPAs and institutions, GRE and physics GRE scores, and demographic information such as gender and race/ethnicity. Supervised machine learning algorithms were used to create models that predict who was admitted into the PhD program. Here, we will present the results of this analysis as well as compare models between the various subdisciplines of physics represented in this department.

CD04: 5:45-5:55 p.m. Natural-based Pigments in Dye-Sensitized Solar Cells

Contributed – Orlando M. Patricio, Laredo College, West End, Washington St., Laredo, TX 78040; orlando.patricio@laredo.edu

Emiliano Castillo, Javier Flores, Jr,. Saul Parra, Ruben Perez. Laredo College

Dye-sensitized solar cells (DSSCs) are the next step towards a non-toxic, environmentally friendly, and economical alternative to current solar cells. We are comparing the efficiency between dye extracts of fruits, flowers, and roots produced locally in the South Texas region, or available in local markets. Our experimental design involves using pigments extracted from the fruits, flowers, and roots of the pomegranate and orange tree. Based on our results, we will be able to determine which part of locally grown plants have the greater potential for dye-sensitized solar cells; fruit, flower, or root. In future research, we will compare the effects of the pigments found in giant ragweed, Osage orange, sunflowers, ginger, and saffron.

CD05: 5:55-6:05 p.m. Just-in-time Teaching (JiTT) & Use of Mobile Devices in Active Learning

Contributed – Shahida Dar, Mohawk Valley Community College, 1101 Sherman Drive, Utica, NY 13501; sdar@mvcc.edu

JiTT (Just-in-time teaching) is a pedagogical strategy that uses feedback between classroom activities and work that students do at home, in preparation for the classroom meeting. I will share the ways I've been using JiTT and other active learning techniques in my classes. My focus will be on the use of mobile devices.

CD06: 6:05-6:15 p.m. Teaching Mars Exploration with a Landing Selection Activity

Contributed – Ken Brandt, Robeson Planetarium and Science Center, 210 e. 2 St., Lumberton, NC 28358-2310; ken.starsabove@gmail.com

With the upcoming launch of the Mars2020 Rover, students are curious about the process of selection of the landing site. Find out how you can engage students while teaching basic concepts about Mars, and how it's being explored with robots.

CD07: 6:15-6:25 p.m.. Incorporating Data Visualization Technology into Astronomy Education Research

Contributed – Alexander K. Sivitilli, University of Cape Town, 123 2nd Avenue, Cape Town, WC 7708 South Africa; alexandersivitilli@gmail.com

Tshiamiso Makwela, Thomas Jarrett, Saalih Allie, University of Cape Town

The Iziko Planetarium in Cape Town recently underwent a complete renovation to bring its dome into the digital era. Concurrently, the Inter-University Institute for Data Intensive Astronomy (IDIA) at the University of Cape Town (UCT) established a Visualization Lab that includes its own immersive projection display as well as a virtual reality system. These new tools are planned to serve multiple purposes, particularly in analyzing large data sets from the Square Kilometer Array. The new Digital Dome also offers itself as an excellent public outreach facility and potential modern teaching tool [1]. This talk will describe these new facilities as well as indicate the research directions being undertaken by the Physics and Astronomy Education Research (PhAsER) group at UCT with regard to exploring their use as teaching instruments.

[1]K. C. Yu, K. Sahami, and J. Dove, American Journal of Physics 85, 550 (2017).

Session CE: PER: Curriculum and Instruction

Location: MH - Cedar **Sponsor:** AAPT **Time:** 5:15–6:45 p.m. **Date:** Monday, July 22 **Presider:** TBD

CE01: 5:15-5:25 p.m. A Revision of a Traditional Astronomy Course through Active Learning

Contributed – Raymond Zich, Illinois State University, Campus Box 4560, Normal, IL 61790; rlzich@ilstu.edu

Amber Sammons, Rebecca Rosenblatt, Illinois State University

We report on the conversion of a general education sophomore-level astronomy course from traditional lecture based methods to a more active learning course. The course was reworked into an active learning environment through the addition of concept oriented group worksheets, hands-on experimental activities, planetarium-based lessons, and observing sessions. We reflect on the process of this transition and report on factors that led to the adoption of active learning, factors that supported the change, and barriers faced while implementing this change. We compare and contrast these findings with other case studies of instructional change and theories of adoption. In addition, student learning pre to post was measured with the TOAST and LPCI, and qualitative data was collected to determine student attitudes and perceptions of the course as currently presented.

CE02: 5:25-5:35 p.m. Balancing Agency and Deliberate Practice in Lab Materials

Contributed – Emily M. Smith, Cornell University, Clark Hall, Ithaca, NY 14850-4931; emsmith@cornell.edu

N. G. Holmes, Cornell University

At Cornell University, we are in the process of transforming the labs for the calculus-based introductory physics sequences. The redesign aligns with the Laboratory Guidelines by AAPT and has focused on shifting the labs to develop students' experimentation and critical thinking skills. We define critical thinking in this context as the evidence-based ways through which we make decisions about what to do and what to trust. In this talk, I will discuss the theoretical basis for curricular decisions involved in lab instruction. We explore how deliberate practice and agency interact in lab materials for two iterations of lab materials used by students in an electricity and magnetism course.

CE03: 5:35-5:45 p.m. Can Students Conduct Authentic Scientific Investigations with Video Experiments?*

Contributed – David T. Brookes, California State University, Chico, 400 W 1st St., Chico, CA 95929-0202; dbrookes@csuchico.edu

Anna F. Karelina, Saint Mary's College of California

Eugenia Etkina, Rutgers University

Matthew Vonk, University of Wisconsin River Falls

Peter Bohacek, Pivot Interactives SBC

We have developed an e-learning resource called video-based Investigative Science Learning Environment, or vISLE, built around a matrix of interactive high-quality Direct-Measurement Videos (DMVs) and the ISLE curriculum. To gain a deeper understanding of whether and how students engage in authentic scientific practices using an e-learning resource we have implemented an experimental study where half the class conducted laboratory investigations using videos while the other half did the same experiments using physical apparatus. Our primary research questions are, i) do students learn fundamental physics principles using vISLE, and ii) what scientific reasoning abilities do they develop using vISLE? We have gathered data from multiple sources including videos, lab reports and exams. In this talk we will report on the results of our experimental study and discuss the potential of vISLE to blur the lines between lecture and lab, opening up the possibility for authentic scientific investigations in non-traditional settings.

*Supported by NSF DUE #1726249

CE04: 5:45-5:55 p.m. Cluster Analysis of Strategies for Designing Labs and Activities

Contributed – Amin Bayat Barooni, Georgia State University, One Park Place, Room 431, Atlanta, GA 30303; abayatbarooni1@student.gsu.edu

Joshua S Von Korff, Brian D. Thoms, Zeynep Topdemir, Georgia State University

Our research project aims to assist instructors who want to design new lab manuals. These instructors may discover that no PER-based activity exactly meets their instructional objectives. We analyze the design strategies used in research-based activities to develop a reliable coding scheme. We use this coding scheme to consider 66 different lab activities from 11 different academic sources and analyze these results using K-means cluster analysis. The best results were found when the labs grouped into two separate clusters: scientific thinking and conceptual understanding. The activities that fit in the first category mainly concentrate on discussion and student design of experiments. The second cluster focuses on student observation and prediction. It mostly covers the labs of designers whose primary goal is student conceptual understanding.

CE05: 5:55-6:05 p.m. Comparing Student Problem-solving Sub-skills between Lecture and Adapted Modeling Instruction

Contributed – Justin Gambrell, Drexel, 32 S 32nd st, #816 Disque Hall, Philadelphia, PA 19104; jeg357@drexel.edu

Roy Smith, Jacob Wikowsky, Eric Brewe, Drexel

We investigate problem-solving approaches used in two introductory physics class sections at one university taught by the same instructor. One section is taught by traditional lecture N=53 and one section is taught with a modified version of Modeling Instruction N=52. Modifying a list of problem solving sub-skills identified by Adams et al (2015), we reduced the sub-skills from 40 down to 11 and coded problem solutions. Two researchers independently coded problem solutions identifying the use or lack of subskills. We compared the two separate codes to check consistency, and accepted a consistency of at least 80 percent. We find that there are significant differences between two sub-skills across sections: visualization and judgement of information. This is one part of a larger study involving the adaptation of a 16-week Modeling Instruction curriculum for studio format instruction to a 10-week curriculum combining lecture and recitation.

CE06: 6:05-6:15 p.m. Differences Between Adapted Modeling Instruction and Lecture in Introductory Mechanics

Contributed – Jacob Wikowsky, Drexel University, 32 S 32nd St, #816 Disque Hall, Philadelphia, PA 19104; jacobwikowsky@gmail.com

Justin Gambrell, Eric Brewe, Drexel University

Modeling Instruction (MI) in physics has been shown to improve student outcomes over standard lectures across a variety of metrics. However, MI is not commonly implemented at the university level. As is typical, Drexel does not have an ideal classroom setting for MI, which was developed with the intention of use in an integrated lab/lecture. We are in the initial phase of adapting MI to accommodate such constraints, perhaps at the cost of efficacy. To evaluate the implementation in introductory mechanics, we compare DFW rates, grades in the course and on exams, and responses on FCI and C-LASS. Contrasting our results with previously published results will inform the ongoing efforts to improve the uptake of MI.

CE07: 6:15-6:25 p.m. Factors Influencing Students' Experience with Online Instructional Videos

Contributed – Guangtian Zhu, East China Normal University, Shanghai, No 00000 China; zhuguangtian@gmail.com

Online instructional videos are commonly used in both remote and on-campus curricula. We investigated students' experience with online instructional videos using a user experience study method called the "UX curve." One hundred and 53 students from three high schools reported their real-time experiences while watching three instructional videos on kinematics and electrostatics. The results suggested that the crucial factors influencing students' experience can be generally classified as sensory factors and pedagogical factors. The sensory factors include oral presentation, blackboard writing, and monitoring visibility. The pedagogical factors include sample question selection, tempo of instruction, and interaction between teachers and students.

CE08: 6:25-6:35 p.m. Lessons Learned While Creating a Learning Progression for Partial Derivatives

Contributed – Michael Vignal, Department of Physics, Oregon State University, 301 Weniger Hall, Corvallis, OR 97331-8507; vignalm@oregonstate.edu

David Roundy, Elizabeth Gire, Corinne A. Manogue, Department of Physics, Oregon State University

Tevian Dray, Department of Mathematics, Oregon State University

The physics education research group at Oregon State University is creating a learning progression for partial derivatives. This learning progression maps desired student learning of partial derivatives and can be a useful tool for instructors, curriculum developers, and physics education researchers. The learning progression highlights connections between physical concepts, different representations, and instructional activities. One of the most important things we have learned is that different representations - graphs, contour plots, equations, tangible models, etc. - convey different aspects of a concept to students, even if they feel repetitive to experts. In this talk, we discuss some of what we learned while making the learning progression, how it has impacted our teaching, and how other instructors might use our learning progression (or others) as a tool for curriculum design.

CE09: 6:35-6:45 p.m. Out-of-Class Social and Online Resources: Student and Instructor Perspectives

Contributed – Brandon James Johnson, University of Maryland - College Park, 9014 Breezewood Terr., Apt 103, Greenbelt, MD 20770; brandon.johnson110@gmail.com

Erin Ronayne Sohr, Ayush Gupta, Andrew Elby, University of Maryland - College Park

Many students' out-of-class learning experience includes working with other people, such as peers and tutors, and using online and social-media resources, such as Khan Academy, YouTube, Chegg, GroupMe, and Wikipedia. Online resources have recently emerged; they change rapidly, are widely used and understudied. One might ask whether these resources help or hurt students' learning, which resources are fair or unfair to use, what emotions are associated with the use of certain resources, and why. Perhaps students and instructors differ in their opinions to the previous questions, and in ways that depend on how they identify. We conducted semi-structured interviews with introductory physics and engineering students and instructors focusing on their ethical and epistemological stances regarding use of out-of-class resources. We will open with a literature review, putting into context our viewpoint of out-of-class resource use. Then we will present preliminary analysis of interview segments.

Session CF Introductory Courses: Fascinating Physics

Location: MH - Amphitheater **Sponsor:** AAPT/PER **Time:** 5:15–6:25 p.m. **Date:** Monday, July 22 **Presider:** TBD

CF01: 5:15-5:25 p.m. Using Coding to Enforce the Physics: Interactive Modules for Electromagnetism*

Contributed – Richelle M. Teeling-Smith, The University of Mount Union, 1972 Clark Ave., Alliance, OH 44601; teelinri@mountunion.edu

Chris Orban, The Ohio State University

There is a need to integrate computation into the introductory physics curriculum. Incorporating new content into an already jam-packed introductory course is a challenging task for absolute beginner programmers. We present a series of interactive electricity and magnetism programming modules that can be easily integrated into an algebra-based introductory physics course, at the high school or undergraduate level. These programming modules are game-like, browser-based, and are designed to highlight only the physical behavior of an interactive simulation, making them ideal for beginner programmers. We will describe the effort to integrate these programming modules into an existing introductory physics lab and the ongoing effort to probe the impact of these coding activities on student conceptual learning through an animated Brief Electricity and Magnetism Assessment. These activities are currently being used at Mount Union and OSU Marion, as well in as in high school physics classrooms across Ohio.

*The STEMcoding Project is supported by the AIP Meggers Award and internal funding from OSU.

CF02: 5:25-5:35 p.m. Designing a Reynolds Number Tutorial for an IPLS Course

Contributed – Jessica C. Hobbs, Texas State University, Roy F Mitte Building, 749 N Comanche St., San Marcos, TX 78666-3432; jch210@txstate.edu

Brandon R. Lunk, Texas State University

My research focuses on creating in-class learning material covering Reynolds number for students in an introductory physics course for life sciences (IPLS). A significant number of students who take general-level physics courses are biology and health science majors. There's a growing initiative to implement biologically relevant material into these courses to provide students with motivation in physics and new insights into biological systems. One biologically-relevant physics concept is Reynolds number (Re); this is the ratio of inertial forces to viscous forces for fluids. Reynolds number can help us to understand whether organisms experience viscous flow or turbulent flow when moving through a fluid; this in turn gives us physical insight into biological phenomena. In order to help support a deeper un-

derstanding of the Reynolds Number, we created an in-class instructional worksheet (tutorial). In this talk, I will discuss the development and testing of this tutorial.
*Sponsored by Dr. Brandon Lunk

CF03: 5:35-5:45 p.m. Using Seismic Design Specifications to Help Teach Introductory Physics*

Contributed – Frederick J. Thomas, Math Machines, 10082 Dove Drive, Freeland, MI 48623-8671; fred.thomas@mathmachines.net

Robert Chaney, Sinclair Community College

Richard Tseng, Bowser Morner

Whether in higher-risk areas like San Francisco and Provo or lower-risk Detroit, civil and structural engineers are required to design all major structures to withstand a clearly defined "maximum considered earthquake" (MCE). The primary quantity which defines the MCE is the peak horizontal ground acceleration (PGA) with a 2 percent probability of occurring within a 50-year period. This session will show how physics learners can obtain PGA specifications for any onshore location in the world, and (in the U.S.) detailed spectral information important to resonance considerations. Suggested activities for introductory physics labs or classrooms include calculations of maximum earthquake loading as a direct application of F = ma, calculation and testing of likely resonant frequencies, modeling of earthquake wave refraction based on near-surface soil and rock characteristics, and investigation of the connection between soil density and "soil liquefaction."

*This material is based in part upon work supported by the National Science Foundation's Advanced Technological Education program under Grants No. DUE-0202202 and DUE-1003381, including our recent book, The Physics of Destructive Earthquakes.

CF04: 5:45-5:55 p.m. A Kinesthetic Activity to Teach Apparent Retrograde Motion

Contributed – Paul R. DeStefano, Portland State University, 18130 SW NIK'S DR Aloha, OR 97003-4483; paul.destefano-aapt@vfemail.net

Ralf Widenhorn ,Portland State University

The apparent retrograde motion of a planet (e.g. the retrograde of Mars as observed from Earth) is a natural consequence of the prograde motion of two bodies orbiting a common focus in combination with parallax. While this situation is easy to replicate in a classroom kinesthetic activity, visualizing the apparent retrograde motion that emerges is more difficult. Using Local Positioning System technology, two students walking concentric paths are tracked in 2D and the emergent phenomenon is clearly demonstrated. Firstly, the displacement between the two students is plotted, which is a view that mimics a observer-centric conception of the system, with the wanderer circling the observer at the origin and exhibiting epicycles. In a second transform, the phase of the wanderer in an arbitrary absolute coordinate system is plotted over time, showing characteristic changes of direction across the "heavens."

CF05: 5:55-6:05 p.m. Surprising Ways to Make Introductory Physics Problems Much More Difficult

Contributed – A. James Mallmann, Milwaukee School of Engineering, 20250 W Jeffers Dr., New Berlin, WI 53146-2522; mallmann@msoe.edu

Steven P. Mayer, Milwaukee School of Engineering

Many problems assigned in introductory general physics courses include simplifying assumptions that make solutions of the problems easy—and sometimes possible. Typical assumptions include: no friction, massless cords, and the sine of an angle approximately equal to the tangent of the angle. Removing those simplifying assumptions often makes the problems much more difficult. The difficult versions of the problems is a good source of extra-credit problems for exams—and the most difficult of those problems can be used to challenge the best students in a class.

CF06: 6:05-6:15 P.M. The Apollo 1 Fire and the Flammability of Fabrics

Contributed – Gregory A. DiLisi, John Carroll University, 8517 Forest View Drive, Olmsted Falls, OH 44138; gdilisi@jcu.edu

Stella McLean, John Carroll University

This January marked the 52nd anniversary of the Apollo 1 fire. On Jan. 27, 1967, the interior of NASA's "AS-204" Command Module (CM), occupied by American astronauts Roger Chaffee, Virgil "Gus" Grissom, and Ed White, caught fire during a ground test. The three astronauts perished. In this case study, we conduct a basic horizontal flame test, patterned after the protocols set forth by the Environmental Protection Agency (EPA) to measure the ignitability of solids. The laboratory activity is a complementary exercise to the vertical flame test described in our previous article that examined the initial source of fuel for the fire that destroyed the massive German zeppelin Hindenburg, in 1937. Combining techniques from both case studies gives students a quantitative understanding of how the flammability of materials is tested and how a forensics-approach to physics can be used to understand significant historical events.

CF07: 6:15-6:25 P.M. Hurricanes, Trade Winds, Sunspots and Angular Momentum

Contributed – L. Edward Millet, Emeritus Professor, California State University, Chico 1148 C St. SW, Ephrata, WA 98823-2112; lemillet@aol.com

Hurricanes (alias typhoons or tropical cyclones) have three basic motions described in terms of Coriolis forces or, equivalently, conservation of zero angular momentum. They cause trade winds to move away from, not toward, the equator. Comparison of sunspots to hurricanes allows explanation of the origin and motion of sunspots, their cycles, why there is a dark umbra and less-dark penumbra, why the Sun shows differential rotation, and why the Sun's upper atmosphere is hotter than its surface.

Session CG Experiments for Introductory Labs

Location: MH - Birch **Sponsor:** AAPT **Time:** 5:15–6:45 p.m. **Date:** Monday, July 22 **Presider:** TBD

CG01: 5:15-5:25 p.m. The Effect of Projectile Mass on Ballistic Pendulum Displacement

Contributed – James C. Sanders, Troy University, 315 McCall Hall, Troy, AL 36082-0001; jcsanders@troy.edu

The relationship between projectile mass and final displacement height for the pendulum arm in a ballistic pendulum is tested. To do this metal projectile balls of five different masses that undergo a perfectly inelastic collision with the pendulum arm, and then the total vertical displacement of the arm is measured. The arm's maximum displacement height increases monotonically for balls of mass less than the effective mass of the pendulum arm, in good agreement with a model based on linear momentum conservation during collision and energy conservation both during the motion of the arm after the collision and (separately) during firing sequence of the ball.

CG02: 5:25-5:35 p.m. Dynamics of a Spool-Block Atwood System

Contributed – Abdallah El Idrissi, 1 Sierra College, 5100 Sierra College Blvd., Rocklin, CA 95677; dcalabrese@sierracollege.edu

Dominic Calabrese, Sierra College

The classic Atwood machine consists of two objects connected by a string over a pulley. In the typical case when the two hanging objects have the same mass and both objects are at rest the system is in equilibrium. What happens if one of the blocks is replaced by a spool of equal mass? We present a classroom demonstration that illustrates the dynamics of a spool-block Atwood system. This apparatus raises some very interesting questions such as: (1) What are the accelerations of the spool and the block if their masses are equal? (2) What is the relationship between their accelerations? (3) What spool to block mass ratio results in a block acceleration equal to zero? We will illustrate how we obtained our results using several techniques, and we present a video to demonstrate our results.2

1 "Sponsored by Dominic Calabrese" 2https://www.youtube.com/channel/UCP_TzAW__2zrofy2GPMynSg

CG03: 5:35-5:45 p.m. Inquiry Labs that Fuel Scientific Curiosity: An Example with Hooke's Law

Contributed – Martin M. Stein, Cornell University, 400 Triphammer Road, Ithaca, NY 14850; ms3452@cornell.edu

Emily M. Smith, Natasha G. Holmes, Cornell University

Making undergraduate students excited about physics labs is at times a formidable task. We present our experiences with labs that are designed to teach experimentation practices through the example of an activity on Hooke's law. Inspired by previous research, we identified three factors that promote authentic inquiry in a seemingly inauthentic task. First, personalization -- students bring in objects from home to test against Hooke's law, giving them the opportunity to focus on experiments they are genuinely interested in. Second, feasibility -- testing Hooke's law is simple enough to let students design experiments that are feasible within the lab time. And third, googleability -- working with objects from home means the "answer" is not readily available, giving student the opportunity to create knowledge that is only attainable to them through the lab activities. We believe honoring these factors can enable instructors to design labs that promote authentic scientific inquiry for their students.

CG04: 5:45-5:55 p.m. Physics of Music Laboratories in a General Education Course

Contributed – Stephen C. Parker, Saint Martin's University, 5000 Abbey Way, SE, Lacey, WA 98503; sparker@stmartin.edu

Darrell Born, Saint Martin's University

A sequence of laboratories in a physics course for non-majors is often a critical component of the general education requirements for many schools. At Saint Martin's University, we will be starting our new "core curriculum" in the fall semester of 2019 with a collection of courses that attempt to capture our Benedictine tradition. One of the required classes here will still be a science class with a laboratory, but it must include some sort of interdisciplinary twist. As a result, finding laboratories that can fully engage and excite students in a Physics of Music course has been quite challenging. I will talk about some of the labs that we do as a part of the class here at Saint Martin's, but I am also curious to hear what successes others might have had in this endeavor.

CG05: 5:55-6:05 p.m. Two Demos on Waves and Uncertainty

Contributed – Michelle Nuttall, Brigham Young University, 642 S Amaya Ave., Boise, ID 83709-5081. muunutt@gmail.com

Dallin Durfee, Nathan Powers, David Allred, Brigham Young University

I will present two short demonstrations. One simple, inexpensive activity uses nuts and bolts to show why tighter localization in space results in greater uncertainty in wavenumber. The other demonstration illustrates effects such as aliasing that occur when a wave is sampled at discrete locations.

CG06: 6:05-6:15 p.m. Unheard of Ultrasonic Demonstrations and How to Use Them Safely

Contributed – Paul E. Noel, Yale University, 217 Prospect St., New Haven, CT 06510; paul.noel@yale.edu

Ultrasonic demonstrations are uncommon for teaching wave phenomena. However they have some interesting properties that are both entertaining and also present a different and useful perspective on the underlying science. I will show several different apparatus, while pointing out aspects of the physics, design, and construction. These demos will include: a parametric speaker, bat detector, and acoustic levitator. An important factor to consider with ultrasonics is safety. To that end I will review maximum recommended sound pressure levels at different frequencies and exposure times. To address this issue and because most commercially available sound meters do not perform well at ultrasonic frequencies, we will demonstrate and present an affordable ultrasonic sound meter circuit/device that you can build yourself. This device is sensitive to ultrasound and has a microphone that is small enough to probe individual nodes in a standing wave.

CG07: 6:15-6:25 p.m. Improved Gay-Lussac Experiment Considering Added Volumes

Contributed – Joel D. Krehbiel, Hesston College, 301 S Main St., Hesston, KS 67062-2093; joel.krehbiel@hesston.edu

Nelson Kilmer, Hesston College

The typical Gay-Lussac experiment requires heating and cooling of a flask connected via small tubing to a pressure sensor. Extrapolation of pressure-temperature data provides a simple way to estimate absolute zero. However, with standard laboratory equipment, the estimates are typically off by 10-15 percent. This error is due to the assumption that the tubing and pressure sensor are at the same temperature as the flask. However, the tubing and pressure sensor are actually closer to room temperature. Thus, the system acts as two connected volumes at two different temperatures. Here we derive the theory for this system and show why many Gay-Lussac experiments provide estimates of absolute zero that are too low. We also provide two alternative ways to estimate absolute zero using the two-volume model. Student results using these methods provide significant reduction in error and provide an excellent learning experience for students in introductory physics or chemistry classes.

CG08: 6:25-6:35 p.m. A FAN-C Exploration of RC Circuits

Contributed – Robert Charles, Ekey University of Mount Union, 1972 Clark Ave, Bracy Science Hall, Alliance, OH 44601-3993; ekeyrc@mountunion.edu

Brandon Mitchell, West Chester University

Recently, small computer fans have been demonstrated to be an effective method for teaching simple resistive circuits both qualitatively [1] and quantitatively [2]. The current through the fans is related to the rotational speed of the fans and allow multiple senses to be engaged (touch, sight, and hearing). The linear relationship between the operational current and applied voltage provides a nearly constant effective resistance for the fan. This suggests that fans can also be used to explore RC circuits both qualitatively and quantitatively, where the fans act as the resistive elements as well as the indicator. In this presentation, we will demonstrate that computer fans can be used to qualitatively explore the charging and discharging times for RC circuits. By monitoring the voltage across the capacitor as a function of time, we will also show that fans can be used for quantitative RC analysis.

1. Robert Ekey, Andrea Edwards, Brandon Mitchell, Roy McCullough, and William Reitz, "A fan-tastic alternative to bulbs: learning circuits with fans," Phys. Teach. 55, 13 (2017). 2. Brandon Mitchell, Robert Ekey, Andrea Edwards, Roy McCullough, and William Reitz, "A fan-tastic quantitative exploration of Ohm's law," Phys. Teach 56, 75 (2018).

CG09: 6:35-6:45 p.m. An Optical Rotator for Introductory Polarization Experiments

Contributed – Mary Ann H. Klassen, Swarthmore College, Dept. of Physics & Astronomy, 500 College Ave.., Swarthmore, PA 19081; mklasse1@swarthmore.edu

Peter J. Collings Swarthmore College, Dept. of Physics & Astronomy

Placing a bottle of corn syrup between two polarizers is a well-known demonstration of optical activity. We present a quantitative experiment to measure the rotation angle for light passing through a small sample of corn syrup. This is a simple and interesting extension of the traditional polarization experiments typically performed in the introductory laboratory.

Session CH Breaking Physics from Ground-breaking Experiments

Location: MH - Arches **Sponsor:** Committee on Educational Technologies **Co-Sponsor:** Committee on Physics in Undergraduate Education
Time: 5:15–6:45 p.m. **Date:** Monday, July 22 **Presider:** Mariel Meier

CH01: 5:15-5:45 p.m. A Flavor of the Flavor Physics at LHCb

Invited – Henry Schreiner, University of Cincinnati, 261 rue du Puits, Mathieu Thoiry, Ain 01710 France; hschrein@cern.ch

The Large Hadron Collider (LHC) at CERN is at the forefront of the high energy frontier. The LHCb detector is a highly specialized forward spectrometer designed to study flavor physics using the LHC beam. We will step through a gentle, colorful introduction to the physics that LHCb was built to study. We will take a look at what makes LHCb a unique experiment, and how it captures some of the most exciting particle decays. We will take a look at some of the achievements of LHCb, such as the pentaquark state.

CH02: 5:45-6:15 p.m. Searching for Evidence for New Physics, NEW g-2 Experiment

Invited – Kevin Giovanetti, James Madison University, 901 Carrier, MSC 4502, Physics DEPT., Harrisonburg, VA 22807; giovankl@jmu.edu

In the 70's the Standard Model was developed as a fundamental description of the way our world works. The previous history of discovery involved dramatic and puzzling challenges. The expectation was that the evolution of our understanding would continue to be tumultuous. However over the next 30+ years the Standard Model survived with only minor enhancements. The general feeling, however, is that an even more fundamental theory must exist and the new g-2 experiment is searching for evidence by looking for a discrepancy between Standard Model predictions and experimental results. G-2 has been designed to precisely measure the magnetic moment of the muon, a number that theorists have precisely calculated. A description of the experiment and the challenges of the measurement will be discussed. The prospects for success and the reasons why this particular measurement might succeed at leading to new physics will be addressed.

CH03: 6:15-6:45 p.m. The Daya Bay Reactor Neutrino Experiment

Invited – Christopher White, Illinois Tech, 10 W 35th St., Chicago, IL 60616-3793; whitec@iit.edu

Neutrino oscillations were definitely discovered in 2002. Since then, the study of neutrinos has captured the interest of experimental particle physicists world wide. In 2012, the Daya Bay Reactor Neutrino Experiment discovered an unexpectedly large value for the neutrino mixing parameter known as theta13, paving the way to the next generation of neutrino oscillation experiments. In this talk I will explain what the excitement is all about, I will review what is currently known, and will provide a brief overview of what we hope to learn in the coming years.

Session CI Science and Society: Climate Change

Location: MH - Canyon **Sponsor:** Committee on Science Education for the Public **Time:** 5:15–6:45 p.m. **Date:** Monday, July 22
Presider: Steve Lindaas

CI01: 5:15-5:45 p.m. Can We Inoculate Science Students Against Pseudoscience?

Invited – Eric A. Schiff, Syracuse University, Dept. of Physics, Syracuse, NY 13244-1130; easchiff@syr.edu

Walter A. Freeman, Syracuse University

Climate change and other "hot button" topics in science confront science teachers with a quandary. Ordinarily, in teaching science we use streamlined narratives. These are successful in improving students' understanding. However, outside the classroom, similarly streamlined narratives are being used to give credibility to conclusions that are far from the science mainstream. Consequently, we are adding material to introductory physics and astronomy courses that may inoculate students against aberrant narratives. Recognizing and understanding "cherry picking" is one example. What distinguishes a discovery such as X-rays from an apparent discovery such as N-rays? In climate science, is the recent rise in the concentration of carbon dioxide in the atmosphere just cherry picking of data from millennia of fluctuating levels? Such questions are not commonly included in textbooks, nor are they typically included in learning outcomes for introductory courses. Inoculation strategies need more instructional materials and guidance in assessment.

CI02: 5:45-6:15 p.m. The M&M Problem

Invited – Brad Hoge, National Center for Science Education, 1904 Franklin St., Oakland, CA 94612; hoge@ncse.com

NCSE's teacher ambassador program has operated under the catch phrase "turning misinformation into educational opportunities" or TMEO. To the consternation of colleagues who hate acronyms, I have often replaced the M in TMEO with the word misconceptions. Why would I do this? Is it just to confuse and annoy my colleagues? Well, maybe, but the program uses misconception-based pedagogy to inoculate students against the misinformation they encounter from sources such as the Heartland Institute and some fairly high-profile politicians, so either word actually works. And it's not simply that I can't decide which word I like best. There is a method to my madness and it has to do with the power the chimeric M provides when explaining the impact of our approach. This works outside of the classroom too and I'll explain how to use this technique to talk to climate change deniers tactfully and without conflict.

CI03: 6:15-6:25 p.m. Cloud Physics II

Contributed – Celia Chung Chow, CSU, 9 Andrew Drive, Weatogue, CT 06089; cchungchow@comcast.net

A continuation of "Cloud Physics I " presented at AAPTSM17.

Session CJ Star Wars Physics

Location: MH - Zion **Sponsor:** Committee on Contemporary Physics **Co-Sponsor:** Committee on Physics in High Schools
Time: 5:15–6:45 p.m. **Date:** Monday, July 22 **Presider:** Martin Shaffer

CJ01: 5:15-5:45 p.m. The Physics of Star Wars

Invited – Patrick Greenleaf G. Johnson, Georgetown University, 506 Reiss Science Building, Washington, DC 20057; pgj7@georgetown.edu

Since he was young, Patrick has loved both science and Star Wars. As an adult, he wrote a book that tries to explain different theories as to how scenes and devices in the Star Wars universe work. Have you ever wondered how the Death Star works? How shields can stop catapults, but droids can walk right through? This talk will offer possible explanations of these scenes and more. This will be an enjoyable talk for anybody who is a fan of Star Wars, physics, or both.

CJ02: 5:45-5:55 p.m. It's a Small World in a Vast Galaxy

Contributed – Richard Gelderman, Western Kentucky University, 1906 College Heights Blvd., Bowling Green, KY 42101-1077; gelderman@wku.edu

In the Star Wars series, the creators much of the time present correct aspects of distances and sizes in our galaxy, though times when they fumble can be just as useful as teachable moments. Students learning how long it takes to send spacecraft to the Moon or Mars can address whether popping in and out of hyperspace within a solar system would work as it does for the Rebellion. A real-time holographic teleconference with Jedi located on worlds scattered across the galaxy becomes a paradox to students learning about the constant speed of light in a war that spans tens or hundreds of light-years. Attempts will be made to not get trapped into prolonged arguments for, or against, Hans Solo's claim for making the Kessel Run.

CJ03: 5:55-6:05 p.m. Classical Mechanics with a Quantum Twist

Contributed – Boaz Almog, Quantum Experience, 13 Moskovich St., Rehovot, Rehovot 7647413, Israel; boazal@quantumlevitation.com

Gil Taran, Quantum Experience

Classical mechanics hasn't changed since the times of Sir Isaac Newton, but experiencing it as a teacher or a learner has now been given a modern twist. We will demonstrate how using tabletop modern physics and a quantum levitation experiment setup to teach classical topics can inject enthusiasm and appeal into somewhat ordinary experiments while also providing a unique learning experience. In this session, we will demonstrate how to conduct classroom classical mechanics experiments including circular motion, harmonic motion, collision and conservation of energy using the Quantum Wave: a specifically designed flexible linear magnetic levitation (MAGLEV) track, suitable for both high school and university classes. Using the Quantum Wave will allow students to conduct experiments in classical mechanics while giving them a taste of quantum mechanics along the way.

CJ04: 6:05-6:15 p.m. Conceptualizing which Solar System Objects Can Form an Exosphere

Contributed – Jordan K. Steckloff, Planetary Science Institute, 2234 E. North Territorial Rd., Whitmore Lake, MI 48189; jsteckloff@psi.edu

The distribution of atmospheres on solid objects in the Solar System appears random, with large airless bodies (e.g., Mercury, asteroids, icy moons) intermixed with objects with atmospheres (Mars, Titan, Pluto). However, the presence of atmospheres is rooted in concepts taught in introductory mechanics. Here I present the mechanisms students must consider for an object to form and retain an atmosphere over time. To form an atmosphere, molecules condensed on the surface of an airless body must be sufficiently warm to sublimate during the day, otherwise such volatile species (e.g., nitrogen, carbon dioxide, methane) will remain condensed as ice. Additionally, the object must have an escape speed greater than the molecular speed of the gas to preventing atmospheric loss. These two processes create a sweet spot in which an object is warm enough to form an atmosphere, yet cool and large enough that atmospheric molecules are moving slower than escape speed.

Session CK PTRA: Quantum Computing in YOUR Classroom

Location: CC - Ballroom A **Sponsor:** Committee on Physics in High Schools **Co-Sponsor**: Committee on Teacher Preparation
Time: 5:15–6:45 p.m. **Date:** Monday, July 22 **Presider:** Kenric Davies

Quantum computing is an exciting branch of quantum mechanics and has the prospect of making cyber security practically unbreakable. With a simple hands-on demonstration, you can bring the ideas of quantum cryptography into your classroom and model the sending of a message and cipher while learning how an eavesdropper is detected.

Session CL PER: Institutional Change

Location: CC - Ballroom B **Sponsor:** AAPT/PER **Time:** 5:15–6:45 p.m. **Date:** Monday, July 22 **Presider:** TBA

CL01: 5:15-5:25 p.m. The Impacts of Students as Partners on Departmental Action Teams

Contributed – Gina M. Quan, San José State University, One Washington Square, San Jose, CA 95192-0106; gina.m.quan@gmail.com

Joel C. Corbo, Alanna Pawlak ,Courtney Ngai, University of Colorado Boulder

Daniel L. Reinholz, San Diego State University

Within colleges and universities, it is rare for faculty and students to work together on change efforts related to undergraduate education. However, research in the higher education community suggests that student-faculty partnerships, or “Students as Partners” (SaP) can be a productive. Within our work, we implement SaP in efforts aimed at department-level changes. Our team facilitates Departmental Action Teams (DATs), teams of faculty, students, and staff within a single STEM department working on some issue related to undergraduate education. We study what it looks like for students and faculty to work in partnership with one another. We will first synthesize literature that suggests the transformative potential of SaP. We then describe how we designed toward SaP in the DAT model. We use preliminary data to discuss how SaP supported faculty learning and positive student outcomes. Finally, we reflect on how SaP can create new opportunities for transforming departments.

CL02: 5:25-5:35 p.m. “Don’t just say, ‘You’re wrong’”: GTAs Normalize Error in a Classroom Simulator

Contributed – Jacquelyn J. Chini, University of Central Florida, 4111 Libra Drive, - PSB 430, Orlando, FL 32816; jchini@ucf.edu

Tong Wan, Constance M. Doty, Ashley A. Geraets, Erin K. H. Saitta, University of Central Florida

Student-centered active learning strategies require instructors to use complex pedagogical skills. Such strategies often require students to share their ideas verballing in class in front of their peers. Research has demonstrated that active learning can both increase and decrease anxiety among college students and that certain strategies, like cold calling, frequently lead to an increase in anxiety. However, research also shows that cold calling can increase participation equity. Instructors may be able to decrease students’ fear of negative evaluation with error framing by framing mistakes as natural and useful. We tasked physics and chemistry graduate teaching assistants (GTAs) to rehearse cold calling paired with normalizing error in a mixed-reality classroom simulator, TeachLivE. In the simulator, GTAs themselves had the opportunity to make mistakes while trying to normalize error without impacting their actual students. In this talk, we will demonstrate how the simulator facilitated GTAs’ rehearsal of this complex pedagogical skill.

CL03: 5:35-5:45 p.m. Impact of Online Discussion in Forming a Community of Practice of Educators

Contributed – Bahar Modir, Texas A&M University-Commerce, Department of Physics and Astronomy, PO Box 3011, Commerce, TX 75429; bahar.modir@tamuc.edu

Robynne Lock, William G. Newton, Texas A&M University-Commerce

Community formation is important in identity development of teachers. However, many teacher communities form in isolation from each other, and demonstrate limited sustainability over time. Texas A&M University-Commerce has designed a new and unique online Master program to prepare high school teachers with better informed teaching practices in their own high schools by reinforcing foundational and pedagogical content knowledge within a remote collaborative learning environment. In this study, we investigate the role of this program in community formation and development for educators nationwide. Using the community of practice theoretical framework, we discuss the role of course structure in promoting an ongoing online discourse among participants as they practice: learning physics, teaching, and overcoming their challenges. The result of this research can help us to gain further evidence supporting formation of teacher communities in high schools.

CL04: 5:45-5:55 p.m. Developing Reflective Practitioners: A Case from Faculty Online Learning Communities

Contributed – Alexandra C. Lau, University of Colorado Boulder, 390 UCB Boulder, CO 80309; alau693@gmail.com

Melissa Dancy, University of Colorado Boulder

Charles Henderson, Western Michigan University

Andy Rundquist, Hamline University

One of the main goals of the New Faculty Workshop Faculty Online Learning Community (NFW-FOLC) program is to develop the reflective practices of our participants. By increasing the reflective teaching practices of our new physics and astronomy faculty, we hope to promote the sustained adoption of research-based instructional strategies and a dedication to continuous teaching improvement. One of the ways we try to achieve these goals is by guiding our FOLC participants through the completion of Scholarship of Teaching and Learning (SoTL) projects. In this talk we report on our analysis of participants' conversations about their SoTL projects, from the beginning stages through final presentations, documenting their trajectories through different levels of reflectiveness. Additionally, we identify mechanisms in the FOLC that seem to support participants through the stages of reflection. This work illustrates in detail one impact of FOLC participation and it offers implications for similar professional development efforts.

CL05: 5:55-6:05 p.m. Online Faculty Communities: Meeting Virtually Is Better than IRL*

Contributed – Edward Price, California State University San Marcos, 333 S. Twin Oaks Valley Road, San Marcos, CA 92096; eprice@csusm.edu

Faculty learning communities provide opportunities for faculty to learn from each other, develop new skills, and deepen their understanding of teaching and learning. The complexity and subtly of these issues might suggest that faculty learning communities require the richness of in-person meetings. However, our experience with a faculty online learning community (FOLC) shows that not only can online faculty communities be effective, but that being a virtual community offers distinct advantages. Without being limited to a particular place, faculty in an online community can connect with others who share particular interests (eg, a specific course), even if there are not others at their institution with similar interests, motivation, or time. Faculty can "meet" from their offices, where they have access to materials they might not bring to an in-person meeting. This talk will describe the advantages and limitations of FOLCs, and lessons learned to maximize their potential.

*Work supported by NSF#1626496

CL06: 6:05-6:15 p.m. Peer Support for Instructors Negotiating New Pedagogical Approaches with Students

Contributed – Stephanie Marie Williams, 10210 Day Ave., Silver Spring, MD 20910-1044; stephanie.williams1881@gmail.com

Chandra Turpen, Univ of Maryland-College Park

Adriana Corrales, San Diego State University

Melissa Dancy, University of Colorado

Edward Price, California State University, San Marcos

Many research-based curricula move classrooms toward more student-centered and activity-based formats. As a result, instructors are expected to attend and respond to students in ways that may not be familiar. Research has shown that one prevalent category of challenges college instructors face involves responding to students' in-class engagement (e.g. managing resistance, navigating expectations about learning, eliciting participation within in-class discussions, and responding to varied understanding of specific physics concepts and representations). In this analysis, we examine the student-centered challenges instructors share while adapting the Next Generation Physical Sciences and Everyday Thinking curriculum [1]. We analyze recordings of conversations within faculty online learning communities to understand the varied forms of support they offer instructors in responding to their students. Across these moments we see faculty at times blaming students, and at times analyzing classroom events to understand the ways that current instructional practices may be contributing to the emergent challenges.

[1] Work supported by NSF#1626496 *And the rest of the NextGenPET Research Team (Fred Goldberg, Alexandra Lau, and Meghan Clemons)

CL07: 6:15-6:25 p.m. Online Learning Communities: How Do they Support Instructors Through Challenges?

Contributed – Chandra Anne Turpen, University of Maryland, 6701 Adelphi Rd., University Park, MD 20782; chandra.turpen@colorado.edu

Stephanie Williams, University of Maryland

Adriana Corrales, San Diego State University

Melissa Dancy, University of Colorado

Edward Price, California State University, San Marcos*

Research has shown that physics instructors encounter challenges in adapting research-based curricula and instructional strategies to their own contexts. Change scholars have called for curriculum developers to move from dissemination approaches toward propagation models that more deliberately and explicitly build supportive activities relevant to the uptake of their specific innovations. We investigate faculty online learning communities (FOLCs) as a potential mechanism for supporting faculty through the challenges they face in adapting the Next Generation Physical Sciences and Everyday Thinking curriculum [1]. Based on recordings of online discussions between faculty using this curricula, we document the challenges that instructors share and the ways in which community members react or respond to those challenges in conversations. We find that our FOLCs discussions often normalize challenges and generate possible solutions, and more rarely invite joint problem-solving. We model how variations in these reactions or responses create different outcomes for faculty participants.

*And the rest of the NextGenPET Research Team (Fred Goldberg, Alexandra Lau, and Meghan Clemons) [1] Work supported by NSF#1626496

CL08: 6:25-6:35 p.m. A DAT's Impact on Equity and Inclusion, Several Years Later

Contributed – Joel C. Corbo, University of Colorado Boulder, 860 35th Street, Boulder, CO 80303; joel.corbo@colorado.edu

Alanna Pawlak, University of Colorado Boulder

Sarah Wise, University of Colorado Boulder

Departmental Action Teams (DATs) are facilitated groups of faculty, students, and staff in a department with the goal of creating sustainable change with respect to undergraduate education and supporting its members in becoming change agents. One of the oldest DATs ran in a physical science department from 2013 to 2015 and focused on improving departmental climate and support for underrepresented students. Since the end of the DAT, the team has continued as a standing committee and a separate offshoot organization, both of which have been active in continuing the DAT's work through a variety of interventions. We discuss the work that these groups have continued to do and the ways in which maintaining "DAT culture" has helped them do so. We also comment on the substantial impact they have had both on the recruitment and retention of underrepresented students and on the discourse in the department around equity and inclusion.

CL09: 6:35-6:45 p.m. Faculty and Student Conceptions of Success Regarding Departmental Change Work

Contributed – Alanna Pawlak, University of Colorado Boulder, 390 UCB Boulder, CO 80309; alanna.pawlak@colorado.edu

Joel C. Corbo, University of Colorado Boulder

Gina M. Quan, San Jose State University

It is often a challenge for STEM departments to implement and maintain changes to their undergraduate programs. The Departmental Action Team model seeks to facilitate more sustainable departmental changes. In the model, teams known as DATs, which are comprised of students, faculty, and staff, work on collectively-determined goals and projects aimed at improving the undergraduate experience in their department. Even though these goals are consensus-driven, individual DAT members can have very different opinions on the success of their team and on their personal success as a team member. To investigate these differences, we interviewed and surveyed DAT members regarding their DAT's work and their personal experiences on their DAT. We present here the results of our analysis, which describe the different ways that DAT members may perceive and assess the success of their team and their involvement in it.

Session CM Doing Physics and Being_____

Location: MH - Juniper **Sponsor:** Committee on Diversity in Physics **Co-Sponsor**: Committee on Women in Physics **Time:** 5:15–6:15 p.m.
Date: Monday, July 22 **Presider:** Carolina Alvarado

CM01: 5:15-5:45 p.m. Doing Physics, Uncomfortable in a Familiar Way

Invited – Catherine M. Herne, SUNY New Paltz, 1 Hawk Dr., New Paltz, NY 12561-2447; hernec@newpaltz.edu

Doing experimental physics is uncomfortable in a familiar way because I have navigated being "other" all my life. Growing up as a lesbian and presenting my gender in a non-stereotypical way meant that I have always been seen as not typical. Thus, joining a field where women are a minority was familiar. In this session, I will first consider issues of self-disclosure in an academic environment. I work at a state university where I teach physics and mentor undergraduate students in research in optical tweezers. Many of our students come from groups underrepresented in higher education. I will also discuss how navigating "otherness" allows me to make connections with students in crucial ways. The field of physics is not representative of us; nevertheless my students and I continue to love the science and exploration of it.

CM02: 5:45-6:15 p.m. Who I am Influences What I Do

Invited – Ayush Gupta, University of Maryland, College Park, Room 1320 ,Toll Building, College Park, MD 20740; ayush@umd.edu

I am an immigrant, South Asian, gay, queer, non-tenure track scholar in physics education research. These aspects of my being have been influential in steering my interests and choices in life. These identities have marked where I don't fall into the stereotypical boxes that society privileges but also have marked where I find community. But have these aspects of being got anything to do with my scholarship in physics/STEM education research? In this talk, I will explore the entwinement of what I do with who I feel I am— and how these two aspects morph over time without disentangling. Through specific personal anecdotes, I will discuss how particular research directions such as ethics in engineering education, I have undertaken are a product of that entanglement of what I do and who I am.

Session CN Local Area Physics Groups – How Do You Make Them Work?

Location: CC - Soldier Creek **Sponsor:** Committee on Physics in Two-Year College **Time:** 5:15–6:15 p.m.
Date: Monday, July 22 **Presider:** Karie Meyers

CN01: 5:15-5:45 p.m. Starting with a Spark: (Central) Ohio Modeling Teachers

Invited – Kathleen A. Harper, The Ohio State University, 244 Hitchcock Hall, 2070 Neil Ave., Columbus, OH 43210; harper.217@osu.edu

A phone call from one high school science teacher to one staff member at a local university in early 2003 led to a physics Modeling workshop offered in central Ohio in the summer of 2004. One of the goals specifically articulated in the grant proposal to fund this workshop was creating community. That first workshop had 22 attendees, mostly from around Columbus. Now, 15+ years later, over 400 Ohio science teachers, plus some from other states, have participated in workshops, joining the central Ohio Modeling community. Although grant support for workshops has disappeared recently, the community remains, finding ways to reconnect friends and welcome new members. Further, the friendships and teaching practices rooted in the Columbus-area workshops have nucleated other communities. In the context of the program's history, this presentation will highlight features of the program that are believed to have created and nurtured this community.

CN02: 5:45-6:15 p.m. STEMteachersNYC – Building a Community "For Teachers, By Teachers, About Teaching"

Invited – Mark Schober, Trinity School, 101 W 91st Street, New York, NY 10024; jmschober@gmail.com

I have been fortunate to be deeply involved with two successful local area physics groups, the St. Louis Area Physics Teachers and STEMteachersNYC. The long-standing St. Louis Area Physics Teachers was ever present in my formative professional development. When I moved to New York City, I found that no such equivalent organization existed. Leveraging our connections, we assembled a group of teachers for our first workshop in the spring of 2011. Eight years later, we've offered over a hundred workshops serving over a thousand teachers with ever-expanding plans. I'll share a step-by-step roadmap of the key components of these organizations that will help you to start or strengthen your own.

CN03: 6:15-6:45 p.m. QuarkNet: Supporting Local Physics Teacher Groups for 20 Years

Invited – Shane Wood, QuarkNet 50 Groveland Ter. Unit 202, Minneapolis, MN 55403; swood5@nd.edu

QuarkNet is a National Science Foundation sponsored, long-term teacher professional development program that immerses teachers in cutting-edge physics research and supports them in developing instructional strategies that bring authentic scientific and engineering practices into their classrooms. QuarkNet began in 1999, and continues to support collaborations between physics teachers and mentor physicists at over 50 centers at universities and national labs across the country today. In this talk, you will learn about some of the factors that continue to keep these partnerships strong over time.

Session CO Physicists with Disabilities

Location: MH - Bryce **Sponsor:** Committee on Diversity in Physics **Co-Sponsor**: Committee on Professional Concerns
Time: 5:15–6:25 p.m. **Date:** Monday, July 22 **Presider:** Professional Concerns Rebecca Lindell

CO01: 5:15-5:45 p.m. Mental Illness IS a Disability: Imposter Syndrome-ing my Disability

Invited – Rachel E. Maxwell, UC Santa Cruz, 1156 High Street, Santa Cruz, CA 95064; cmdr.rachel@gmail.com

I will discuss the difficulties in coming to accept mental illness as a (typically unseen) disability and its impacts on my ability to navigate the field of academia from undergrad to grad school. I hope to encourage those with mental health problems to find a healthy path for themselves, and offer advice and strategies to people with depression/anxiety, either as a chronic disability or with single/intermittent episodes.

CO02: 5:45-6:15 p.m. The Value in Support: Lifting Those Around Us

Invited – Dedra Demaree, 105 Pear Tree Lane, Franklin Park, NJ 08823-1414; dedra.demaree@gmail.com

My story is not a simple one – my path has not been linear or clear. This is in part due to my personal struggles with mental health – struggles that, while serious, are not uncommon. In fact, the symptoms I deal with on a daily basis hit everyone at some point in their life. My anxiety disorder can be debilitating and throw what should be my safe spaces into chaos, making it very hard for me to function. I have also floundered without appropriate role models. It's the people in my life that have helped me without any knowledge of how deeply I struggle that have made the most impact on me. In telling my story, I will emphasize what can be done to assist students, mentees, and peers in finding their personal version of success, and hopefully make a compelling argument that everyone deserves this support regardless of their personal struggles.

CO03: 6:15-6:25 p.m. Using Head-Mounted Displays to Deliver American Sign Language

Contributed – M. Jeannette Lawler, Brigham Young University, N283 ESC BYU, Provo, UT 84602; lawler@byu.edu

Michael Jones, Brigham Young University

One of the logistical issues Deaf and hard-of-hearing students face is the need to divide their attention between the visual and the visually-delivered-verbal components of a classroom presentation. Head mounted displays provide a technology that allows for a new and promising approach for delivering the verbal portion. Here we present some preliminary results regarding the usefulness of this approach in providing an ASL narration in the visually challenging environment of a planetarium.

PST1A01: 8:30-9:15 p.m. Development of a Studio-Style Introductory Astronomy Course

Poster – Josh Fuchs, Texas Lutheran University, 1000 W Court St., Seguin, TX 78155-9996; jfuchs@tlu.edu

I will present the development and implementation of a studio-style Introductory Astronomy course designed for non-science students. This course meets three times a week for two hours each time, permitting longer and more involved activities to be included. This approach allows for many different engaging pedagogies to be used in the course, including Lecture-Tutorials, hands-on and online labs, role-playing games, and card sorting. I will discuss how these different pedagogies are used to reach learning goals, create a student-centered active learning classroom, and benefit the TLU Department of Physics.

PST1A02: 9:15-10:00 p.m. First Steps Towards Building Curriculum Around Student Interests in Astronomy

Poster – Daniel Barringer, Texas State University, Roy F. Mitte Bldg (RFM) 3240, 749 N. Comanche St., San Marcos, TX 78666-2231; dbarringer@txstate.edu

Alice Olmstead, Kayley Green-Tooney, Texas State University

What role should students have in designing their educational experiences? In the physics department at Texas State University, recent feedback from students motivated faculty to expand astronomy-related opportunities in the physics curriculum. Students can currently take one astrophysics course, participate in an astronomy club, and conduct research with a faculty member. We have been consulting with students to identify areas for further growth. As part of this process, we interviewed students to understand the connections between their interests in astronomy and their participation in astronomy-related activities at Texas State. We describe several aspects of students' interest that seem to drive their continued engagement with astronomy, such as their desire to be part of a community of practitioners and to engage others in the excitement of learning about astronomy. We consider how these interests can inform future curriculum development at Texas State and elsewhere.

PST1A03: 8:30-9:15 p.m. Odds of Habitable Planets: Linking Data and Simulations in the Classroom

Poster – Mary M. Brewer Sherer, William Jewell College, 500 College Hill, Liberty, MO 64068; brewerm@william.jewell.edu

Caeley Pittman, William Jewell College

Students in our introductory astronomy and astrobiology classes are taught that habitable planets are most likely around stars of certain spectral classes, luminosity classes, and metallicity. While students are able to explain why this is the case, they do not always have the mathematical skills to explore how much each of these parameters affects the predicted number of habitable planets in the Galaxy. We have developed a simulation that allows students to vary their ranges for spectral type and metallicity, as well as select which luminosity classes they want to include. They are able to visualize how these constraints can affect the number of habitable planets. These simulations are linked back to stellar population data. Students compare their simulation results to Kepler data in order to better understand selection effects and discovery rates.

PST1A04: 9:15-10:00 p.m. Radio Astronomy Observations for Undergraduates*

Poster – Gordon C. McIntosh, University of Minnesota, Morris 600 E 4th St., Morris, MN 56267; mcintogc@morris.umn.edu

Lynn D. Matthews, Massachusetts Institute of Technology Haystack Observatory

MIT Haystack Observatory is developing a series of observational projects using its Westford Radio Telescope to introduce undergraduates to radio astronomy. The projects include mapping the telescope beam and determining the observing system's sensitivity, observing radio recombination lines, and observing hydroxyl (OH) masers. These projects are intended to be carried out remotely from the user's home institution. They can be used one time during a course or a more extensive observing program can be developed. The projects can be used as presented or adapted for courses in astronomy, optics, quantum mechanics, quantum chemistry, and engineering.

*This research is supported by a grant from National Science Foundation (award 6932425).

PST1A05: 8:30-9:15 p.m. Smartphone Astronomy

Poster – Martín Monteiro, Universidad ORT Uruguay, Aconcagua 5152 Montevideo, 7 11400 Uruguay; fisica.martin@gmail.com

Ludmila Villarreal, Arturo C. Martí, Universidad de la República

Smartphones have become ubiquitous, they are with us all the time and everywhere. These pocket computers incorporate sensors to improve interactivity between the user and the device and although they are not specifically designed to do science, it is noteworthy that they can be used as portable laboratories for a wide variety of scientific and educational activities. During the last years many experiments have been published in the area of physical sciences that manage to involve students by allowing them to do science by their own means. In this poster we show some activities that can be done in basic courses of astronomy and geosciences of secondary or university level: 1) Experimental simulation of asteroid light curve and determination of rotation period and form factors, 2) Experimental simulation of planetary transits and determination of orbital period and size of exoplanets, 3) Experimental simulation of measurements of stellar distances using parallax, 4) Experimental explanation of seasons, 5) Tools for access to astronomical information, 6) Virtual Reality and Augmented Reality tools for educational purposes. More information available at http://smarterphysics.blogspot.com/p/astronomia.html

Lecture/Classroom

PST1B01: 8:30-9:15 p.m. A Collection of Games Used to Synthesize Physics Understanding

Poster – Matthew Olmstead, King's College, 133 N River St,. Wilkes Barre, PA 18711-0800; matthewolmstead@kings.edu

One of the goals of our physics senior seminar course is to get students to understand physics at a deeper level. This is primarily done through a semester long research project on a topic of interest to them that they will write a paper about, give a 20-minute presentation, and give a poster presentation. Another way to get at this goal is by playing several different games to utilize their physics knowledge and to see how they can incorporate it into something other than just answering questions. Several of these games will be discussed including those that combine drawing and concepts, social deduction, combining teamwork and question giving, and answering questions when only being given a well-constructed figure.

PST1B02: 9:15-10:00 p.m. Using Skateboarding Experiential Learning to Teach Introductory College Physics Course

Poster – Liang Zeng,The University of Texas-Rio Grande Valley, 1201 W. University Drive, Edinburg, TX 78539; liang.zeng@utrgv.edu

Guang Zeng, Texas A & M University-Corpus Christi

George Garcia, The University of Texas-Rio Grande Valley

Instructors teaching introductory college physics courses are in a unique position to explain physics in skateboarding and associated potential risks. Taking students to a skate park and measuring the impact forces together can enhance their understanding of physics in skateboarding, analytical thinking skills, and appreciation of physics in everyday life. Students can communicate with each other their practical experiences and learn preventative measures to avoid injuries.

PST1B03: 8:30-9:15 p.m. Using Money to Understand Temperature

Poster – Gerardo Giordano, King's College, 133 N River St., Wilkes Barre, PA 18711-0800; gerardogiordano@kings.edu

Three years ago, I presented the implementation of class activities and discussions that use money to explain temperature as part of a one-semester, introductory, conceptual physics class. The activities and subsequent conversations attempted to explain temperature as a measure of the average translational kinetic energy per particle, its role in heat flow direction, its lack of dependence on the quantity of a substance, how a thermometer measures it, and why it has a lower limit but no upper limit. Using the Thermal Concept Evaluation created by Shelley Yeo and Marjan Zadnik and published in The Physics Teacher (Vol. 39, November 2001), I present three years' worth of pre-test and post-test scores in general and on select temperature related questions. Additionally, results from temperature-related questions on the final exam as well as FCI data are included to evaluate the effectiveness of the money-related activities.

PST1B04: 9:15-10:00 p.m. Using Seismic Design Specifications to Help Teach Introductory Physics

Poster – Frederick J. Thomas, Math Machines, 10082 Dove Drive, Freeland, MI 48623-8671; fred.thomas@mathmachines.net

Robert Chaney, Sinclair Community College

Richard Tseng, Bowser Morner

Whether in higher-risk areas like San Francisco and Provo or lower-risk Detroit, civil and structural engineers are required to design all major structures to withstand a clearly defined "maximum considered earthquake" (MCE). The primary quantity which defines the MCE is the peak horizontal ground acceleration (PGA) with a 2% probability of occurring within a 50-year period. This poster shows how physics learners can obtain PGA specifications for any on-shore location in the world, and (in the US) detailed spectral information important to resonance considerations. Suggested activities for introductory physics labs or classrooms include calculations of maximum earthquake loading as a direct application of F=ma, calculation and testing of likely resonant frequencies, modeling of earthquake wave refraction based on near-surface soil and rock characteristics, and investigation of the connection between soil density and "soil liquefaction."

*This material is based in part upon work supported by the National Science Foundation's Advanced Technological Education program under Grants No. DUE-0202202 and DUE-1003381, including our recent book, The Physics of Destructive Earthquakes.

PST1B05: 8:30-9:15 p.m. Leading Departmentally Based Change Initiatives: The Science Education Initiative Handbook

Poster – Stephanie Chasteen, University of Colorado Boulder, 247 Regal St., Louisville, CO 80027; stephanie.chasteen@colorado.edu

Warren Code. University of British Columbia

Educational change efforts focused at the department level can be particularly powerful. Positive outcomes, however, are not automatic. This poster will share some of the big lessons-learned from the Science Education Initiatives (SEIs) designed by Carl Wieman, in which postdoctoral fellows were embedded directly within disciplinary departments as catalysts of change. Come see our messages for initiative leaders, departmental faculty, and embedded postdocs and instructors, and take a look at a printed copy of our new free SEI Handbook.

*The Science Education Initiative Handbook is available online for free at https://pressbooks.bccampus.ca/seihandbook/.

PST1B06: 9:15-10:00 p.m. A Decade of Progress Catalyzed by Prioritizing Teaching

Poster – Paul M. Miller, West Virginia University, Department of Physics and Astronomy, Box 6315, Morgantown, WV 26506-6315; paul.miller@mail.wvu.edu

Ten years ago, the West Virginia University Department of Physics and Astronomy hired its first permanent teaching faculty member. This choice began a series of teaching-focused changes within and beyond the department which have improved course delivery, program design, and (especially) secondary teacher preparation. With the involvement of many, we implemented a Learning Assistants program, collected years of longitudinal data, installed two separate updates to the calculus-based physics sequence, and transitioned the Conceptual Physics course curriculum to a custom implementation of Next Gen PET. Most significantly, the initial decision to prioritize teaching helped to secure the hiring of two senior faculty, which brought physics education research to the department and led to successful PhysTEC and WVUteach site proposals. While we still have plenty to work on, we are excited to share the highlights and lessons learned from an eventful 10-year journey.

PST1B07: 8:30-9:15 p.m. Demonstrating the Mechanics of Materials with a Pool Noodle

Poster – Kristi D. Concannon, King's College, 133 N River St., Wilkes Barre, PA 18711; kristiconcannon@kings.edu

A Mechanics of Materials course examines the behavior of structural beams and shafts that experience an applied load. Students learn how the load produces stresses within the system and how the resulting deformation of the member depends on its material properties. At our institution, the Mechanics of Materials class is a sophomore-level course that is required of all pre-engineering students and serves as an elective for physics majors. There is no required lab component. To provide a hands-on, design-focused component to the course, students were tasked with identifying means in which a polyethylene pool noodle can be used to demonstrate fundamental concepts related to the course. This poster will present a sample of the activities devised by the students to illustrate principles such as the elastic modulus, the internal bending moments of a beam and the torsional deformations of a rotating shaft.

PST1B08: 9:15-10:00 p.m. Developing and Sharing Weekly Topical Assessment for Introductory Mechanics

Poster – Byron C. Drury, MIT, 77 Massachusetts Avenue, Cambridge, MA 02139; bdrury@mit.edu

Dave Pritchard, MIT

We have developed a comprehensive set of online topical quizzes for calculus based introductory mechanics courses. The quizzes are designed to be administered weekly or bi-weekly and take thirty minutes to complete. They are composed of questions from research validated assessments supplemented with questions tested on hundreds of students in both MOOCs and on-campus courses. We will make the quizzes available to interested college and high school instructors for use this fall. We present analysis of results from the administration of these quizzes to approximately 250 students across five classes. The online quizzes were administered concurrently with traditional rubric-graded written quizzes. We argue that weekly online assessment presents numerous advantages over traditional written tests. The online quizzes provide more reliable measurement of student ability, timelier feedback to both students and teachers, and already electronic data for education research, as well as reducing time spent grading.

PST1B09: 8:30-9:15 p.m. Energy and Civil Constructions: An Experience with Edifications Technical Course

Poster – Isabelle Priscila Carneiro De Lima, Federal Institute of Bahia/Federal, Rua Barão de Loreto, 65 SALVADOR, Bahia 40231-305 Brazil; isapris@gmail.com

Rodrigo Gomes, Ismália Santos, Federal Institute of Bahia

The goal of this paper is to show experience of undergraduate physics students in the Pedagogic Residency Training project. This experience was developed in high school classrooms of Edifications technical course. The experience consisted of showing the importance of the energy theme for the course, focused in constructions. To this, we developed activities with the STSE approach and made the question: "How much energy ensure my welfare?" To answer this question, the high school students should think about a small project of a house that used as little energy as possible. To do this, they solved real problems about the conscious use of energy, calculated the average energy consumption in residential buildings and decided the forms and sources of energy they could use to make this possible. They could comprehend the connection between physics and their course and how science is inside society.

PST1B10: 9:15-10:00 p.m. Enriching Student Learning Experience in Introductory Courses Using Physclips

Poster – Adriana Predoi-Cross, University of Lethbridge, Department of Physics and Astronomy, Lethbridge, AB T1K 3M4 Canada; adriana.predoicross@gmail.com

Physclips are multimedia modules originally developed at the Department of Physics, University of South Wales, Australia, that can be used in introductory physics courses. They contain short lecturing sections combined with videos of experiments and animations of the variation of relevant physical variables. I will present two different scenarios of using physclips and will discuss how these resources have benefitted my students. Future plans of implementing these resources in undergraduate teaching will also be outlined.

PST1B11: 8:30-9:15 p.m. Ethical Cases in Physics

Poster – Karen A. Williams, East Central University, 1100 E. 14th St., Ada, OK 74820; kwillims@ecok.edu

This poster will illustrate a few ethical cases in physics that I have presented in an ethics workshop and one from a textbook that I introduce to my students in class. It is paramount our students have ethics education and begin thinking about ethics in what they do in their research and career.

PST1B12: 9:15-10:00 p.m. FCI Challenge: Tug-of-War

Poster – Paul R. DeStefano, 18130 SW NIK'S DR, Aloha, OR 97003-4483; paul.destefano-aapt@vfemail.net

Roberto Perez-Franco, Cora Siebert, Ralf Widenhorn Portland State University

The game of Tug-of-War is a convenient scaffold for introducing concepts of Newtonian mechanics. This is because it can be thoroughly analyzed using Newtons laws, while posing interesting challenges for learners. Using a load cell and a Local Positioning System, both the tension force and position of the rope in a Tug-of-War game played by students are recorded. We show that the data from this activity can be used to confront several misconceptions of force identified in the Force Concept Inventory. Additionally, the winner and loosing of the game is typically correlated with a decrease in the tension force. This is consistent with the hypothesis that the losing team is not able to maintain a posture that allows it to exert a maximum force between the players and the ground.

PST1B13: 8:30-9:15 p.m. Hacking Historical Experiments in the Classroom: Brazilian Style

Poster – Thiago Faustino, Universidade Federal da Bahia, Adelaide Guimarães St., Salvador, Bahia 40260080 Brasil; thenear9@gmail.com

Filipe Gomes, Katemari Rosa, Universidade Federal da Bahia

The use of history, sociology, and philosophy of science HSPC in physics teaching has been largely defended in the literature. One way for an HSPC approach is the use of historical experiments in physics. However, what is the role of a historical experiment in this high-tech era? In this presentation, we share the development of a classic experiment, Galileo's inclined plane experiment, with a modern twist and low-cost materials. Our setting was a Brazilian public school, lacking science and computer labs, in an urban low-income neighborhood. As part of a university-school program, undergraduate and high-school students built the experimental apparatus, finding creative ways to reconstruct Galileo's famous experiment, and engaged in discussions around physical phenomena. Our experience indicates the low-tech, low-cost, and historical combination can be an aid for high-quality physics teaching

PST1B14: 9:15-10:00 p.m. How My Students Determined the Fate of the Universe

Poster – Steve Cederbloom, University of Mount Union, Department of Physics and Astronomy, Alliance, OH 44601; cederbse@mountunion.edu

Teaching science courses to non-STEM majors can be frustrating, especially to students who struggle with math. It is difficult in mathematically involved topics (such as cosmology and general relativity) to find problems that these students can actually investigate themselves. Yet having the students take an active role is important in developing scientific literacy – "the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity" (National Academy of Sciences, 1996). To get the students to DO cosmology, a scaffolded method for teaching computational problem solving on Excel was used. The students were able to solve the Friedmann equation, along with several other coupled equations, to find the history of a model universe. Additional problems that might also be accessible are being investigated.

PST1B15: 8:30-9:15 p.m. HTML5 Simulations for College and High School Active-Learning Environments*

Poster – Andrew Duffy, Boston University, Department of Physics, 590 Commonwealth Ave., Boston, MA 02215; aduffy@bu.edu

Manher Jariwal, Emily Allen, Boston University

We have developed HTML5 simulations for use in introductory physics courses at the college and high school levels. Over 200 simulations in physics have been developed to support learning in various settings, including discussion and lab activities. We will discuss how four particular simulations are being used in a variety of active learning environments, including studio classrooms and small discussion-based classes. Images and accompanying curricula for simulations on conservation of energy and momentum, simple harmonic motion, and rotational dynamics will be presented. A link to the collection of resources will be provided.

*Funded by NSF DUE-1712159.

PST1B16: 9:15 -10:00 p.m. Integrating Lecture and Labs in Introductory Physics

Poster – Martin Kamela, Elon University, 2625 CB, 100 Campus Drive, Elon, NC 27244; mkamela@elon.edu

Over the past four years we have experimented with integrating labs, hands-on activities, and coding into the introductory physics sequence. The class meets three times a week for two hours at a time and each section is capped at 24 students. The main goals of the course are (i) to help students transition from novice to more expert-like learners of physics, (ii) to make the physics-reality connection paramount, (iii) to help students develop skills of physical model building and computational analysis, (iv) to improve students' competence in communicating scientific ideas, and (v) to make this entry course into the physics major distinct from the students' high school physics experience. In this poster I present some of the lab activities developed for the course and comment on the initial successes and challenges in revising the introductory physics sequence.

PST1B18: 9:15-10:00 p.m. Stacked Potential/Field Visuals as Conceptual Problem-Solving Tools in Electrostatics

Poster – Richard A. Zajac, Kansas State University, Polytechnic Campus, 2310 Centennial Road, Salina, KS 67401-8196; rzajac@ksu.edu

Examples are presented of combining surface plots of electric potentials with corresponding plots of electric fields into an integrated visual device to emphasize conceptual understanding. This is especially useful in the algebra-based introductory course in which students' mathematical methods are limited, and students' work on numerical problems is not always well connected with the use of traditional conceptual tools (e.g. drawing lines of force). These striking visuals are straightforward to produce with common office software. Combined with online homework, they are found to provide students an intuitive language for problem-solving, and to build a foundation for later visual tools used in circuit analysis.

PST1B19: 8:30-9:15 p.m. Standards-based Grading in Introductory Physics: An Example

Poster– Laura E. McCullough, University of Wisconsin-Stout, 327 12th Ave. W, Menomonie, WI 54751-2434; lauramccphd@gmail.com

Standards-based grading is gaining popularity in the K-12 system, but remains rare in the post-secondary classroom. In this poster I show how I use standards-based grading in my two-semester calculus-based introductory physics classes. SBG can take many forms, and I am providing just one example of how it can work for intro physics. I will share my standards, examples of assessments, as well as how I incorporate writing practice and scientific thinking into the class. I will also show the process I took to get to where I am at now: what I tried and gave up on, what I tried and refined. I find SBG gives students motivation to study, improves accessibility and reduces need for test accommodations, and frees me to focus on the content of physics rather than the administrivia of teaching.

PST1B20: 9:15-10:00 p.m. Student Understanding of the Big Picture in Physics: Use of Scaffolding in Introductory College Physics Classes

Poster – William G. Newton, Texas A&M University-Commerce, Department of Physics and Astronomy, Commerce, TX 75429-3011; William.Newton@tamuc.edu

Students in introductory physics classes often have trouble seeing how specific pieces of content fit into the big picture of physics. They are often unaware of the fact that the equations and concepts they encounter can be categorized, or that in solving many problems they are simply treading the same ground in the physics landscape, just following slightly different trajectories. I will present two strategies that have been implemented in an introductory E&M studio physics class to help students fit the content into the larger context of physics : firstly, the use of different colored flashcards to categorize the content they encounter into laws of physics, definitions, derived quantities, numerical values, and skills, and secondly, the use of a template "map of physics" onto which students place the various elements of a problem and trace out the trajectories taking them from the problem's starting place to it's end point.

PST1B21: 8:30-9:15 p.m. Topical, Randomized Quizzes in Electromagnetism

Poster – Ale;xander J. Shvonski, Massachusetts Institute of Technology, 22 Dearborn St., Medford, MA 02155-4315; shvonski@mit.edu

Michelle Tomasik, Byron Drury, David E. Pritchard, Massachusetts Institute of Technology

We developed five 30-minute topical quizzes in an introductory electromagnetism course (n~150) at MIT, and administered them electronically in class. For each problem on the quiz, students were given a randomized variant from a subset of three variants. We analyzed both the self-consistency of these quizzes and their correlation with other components of the course, including the final exam. We also looked at correlations between "types" of problems on both quizzes and the final. Interestingly, the quizzes exhibited a low score of consistency, as measured by Cronbach's alpha, perhaps reflecting the compartmentalized nature of the material. However, quizzes, as a category, correlated more strongly with the final exam than any other component of the course, including the midterm exam. We argue that frequent quizzes are an effective and superior assessment compared to other assessments in the course. We intend to make these materials available to instructors at other institutions.

Other Poster

PST1C01: 8:30-9:15 p.m. A New Online Resource for Instructors to Choose Demonstrations

Poster – Dawson Thomas Nodurft, Texas A&M University, Department of Physics and Astronomy, 725 San Benito Dr., College Station, TX; 77845-6510 nodurft@physics.tamu.edu

Daniel Melconian, Texas A&M University Department of Physics and Astronomy

In large departments or institutions, lack of communication becomes a significant impediment to success. The nature of education at times leaves instructors preparing and adjusting lectures the night or even hours before their classes. A crucial part of physics instruction are hands-on demonstrations and physics experiments in lecture. A website was developed to assist instructors in choosing the correct demonstrations for their classes as well as ordering them to ensure on time arrival. The effect of this website on the department is analyzed and presented.

PST1C02: 9:15-10:00 p.m. AP Physics Results and their Implications for Diversity in Physics*

Poster – Andrew G. Duffy, Boston University, Department of Physics, 590 Commonwealth Ave., Boston, MA 02215; aduffy@bu.edu

The importance of diversity in the physics community has, in recent years, become widely recognized. The College Board publishes data that breaks down AP results along racial and ethnic lines. An important connection between the previous two sentences is that the demographic information from the College Board, pertaining to the AP Physics exams, indicates that the exact groups that we would like to attract to the physics community are, in general, doing rather poorly on AP Physics. Visualizations of this data will be presented in this poster, in hopes of starting some useful discussions about what to do about the issue.

*Funded by NSF grant DRL 1720914.

PST1C03: 8:30-9:15 p.m. Early Career Research Training Course

Poster – Nina Abramzon, California State Polytechnic University Pomona, 3801 W Temple Ave., Pomona, CA 91768-4031; nabramzon@cpp.edu

Paul Beardsley, Winny Dong, Everardo Barraza, California State Polytechnic University Pomona

Rebecca Eddy Cobblestone, Applied Research & Evaluation, Inc.

Although undergraduate research is a proven high impact practice for increasing retention and graduation, lower division students do not have the opportunity to engage in these activities. Their lack of research training makes it unlikely for faculty members to accept early career students into research assistantship positions. We report on design and implementation of an Early Research Training Course taught by interdisciplinary teams of STEM faculty. The goal of the course is to introduce students to a range of authentic research techniques from a broad array of disciplines. Students develop and refine research skills, design an experiment, test an hypothesis, collect data, preform error and statistical analysis write up research results, and communicate findings. Pre and Post surveys are conducted, results to be shared include improvement of student's perception and skill repertoire in conducting independent research, student persistence in STEM, and STEM awareness and STEM identity.

PST1C04: 9:15-10:00 p.m. Incorporating the Engineering Design Process into First-Year HS Physics Courses

Poster – Debbie S. Andres, Paramus High School, 99 East Century Road, Paramus, NJ 07652; dandres@paramusschools.org

The Next Generation Science Standards (NGSS) call for teachers to incorporate the engineering design process into the instruction and learning of their students. This means teachers must help students develop skills such as: how to define engineering problems, design a solution, and optimize a solution. How can we incorporate engineering instruction more naturally into a high school physics classroom? Using my experience in engineering education and training in physics education, I developed multiple engineering design activities for use with my first year physics students. The activities are not only for the application of physics concepts but also to help students develop physics concepts through the engineering design process. Students are able to see how engineers rely on their science background to not only design solutions but also identify problems. I will be sharing my activities that span across various NGSS topics as well as student feedback on their experiences.

PST1C05: 8:30-9:15 p.m. Machine Learning: Using Tensorflow in a First Year Seminar

Poster – Stefan A. Jeglinski, UNC Chapel Hill, 130 E Cameron Ave., Chapel Hill, NC 27599; jeglin@physics.unc.edu

A First Year Seminar in Mechatronics for students of any intended major (first year only) has been developed. The curriculum is wide ranging, with the intent of introducing students to material they must master for STEM courses (e.g. numeracy, basic mechanics, data manipulation) and also topics that are relevant for future speculative technologies, such as machine learning and quantum computing. I will describe my experience teaching Tensorflow to students with a broad range of incoming skill sets, and my attempts to tie machine learning to neural networks and quantum (annealing) computing.

PST1C06: 9:15-10:00 p.m. Student-initiated Research in a Bachelor's-only Physics and Astronomy Department

Poster – Matthew R. Semak, University of Northern Colorado, Physics, 0232G Ross Hall, Greeley, CO 80639; dr.matthew.semak@gmail.com

Cynthia Galovich, University of Northern Colorado

At the University of Northern Colorado, undergraduate research has been a required component of the physics degree for over 30 years. Students work on faculty research projects or develop their own research. However, some are wary of approaching this challenge given their limited experience. Moreover, without the extensive research facilities, graduate student mentors, and other important resources associated with graduate institutions, can an undergraduate program provide a meaningful research experience for its students? In fact, some of our students independently develop projects, taking ownership of the process. Faculty still advise them, yet, their self-direction and vision is impressive. Here we highlight two such projects. One is theoretical in nature and involves the construction of an equation of state for an ideal gas using a Monte Carlo simulation. The other project is experimental/computational and concerns the development of a random number generator using an electric circuit producing chaotic behavior.

Physics Education Research

PST1D01: 8:30-9:15 p.m. Developing Robust Clicker Question Sequences for the Addition of Angular Momentum in Quantum Mechanics

Poster – Paul D. Justice, University of Pittsburgh, 3941 O'Hara St., Pittsburgh, PA 15260; paj42@pitt.edu

Emily Marshman, Chandralekha Singh, University of Pittsburgh

Engaging students with well-designed clicker questions is one of the commonly used research-based instructional strategies in physics courses partly because it has a relatively low barrier to implementation. Moreover, validated robust sequences of clicker questions are likely to provide better scaffolding support and guidance to help students build a good knowledge structure of physics than an individual clicker question on a particular topic. Here we discuss the development, validation, and in-class implementation of a clicker question sequence (CQS) for helping advanced undergraduate students learn about addition of angular momentum, which takes advantage of the learning goals and inquiry-based guided learning sequences in a previously validated Quantum Interactive Learning Tutorial (QuILT). The in-class evaluation of the CQS using peer instruction is discussed by comparing upper-level undergraduate students' performance after engaging with the CQS with previous published data from the QuILT pertaining to these concepts.

PST1D02: 9:15-10:00 p.m. Epistemological Discussions on Characteristics of Scientists Help At-Risk Students

Poster – Bradley K. McCoy, Azusa Pacific University, 901 E Alosta Ave., Azusa, CA 91702; bmccoy@apu.edu

In this quasi-experimental study, we included short daily discussions of characteristics of scientists in introductory courses and measured changes in students' epistemologies using EBAPS. In sections that did not include the discussions on characteristics of scientists, students with pre-scores in the first quartile showed large decreases in post-scores on the source of ability to learn axis. However, in sections that did include the discussions on characteristics of scientists, scores of students in the first quartile increased on the source of ability to learn axis. We conclude that this population of at-risk students would benefit from more frequent discussions of characteristics that lead to success in science.

PST1D03: 8:30-9:15 p.m. Examining the Effectiveness of Two Methods to Improve Student Transfer from Online Problem Solving Tutorials

Poster – Kyle Whitcomb, University of Pittsburgh, 3941 O'Hara St., Pittsburgh, PA 15260; kmw136@pitt.edu

Zhongzhou Chen, Matthew W. Guthrie, University of Central Florida

Chandralekha Singh, University of Pittsburgh

In an earlier study involving a sequence of three online learning modules, we found that college students lack the ability to transfer their learning from an online problem-solving tutorial to solving similar new problems. In the current study, we examined the effectiveness of two methods attempting to improve students' ability to transfer. First, we added an "on-ramp" module focusing on developing proficiency of basic skills that are important to solving the types of problems they encounter in the tutorial. Second, we added a new module containing a new transfer problem before the last module, for which half of the students were asked to explicitly compare and contrast the new problem with a previous problem, and the other half were given a tutorial on the new problem. We found that the on-ramp module significantly improved students' performance on their subsequent transfer attempts, while this year's students scored lower than last year's students on common problems in a preceding midterm exam. On the other hand, neither the compare-contrast condition nor the new tutorial condition had a significant impact on improving students' performance on the subsequent transfer problem, nor were the performance between the two groups significantly different. We did find that students' performance on the new problem was significantly lower than expected, which may suggest that those new problems were not as similar to the existing problems as perceived by experts. The study demonstrated that online learning modules can be a powerful and flexible tool that allows instructors and researchers to easily examine the effectiveness of new pedagogical design and instructional materials, accelerating the improvement of physics and STEM education.

PST1D04: 9:15-10:00 p.m. Exploring One Aspect of Pedagogical Content Knowledge of Physics Instructors and Teaching Assistants Using the Force Concept Inventory*

Poster – Alexandru Maries, 345 Clifton Court, Cincinnati, OH 45220; mariesau@ucmail.uc.edu

Chandralekha Singh, University of Pittsburgh

The Force Concept Inventory (FCI) has been widely used to assess student understanding of introductory mechanics concepts by a variety of educators and physics education researchers. One reason for this extensive use is that many of the items on the FCI have strong distractor choices that correspond to students' alternate conceptions in mechanics. Instruction is unlikely to be effective if instructors do not know the common alternate conceptions of introductory physics students and explicitly take into account students' initial knowledge state in their instructional design. Here, we discuss research involving the FCI to evaluate one aspect of the pedagogical content knowledge of both instructors and teaching assistants (TAs): knowledge of introductory student difficulties related to mechanics as they are revealed by the FCI. We used the FCI to design a task for instructors and TAs that would provide information about their knowledge of common student difficulties and used FCI pre-test and post-test data from a large population (~900) of introductory physics students to assess this aspect of pedagogical content knowledge of physics instructors and TAs. We find that while both physics instructors and TAs, on average, performed better than random guessing at identifying introductory students' difficulties with FCI content, they did not identify many common difficulties that introductory physics students have, even after traditional instruction. Moreover, the ability to correctly identify students' difficulties was not correlated with the teaching experience of the physics instructors or the background of the TAs.

PST1D05: 8:30-9:15 p.m. Exploring One Aspect of Pedagogical Content Knowledge of Teaching Assistants Using the Test of Understanding Graphs in Kinematics*

Poster – Alexandru Maries, 345 Clifton Court, Cincinnati, OH 45221; mariesau@ucmail.uc.edu

Chandralekha Singh, University of Pittsburgh

The Test of Understanding Graphs in Kinematics (TUG-K) is a multiple choice test developed by Beichner in 1994 to assess students' understanding of kinematics graphs. Many of the items on the TUG-K have strong distractor choices which correspond to students' common difficulties with kinematics graphs. We evaluate one aspect of the pedagogical content knowledge of first year physics graduate students enrolled in a teaching assistant (TA) training course related to topics covered in the TUG-K. We used the TUG-K to design a task for TAs that would provide information about their knowledge of common student difficulties and used the TA data and the data from Beichner's original paper for introductory physics students (which was collected from over 500 college and high-school students) to assess this aspect of the pedagogical content knowledge (PCK) of the graduate students, i.e., knowledge of student difficulties related to kinematics graphs as they are revealed by the TUG-K. We find that, although the graduate students, on average, performed better than random guessing at identifying introductory student difficulties on the TUG-K, they did not identify many common difficulties that introductory students have with graphs in kinematics. In addition, we find that the ability of graduate students to identify the difficulties of introductory students is context dependent and that discussions among the graduate students improved their understanding of student difficulties related to kinematics graphs. Moreover, we find that the ability of American graduate students in identifying common student difficulties is comparable with that of foreign graduate students.

*Work supported by the National Science Foundation

PST1D06: 9:15-10:00 p.m. Feedback Requested: Understanding and Humanizing the Journal Review Process

Poster – Kathleen A. Harper, The Ohio State University, 244 Hitchcock Hall, 2070 Neil Ave., Columbus, OH 43210; harper.217@osu.edu

Charles R. Henderson, Western Michigan University

Amy D. Robertson, Seattle Pacific University

Gary D. White, The George Washington University

Michael C. Wittmann, The University of Maine

Informal conversations in the Physics Education Research (PER) Community raised concerns that sometimes the journal review process might be unnecessarily harsh. This caused the authors of this poster to seek feedback from the larger PER community via a survey. Responses to the survey confirmed that many authors have received reviews that could be described as insulting or dehumanizing. The information provided by the respondents led us to consider the role of reviews in the publication process specifically and in the research community more broadly. We are calling upon the PER community to carefully consider the balance between the role of ensuring that high quality work be published and the role of providing constructive feedback to authors to help them attain that high quality. To that end, we have drafted a set of review writing recommendations. In this poster, we share this draft and ask for your feedback.

PST1D07: 8:30-9:15 p.m. Physics Reading Strategy Exploration (PRSE) at Spelman Colege

Poster – Christopher A. Oakley, Spelman College, 350 Spelman Ln SW, Atlanta, GA 30314-4395; coakley@spelman.edu

Processing and evaluating written material is a critical skill to develop for students that plan to earn an advanced degree or perform in a technical position. This research addresses the following questions: a) Do experts and students employ specific strategies when reading refereed journal articles? b) What courses/activities, if any, relate to changes in student reading strategy? Spelman students in the introductory sequence and a multi-year reading seminar provided eye gaze data taken via a monitor mounted eye-tracker. Eye-tracker data identifies Areas of Interest (AOIs) and establishes, chronologically, how the paper is viewed. Eye-tracker data alone is not adequate to draw inferences about student understanding. We provide a survey assignment that was created to provide data to corroborate eye gaze pattern information as well as investigate general content retained from the paper. The data are presented to begin the process of identifying reading habits employed by participants.

PST1D08: 9:15-10:00 p.m. Physics Reading Strategy Exploration (PRSE) for Journal Articles and Physics Texts

Poster – Christopher A. Oakley, Spelman College, 350 Spelman Way, Atlanta, GA 30314; coakley@spelman.edu

The ability to process and evaluate written material is a critical skill to develop for students that plan to earn an advanced degree or perform in a technical position. Physics texts often employ many different representations (graphs, diagrams, words, or equations) to explain the content of the text. An eye-tracker follows the gaze of student participants. The participants have read a short refereed journal article or chapter from a physics text. The duration of a gaze allows the identification of Areas of Interest (AoIs). The sequence of eye motion allows us to infer how the participant combines different representations within the text. Eye-tracker data is compared to notes taken by the students as well as a post-reading survey.

PST1D09: 8:30-9:15 p.m. Prevalence of Impetus-Force-Like Drawings Among Contemporary University Physics Students*

Poster – Amy D. Robertson, Seattle Pacific University, 3307 Third Ave W, Suite 307, Seattle, WA 98119-1997; robertsona2@spu.edu

Paula R. L. Heron, Lisa M. Goodhew, Rachel E. Scherr, University of Washington

Decades ago, one of the most salient and commonly reported force ideas in the literature was the notion of an “impetus force” – the “belief that there is a force inside a moving object that keeps it going and causes it to have some speed” (Clement, 1983). Such beliefs were reported to be extremely widespread. For example, Clement (1982) reported that nearly 75% of the students in his sample drew an upward arrow, indicative of a “throw” force, in the direction of motion of a tossed object after it has left a person’s hand. In a recent study, we asked the same questions as in earlier studies and found that the prevalence of impetus-force-like ideas both varies substantially across samples and is consistently lower than what is reported in earlier work. In this poster, we will share our data and propose hypotheses about why this might be the case, including the influence of research-based instructional strategies. Please come and suggest your own interpretations!

*This work was supported in part by NSF Grant No. 1608510.

PST1D11: 8:30-9:15 p.m. Creation of a Pre-test for an Upper-division Physics Laboratory Assessment

Poster – Laura Ríos, CU Boulder/JILA, 2000 Colorado Ave., Department of Physics, University of Colorado, Boulder Boulder, CO 80309-0440; Laura.Rios@colorado.edu

Benjamin Pollard, Heather J. Lewandowski, CU Boulder/JILA

Physics laboratory courses are unique learning environments, and assessments that track their impact and improvement are few, especially at the upper-division level. To assess laboratory courses in a way that is sensitive to their unique affordances and limitations, our team is developing assessments for model-based reasoning (MBR) in the context of analog electronics and optics. Our team is also assiduously cataloging the assessment development process to increase the transparency of the process and confidence in the final product. Here, we describe one portion of the creation of a pretest for MBR: think-aloud activities focused on a prototypical pendulum lab. We discuss some important outcomes, including describing the problem space that students explore, and ways that the pendulum activity is an appropriate pre-test for this assessment.

PST1D14: 9:15-10:00 p.m. Equity in Introductory Physics Students’ Attitudinal Development

Poster – Jayson M. Nissen, California State University - Chico, 659 SW Jefferson Ave., Apt 2 Corvallis, OR 97333; jayson.nissen@gmail.com

Ben Van Dusen, California State University - Chico

We explored the intersectional nature of race/racism and gender/sexism in broad scale inequities in physics student attitudes and how lecture-based and collaborative learning activities moderated those inequities. Grounding the research in a framework of critical quantitative intersectionality allowed us to investigate the role of power and differences in power between lecture-based and collaborative-based instruction in these inequities. The analyses used hierarchical linear models to examine student’s attitudes as measured by the Colorado Learning Attitudes about Science Survey. The data came from the Learning About STEM Student Outcomes’ (LASSO) national database. To create a more nuanced picture of student attitudinal development and problematize how physics education research investigates equity, we interpreted the models using competing operationalizations of equity. We will discuss the implications of our findings and identify areas for future research using critical quantitative perspectives in physics education research.

PST1D15: 8:30-9:15 p.m. How Do Introductory Physics and Mathematics Courses Predict Engineering Students’ Performance in Subsequent Engineering Courses?

Poster – Kyle Whitcomb, University of Pittsburgh, 3941 O’Hara St, Pittsburgh, PA 15260; kmw136@pitt.edu

Z. Yasemin Kalender,Timothy J. Nokes-Malach, Christian D. Schunn, Chandralekha Singh, University of Pittsburgh

In collegiate engineering curricula in the US, physics and mathematics are treated as foundational with all students taking physics and mathematics in both semesters of freshman year and additional mathematics courses in later semesters. Using academic data from the cohorts of students in introductory physics since 2009, we investigated the correlation between the performance of undergraduate engineering majors in introductory physics and mathematics courses and their performance in subsequent engineering courses. We find an interesting relationship between the best predictors of performance, advanced mathematics courses, and the physics sequence. We thank the National Science Foundation for support.

PST1D16: 9:15-10:00 p.m. Improving an Innovative Curriculum to Teach Circuits Using Design Research

Poster – Jan-Philipp Burde, Goethe-University Frankfurt, Max-von-Laue-Str.1, Frankfurt Am Main, 60438 Germany; burde@physik.uni-frankfurt.de

Thomas Wilhelm. Goethe-University Frankfurt

Effective reasoning about electric circuits requires a solid understanding of voltage and potential. However, most students fail to correctly analyze electric circuits as they tend to reason exclusively with current and resistance. The key idea of a curriculum developed in Frankfurt/Germany is to introduce voltage even before the electric current by comparing it with air pressure differences. Voltage as an “electric pressure” difference can then be understood as the causal agent of current propulsion just as air pressure differences are the cause of air flow (e.g. bicycle tires). In line with the cyclical character of design-based research, the original curriculum was further refined using a variety of research methods and working closely with practitioners. The poster presented illustrates the key ideas of the refined curriculum and provides insight into the most important design decisions behind it.

PST1D17: 8:30-9:15 p.m. Investigating Attitudes and Performance of Students in Introductory Physics Courses: Racial and Ethnic Minorities

Poster – Z. Yasemin Kalender, University of Pittsburgh, 2000 Wendover Apt 3, Pittsburgh, PA 15217; zyk2@pitt.edu

Emily Marshman, Community College of Allegheny

Timothy J. Nokes-Malac, Christian D. Schunn, Chandralekha Singh, University of Pittsburgh

Despite some efforts to encourage students from underrepresented groups to pursue college study (especially in the STEM disciplines), the percentage of minority students majoring in physics remains low. Prior research has focused on the relationships between student performance, motivation, and retention in STEM disciplines. However, there is relatively little known about the attitudes of students from underrepresented racial or ethnic groups enrolled in physics courses. We performed a longitudinal analysis of students in introductory physics courses by administering pre and post attitude surveys which assessed, e.g., their self-efficacy, grit, fascination with physics, and theory of intelligence. Pre and post conceptual tests were also administered to the students. We examined the attitudes and performance outcomes of ethnic minorities in introductory physics courses. Findings will be discussed.

PST1D18: 9:15-10:00 p.m. Large Gender Differences in Physics Self-efficacy at Equal Performance Levels: A Warning Sign?

Poster – Z. Yasemin Kalender, University of Pittsburgh, 2000 Wendover St,. Apt 3. Pittsburgh, PA 15217; zyk2@pitt.edu

Emily Marshman, Community College of Allegheny

Timothy J. Nokes-Malach, Christian D. Schunn, Chandralekha Singh, University of Pittsburgh

Self-efficacy, or the belief in one's capability to succeed in a particular task, course, or subject area, has been shown to be strongly correlated with students' learning outcomes. Previous studies have shown that female students have lower self-efficacy than males in physics courses. However, few studies have focused on self-efficacy gender differences among equal performance levels. Differences in self-efficacy for similarly performing males and females can have detrimental short-term and long-term effects. We report on the self-efficacy of female and male students who perform similarly on standardized physics conceptual tests and who received the same course letter grade in physics. The findings will be discussed in detail. We thank the National Science Foundation for support.

PST1D22: 8:30-9:15 p.m. Students' Conceptual Resources for Understanding the Principle of Superposition*

Poster– Lauren C. Bauman, Quest University, Canada, 3200 University Blvd., Squamish, BC V8B 0N8 Canada; lauren.bauman@questu.ca

Lisa M. Goodhew, University of Washington

Amy D. Robertson, Seattle Pacific University

Superposition is central to understanding numerous physical phenomena, from pulses on a string to electric fields. In this talk, we report the preliminary results of our investigation into introductory undergraduate students' conceptual resources for understanding the principle of superposition. We analyzed 368 written responses to a conceptual question that explored applications and attributes of superposition. We identified four recurring resources related to superposition: (1) additiveness; (2) separability; (3) quantifiability; and (4) localization. Our objective is to support educators by drawing attention to these resources and by suggesting how they can be taken up alongside students to enhance instruction.

*This work is supported in part by grant NSF 1608510.

PST1D23: 9:15-10:00 p.m. A Longitudinal Exploration of Students' Beliefs about Experimental Physics*

Poster – Rachel Henderson, Michigan State University, 567 Wilson Rd., East Lansing, MI 48824; hende473@msu.edu

Kelsey Funkhouser, Marcos D. Caballero, Michigan State University

Michigan State University physics department has recently transformed its algebra-based, introductory physics laboratory curriculum. This transformed, two-course sequence, Design, Analysis, Tools, and Apprenticeship (DATA) Lab, emphasizes the development of experimental skills and laboratory practices and provides students with an authentic physics laboratory experience. In this presentation, we will discuss the longitudinal results on how students perceive experimental physics through the two course sequence: mechanics (DL1) and electricity and magnetism (DL2). In both courses, data was collected pre- and post-instruction via the Colorado Learning Attitudes and Science Survey for Experimental Physics (E-CLASS). Students in the traditional-to-traditional course sequence demonstrated an overall decline in their expert-like responses. Students enrolled in the transformed-to-transformed course sequence showed higher yet stable expert-like responses toward experimental physics. Students in the traditional-to-transformed sequence experienced a significant increase in their beliefs toward experimental physics; however, it only occurred during the second half of the two-course sequence.

*This work was supported by the Howard Hughes Medical Institute.

PST1D24: 8:30-9:15 p.m. A Methodology for Developing and Validating Equivalent Short Concept Inventories

Poster – Yang Xiao, School of Physics and Telecommunication Engineering, South China Normal University, Guangzhou, Guangdong 510006 China; 20092305002@m.scnu.edu.cn*

Kathleen Koenig, Physics Department, University of Cincinnati

Jing Han, Lei Bao, Department of Physics, The Ohio State University

While many validated concept inventories (CIs) have been developed to assess student learning, the use of these CIs in teaching practices is less popular due to the considerable class time needed in their implementation. In order to streamline the process to convert existing CIs into short versions that retain their statistical power for student assessment, we have explored possible standard methodologies for developing and validating short CIs from established CIs currently used in physics education. This poster shows a mixed methodology for developing and validating equivalent short CIs which combines classical test theory with item response theory. Several successful cases will be discussed in detail, which include the Force Concept Inventory, the Conceptual Survey on Electricity and Magnetism, and the Brief Electricity and Magnetism Assessment for Electricity and Magnetism.

*Sponsored by Dr. Lei Bao.

PST1D25: 9:15-10:00 p.m. Assessing Motivations to Engage in Responsible Conduct of Research

Poster – ALEXANDER N. Coon, Kansas State, 1856 Anderson Ave. apt. 13, Manhattan, KS 66502; alexandercoon@ksu.edu

Scott Tanona, Jonathan Herington, James Laverty, Kansas State

There have been many calls to broaden and deepen scientist's willingness to engage in the Responsible Conduct of Research (RCR). In this context we define RCR as scientific practices consistent with established rules and professional norms for conducting research ethically. Our goal is to identify scientists' motivation to engage in RCR before and after an intervention. To measure this, we created the RCR-Motivations survey (RCR-M). This survey has two goals: 1) to identify sources of motivation to engage in RCR, and 2) to identify attitudes that could affect engagement. Using this survey we can identify the degree of success of the intervention and if it should be recommended to more researchers and institutions.

PST1D26: 8:30-9:15 p.m. Building Student Networks through CUWiP*

Poster – Eric T. Brewe, Drexel University, 3141 Chestnut St., Philadelphia, PA 19104-2816; eric.brewe@drexel.edu

Zahra Hazar, Florida International University

Renee-Michelle Goertzen, American Physical Society

Theodore Hodapp, American Physical Society

The American Physical Society Conferences for Undergraduate Women in Physics (CUWiP) are a distributed set of simultaneous conferences that are designed to promote and support women in physics. Between 2014 and 2018, over 5800 women have participated in the conferences at 47 sites. One of the stated goals of the conferences are to encourage participants networking with their peers. As part of the evaluation of these conferences, we have given pre and post conference surveys to participants. The surveys included a question about participants' networks. The evidence is clear: all conference sites promote the formation of participant networks. However, some sites have much greater growth in networks. We employ social network analysis to better characterize the growth of the networks, as well as understanding characteristics of conference sites in terms of size, allocation of time, and structure.

*These analyses supported in part by NSF grants PHY-1346627 and PHY-1622510

PST1D27: 9:15-10:00 p.m. Comparing Student Learning Behavior Under Mastery-Based vs. Traditional Online Instruction

Poster – Matthew W. Guthrie, University of Central Florida, 4111 Libra Drive, Orlando, FL 32816-2385; matthew.guthrie@ucf.edu

Zhongzhou Chen, University of Central Florida

Mastery-based online (MBO) learning has been the focus of recent studies aimed at improving the effectiveness of online physics education. While traditional instruction, practice, and assessments are organized separately in larger units, MBO learning integrates these elements into learning module sequences, enabling students to proceed based on individual mastery level. MBO homework has been shown to improve learning outcomes while generating more interpretable and informative learning data. However, MBO systems may lead students to focus on passing assessments rather than learning. To compare student learning and behavior under MBO and traditional systems, we created two forms of modules using each design principle for the same introductory physics level content. Two module sequences were assigned as homework to classes of approximately 250 students, and the two designs were switched between the classes after the first unit. This poster will detail what we learned by analyzing student interaction throughout the two conditions.

PST1D28: 8:30-9:15 p.m. Developing Resources-oriented Instructional Materials for Introductory Physics

Poster – Lisa M. Goodhew, University of Washington - Seattle, 3910 15th Ave. NE, Seattle, WA 98195; goodhewl@uw.edu

Amy D. Robertson, Seattle Pacific University

Paula R. L. Heron, University of Washington - Seattle

Rachel E. Scherr, University of Washington - Bothell

In this poster, we describe preliminary instructional materials that elicit and build upon some of these common conceptual resources for mechanical wave propagation. Our approach contrasts with that of most research-based instructional materials in physics, which are informed by investigations of students' common misunderstandings, misconceptions, or difficulties – that is, ways in which student ideas are inconsistent with canonical understandings. In our work, we have identified common student resources for understanding physics – ways in which student ideas are consistent with canonical understandings. We describe design elements of instructional materials intended to elicit and refine some of these common conceptual resources. We discuss preliminary use of these materials with small groups of introductory physics students.

PST1D29: 9:15-10:00 p.m. Expectations for Vectors in Curvilinear Coordinates in Upper-Division Physics

Poster – Brian D. Farlow, North Dakota State University, 1211 Albrecht Blvd., Fargo, ND 58108; brian.farlow@ndsu.edu

Chaelee Dalton, Pomona College

Ruby Kalra, University of California Los Angeles

Warren M. Christensen

Our broad research goal is to develop research based instructional materials to help students more effectively translate across the math-physics interface in the middle- and upper-divisions in the context of some vector concepts in various spatial coordinate systems. A portion of that effort is to define the associated instructional gap between math and physics curricula. Thus, we began a study to analyze both the curricula and student understanding of that curricula in both calculus and upper-division physics courses. Previous analysis of popular calculus textbooks found that approximately 95% of their content is based on Cartesian coordinates with much of the remaining 5% being curvilinear content presented at a surface level (see Dalton et al). Analysis of common upper-division physics textbooks reveals different expectations and directions for the application of vectors in curvilinear coordinates. We highlight these differences and how they will inform future curriculum development.

PST1D30: 8:30-9:15 p.m. Introductory Physics I Lab Practical Exam Development*

Poster – Steven F. Wolf, East Carolina University, C-209 Howell Science Building, East 10th Street, Greenville, NC 27858-4353; wolfs15@ecu.edu

Feng Li, Annalisa M. Smith-Joyner Mark W. Sprague, Joi P. Walker, East Carolina University

This study reports the development and validation of an instrument to assess science practices in an introductory physics laboratory. The instrument, called Investigation Design, Explanation, and Argument about Core Ideas Assessment (IDEA), asks students to design and conduct an investigation, perform data analysis and write an argument. The physics IDEA instrument was validated with (1) advanced physics undergraduate students, (2) physics graduate students and faculty, and (3) undergraduate students in introductory physics laboratory courses. This study establishes construct validity in that the instrument measures targeted science practices. Face validity was established by administering the practical in 20 laboratory sections in the course of one week. We discuss results from implementation over a 1 year period, and implications for our lab curricula. This is part of a NSF-funded study into how science practices transfer between the scientific disciplines.

PST1D31: 9:15-10:00 p.m. Investigation on How Students do their Homework and Knowledge Retention

Poster – Justin Lee, University of the Pacific, PO Box 7097, Rancho Santa Fe, CA 92067; jhlinrsf@gmail.com

Binod Nainabasti, University of the Pacific

Yuehai Yang, Oregon Institute of Technology

The primary goal of this study was to investigate the ways students do their homework problems and how their ways of doing homework problems affect their performance in the class. This study was conducted on homework and exam problems assigned in introductory physics classes at two different academic institutions, University of the Pacific and Oregon Institute of Technology. We characterize students' effort on doing homework in terms of consistencies of force diagrams with corresponding mathematical representations used in solving physics problems. We checked the connection between pictorial diagrams with equivalent mathematical equations and how these play a role in their knowledge retention. Preliminary findings indicated that students who were more consistent in doing homework problems could retain their knowledge and apply them better when solving similar problems.

PST1D32: 8:30-9:15 p.m. The Effect of Explicit Instruction on Scientific Reasoning Skills

Poster – Tyler A. Garcia, Cal Poly Pomona, 3081 W Temple Ave., Pomona, CA 91768; tagarcia@cpp.edu

Homeyra Sadaghiani, Cal Poly Pomona

Scientific reasoning is an important skill that defines the development of claims and explanations from observed evidence. However, these skills are not often explicitly taught in schools and no significant gains have been reported over a period of a single college lecture course. Over the past few years, we are investigating the impact of more explicit instruction and practices in inquiry-based physics course designed for non-STEM majors on increasing scientific reasoning ability. We have collected pre- and post-test data using Lawson's Classroom Test of Scientific Reasoning (LCTSR) to gauge the student's gain. We will share examples of explicit interventions and report on our findings.

PST1D33: 9:15-10:00 p.m. The Enactment of Content Knowledge for Teaching in Instructional Artifacts

Poster – Robert C. Zisk, Rutgers University, 10 Seminary Pl., New Brunswick, NJ 08901; robert.zisk@gse.rutgers.edu

Eugenia Etkina, Rutgers University

Content Knowledge for Teaching (CKT; Ball, Thames, & Phelps, 2008) describes the knowledge that teachers have for teaching a particular subject. As such, there should be a relationship between teachers' CKT and their classroom practice. In this poster, we describe two high school teachers' content knowledge for teaching energy (CKT-E) and how that knowledge is reflected in the assignments and assessments they develop for energy instruction. Specifically, we focus on their knowledge for teaching the concepts of work and systems. Through this analysis, we provide a framework for measuring the enactment of knowledge for teaching through the analysis of classroom artifacts.

PST1D34: 8:30-9:15 p.m. The Moderation of Domain Specific Self-Efficacy by Gender

Poster – Rachel Henderson, Michigan State University, 567 Wilson Rd., East Lansing, MI 48824; hende473@msu.edu

John Stewart, West Virginia University

A student's academic self-efficacy is expected to depend on academic domain (math, physics, chemistry). Many studies have reported differences in self-efficacy by gender. The self-efficacy of students in introductory calculus and physics classes was measured with a modified version of the self-efficacy subscale of the Motivated Strategies for Learning Questionnaire. Students demonstrated three tiers of self-efficacy: toward their current math or physics class, toward other math and physics classes, and toward their intended profession. There were no differences between men and women in any domain except in their current math or science class with women reporting lower self-efficacy. This difference was evident very early in the class before the students had received significant course feedback. Self-efficacy evolved within the class and was influenced by performance feedback (test grades); however, this process was not moderated by gender. Both men and women processed course feedback into their self-efficacy in the same way.

PST1D36: 8:30-9:15 p.m. The Relation of Personality, Self-Efficacy, and Achievement in Physics

Poster – Dona S. Hewagallage, West Virginia Unversity, 135 Willey Street, Morgantown, WV 26506; dhh0001@mix.wvu.edu

John Stewart, West Virginia University

This research compares the personality facets of 1911 students in an introductory physics class taken primarily by future engineers and physical scientists using the Big Five Inventory (BFI). The relation of personality to four measures of academic achievement were compared: high school GPA (HSGPA), ACT/SAT mathematics score, physics test average, and physics course grade. Personality explained more variance in college achievement measures than in high school measures. The conscientiousness facet was the strongest predictor of achievement for HSGPA, test average, and grade, but not for ACT/SAT score. A secondary analysis was carried out to investigate whether self-efficacy mediated the relation of personality facets to academic achievement. Two measures of self-efficacy were compared, self-efficacy in physics class and general STEM self-efficacy. Self-efficacy was a significant mediator only for the conscientiousness facet. These results were similar for men and women.

PST1D37: 9:15-10:00 p.m. Tracking Students' Learning Behavior Through an Online Learning Module Sequence

Poster – Geoffrey Garrido, University of Central Florida, 4111 Libra Drive, Orlando, FL 32816; geoff.garrido@knights.ucf.edu

Zhongzhou Chen, Matt Guthrie, University of Central Florida

This study investigates changes in students' learning behavior as they proceed through a sequence of 10 mastery-based online learning modules in order. In an earlier study, we divided students' interaction patterns into multiple categories via a clustering algorithm on the time-on-task information. In this study, we use the same categories to sort students' interaction patterns into one of 28 states. Those states are arranged in an order that reflects the amount of learning effort for each module. Students' interactions can be visualized in a sequence of parallel coordinate graphs, and the most common pathways can be identified through a hierarchical clustering algorithm. This poster showcases our findings: after dividing the student population into three cohorts based on total course credit, a challenge in module 7 caused most of the bottom cohort to significantly lower their learning effort, while the top cohort kept the same high level of learning effort.

PST1D38: 8:30-9:15 p.m. Using Machine Learning to Understand Physics Graduate School Admissions

Poster – Nicholas T. Young, Michigan State University, 567 Wilson Road, East Lansing, MI 48824; youngn18@msu.edu

Marcos D. Caballero, Michigan State University, University of Oslo

Among all of the first-year graduate students enrolled in doctoral-granting physics departments, the percentage of women and underrepresented minorities has remained unchanged for the past 20 years. The current graduate program admissions process can create challenges for achieving diversity goals in physics. In this presentation, we will investigate how the various aspects of a prospective student's application to a physics doctoral program affect the likelihood the applicant will be admitted. Admissions data was collected from a large, Midwestern public research university that has a decentralized admissions process and included applicants' undergraduate GPAs and institutions, GRE and physics GRE scores, and demographic information such as gender and race/ethnicity. Supervised machine learning algorithms were used to create models that predict who was admitted into the PhD program. Here, we will present the results of this analysis as well as compare models between the various subdisciplines of physics represented in this department.

PST1D39: 9:15-10:00 p.m. Using Peer Instruction To Elicit and Remediate Student Nonnormative Ideas of Induced Electromotive Force

Poster – Ping Zhang, Department of Physics, Beijing Normal University No. 19, Xinjiekouwai Street Beijing, 100875 P. R. China; zhangping@bnu.edu.cn

Lin Ding, Department of Teaching and Learning, The Ohio State University

One important benefit of peer instruction lies in the opportunities that instructors create for students to articulate and evaluate their thoughts about learned physics concepts, thoughts that otherwise are likely to be hidden, nonnormative, and remain unremedied. In this study, we implemented peer instruction in a calculus-based introductory electricity and magnetism course taught at a large Chinese research university. We recorded students' dialogues during peer instruction to explicate their ideas about induced electromotive force (EMF). Drawing on these ideas, we developed and administered a diagnostic concept test on EMF to a class of 130 students. Results reveal a number of interesting and prevalent naïve views about this topic. We also took advantage of peer instruction to help students engage in explanation and reasoning so as to rectify their nonnormative ideas.

PST1D41: 9:15-10:00 p.m. What Group Exam Performance Tells Us About Forming Effective Groups

Poster ,– Joss Ives, University of British Columbia, 6224 Agricultural Road, Vancouver, BC Canada; joss@phas.ubc.ca

Jared Stang, Analise Hofmann Patrick Dubois, University of British Columbia

Two-Phase (or two-Stage) Collaborative Group Exams are an easy to implement technique that leverages students' desire to discuss challenging exam questions with each other immediately after an exam. This instructional technique adds an additional group phase immediately after a regular solo exam. Based on over 1200 student-groups, we have developed a model that predicts how a group will perform on the group phase, based on their individual scores from the solo exam. This model has allowed us to investigate factors (based on demographic and survey information) that may result in groups under- or over-performing relative to the model.

PST1D42: 8:30-9:15 p.m. What Physics Teachers Should Know About STEM Identity and Gender?

Poster – Nina Abramzon, California Polytechnic University Pomona, 3801 W Temple Ave., Pomona, CA 91768-4031; nabramzon@cpp.edu

Viviane Seyranian,Alex Madva, Nicole Duong, California Polytechnic University Pomona

Yoi Tibbetts, University of Virginia

Judith Harackiewicz, University of Wisconsin, Madison

This study investigated gender disparities in academic achievement and flourishing in an undergraduate introductory physics course. 160 undergraduate students enrolled in an introductory physics course were administered a baseline survey and a post-survey at the end of the academic term. Students also completed force concept inventory (FCI) and physics course grades were obtained. Women reported less course belonging, less physics identification, and more belonging uncertainty than men. Men scored higher on the FCI than women, although no gender disparities emerged for course grades. Women who highly identified with physics tended to flourish more over the course of the term than low identifiers. Overall, this study underlines gender disparities in physics classrooms both in terms of belonging and physics knowledge. It suggests that strong STEM identity may be associated with academic performance and flourishing in undergraduate physics courses at the end of the term, particularly for women.

PST1D43: 9:15-10:00 p.m. Who Declares an Engineering Major – A Study of Engineering Pathways

Poster – Seth T. DeVore, West Virginia University, 135 Willey St., Morgantown, WV 26506; stdevore@mail.wvu.edu

Cabot Zabriskie, John Stewart, West Virginia University

Engineering majors make up a large percentage of students moving through many introductory physics sequences. This being said, understanding the pathways that these students take to enter, exit, or maintain their path through engineering degree programs is an important step in increasing the number of STEM graduates generated. In this study, we examine 15 years worth of institutional data from one Eastern land-grant university to identify common pathways leading to successful degree completion, as well as departure from the engineering program. A better understanding of the commonalities of students on these pathways may lead to targeted interventions to prevent unnecessary departures from engineering programs.

PST1D44: 8:30-9:15 p.m. Student Behavior and Test Security in Online Conceptual Assessment

Poster – Bethany R. Wilcox, 2510 Taft Dr., #123 Boulder, CO 80302; bethany.wilcox@colorado.edu

Steven Pollock, University of Colorado Boulder

Historically, the implementation of research-based assessments (RBAs) has been a driver of education change within physics and helped motivate adoption of interactive engagement pedagogies. Until recently, RBAs were given to students exclusively on paper and in-class; however, this approach has important drawbacks including decentralized data collection and the need to sacrifice class time. Recently, some RBAs have been moved to online platforms to address these limitations. Yet, online RBAs present new concerns such as student participation rates, test security, and students' use of outside resources. Here, we report on a study addressing the second two concerns. We gave two upper-division RBAs to courses at five institutions; the RBAs were hosted online and featured embedded JavaScript code which collected information on students' behaviors (e.g., copying text, printing). With these data, we examine the prevalence of these behaviors, and their correlation with students' scores, to determine if online and paper-based RBAs are comparable.

PST1D45: 9:15-10:00 p.m. Student Network Positions in Active Learning Physics Classrooms

Poster – Adrienne L. Traxler, Wright State University, 3640 Colonel Glenn Hwy., Dayton, OH 45435-0001; adrienne.traxler@wright.edu

Tyme Suda, Wright State University

Eric Brewe, Kelley Commeford, Drexel University

This work analyzes social positions in student collaborative networks in physics. The Characterizing Active Learning Environments in Physics (CALEP) project combines classroom observations with network analysis to identify distinctive features of several research-based physics curricula. Though all these curricula include student interactions as a key element, very different collaboration networks can emerge based on the classroom structure and practices. Position analysis is a technique from social network analysis that looks for common structural roles in a network. It groups people who occupy a similar social position, whether or not they know each other. One method for position analysis is CONCOR, which uses the convergence of correlations in the network adjacency matrix. We present preliminary results from a CONCOR role analysis on CALEP data, comparing roles between University of Washington tutorials and Peer Instruction.

PST1D46: 8:30-9:15 p.m. Student Performance and Stress Level in Different Testing Environments

Poster – Sarah E. Muller, University of Central Florida, 3200 N Alafaya Trail, Orlando, FL 32826; smuller@Knights.ucf.edu

Archana Dubey, University of Central Florida

This study examines how student quiz scores and behavior differ when taking quizzes in an Evaluation and Proficiency Center (EPC) versus a studio classroom setting. The studio classroom promotes collaborative learning by having the students work in groups of about three. All focus groups have the same professor, a graduate TA, and an undergraduate Learning Assistant. Student quiz scores and stress levels will be compared in the two environments to see if one setting is more favorable than the other. Quiz scores from the EPC will be compared to paper quiz scores. A statistical analysis will be run to see the difference between the two locations. Student self-evaluation of stress levels will be analyzed via an anonymous survey given at the end of each semester. The spring 2019 data will be compared to the data to be attained in the fall 2019 semester when we will implement Personalized Adaptive Learning.

PST1D47: 9:15-10:00 p.m. Students' Perceptions of the Math-Physics Interactions Throughout Spins-first Quantum Mechanics

Poster – Armando Villasenor, California State Polytechnic University, Pomona, 3801 W Temple Avenue, Pomona, CA 91768; schermerhorn@cpp.edu

Darwin Del Agunos, Benjamin Schermerhorn, Homeyra Sadaghiani, California State Polytechnic University Pomona

One of the purported benefits of teaching a spins-first approach to quantum mechanics is that it allows students to build up quantum mechanical ideas and learn postulates before moving to the more complicated mathematics used in the context of wave functions. In order to begin to explore this claim in a spins-first course, a survey was developed and administered as an extra credit activity at three different universities. All universities teach spins-first quantum mechanics but to different student populations. This work compares students' responses to identical questions about the relationship between and difficulty of math and physics from two administrations of the survey given at the ends of the spins and wavefunctions portions of the course. Results offer insight into students' perspectives about the nature and difficulty of mathematics in these two paradigms of quantum mechanics.

PST1D48: 8:30-9:15 p.m. Supporting Science Students with Scholarships, Academic Activities, and Reflective Journaling

Poster – Andrew Morrison, Joliet Junior College, 1215 Houbolt Rd., Joliet, IL 60431-8938; amorriso@jjc.edu

Cathleen Dobbs, Joliet Junior College

Joliet Junior College recently completed the first year of a five-year project to award scholarships to highly qualified students intending to complete a STEM-related major. The scholarships are for students with demonstrated financial need and are also intended to target students from traditionally underrepresented groups in STEM. Students in the program are asked to keep a reflective journal that they discuss regularly with an assigned faculty mentor. Activities throughout the academic year include: introductions to student support offices, information sessions on transfer options, working on summer research applications, invited speakers on campus, and field trips to museums, national laboratories, and industry partners. We will share the results to date of our research component of this project and discuss ways in which a broader range of JJC students can be reached.

PST1D49: 9:15-10:00 p.m. Survey of Physics, Mathematics and Chemistry Faculty

Poster – Melissa Dancy, University of Colorado, department of physics, Boulder, CO 80309; melissa.dancy@gmail.com

Naneh Apkarian, Charles Henderson, Western Michigan University

Jeff Raker, University of South Florida

Estrella Johnson, Virginia Tech

Marilyne Stains, University of Nebraska

We report initial findings from a survey of a representative sample of physics, mathematics, and chemistry instructors in the United States. Faculty who recently taught an introductory course were asked about their instructional practices, knowledge of research based instructional strategies, local context, beliefs about teaching and learning, and personal background. The survey design allows us to document the extent to which faculty know about and use research based pedagogies and to connect this use to correlating factors and to compare across disciplines.

PST1D50: 8:30-9:15 p.m. Impact of Social Positioning on Group Efficacy in an ISLE Physics Class

Poster – Yuehai Yang, Oregon Institute of Technology, 3201 Campus Dr., Klamath Falls, OR 97601; yuehai.yang@oit.edu

David T. Brookes, California State University, Chico

Binod Nainabasti, University of the Pacific

We collected video and audio data of students interacting with each other in groups while conducting learning activities in an introductory physics class. For each episode of these activities, we categorized each 15 seconds of interaction into five different social positions, for each student in the group. Our analysis found that the way group members talk to each other plays an important role in opening the collaborative space for other group members. This resulted in deeper and richer discussions. On the other hand, a single group member can shut down the collaborative space simply through the manner in which they address other group members. We have found a remarkable correlation between how students position themselves when interacting with each other, and the effectiveness of the group in conducting and completing the learning activities

Teacher Training/Enhancement

PST1E01: 8:30-9:15 p.m. FliP-CoIn – Multi-Cultural Concept Inventory for Flight Physics

Poster – Florian Genz, Universität zu Köln/Cologne, Germany GronewaldStr.2 Köln, NRW 50931; fgenz1@uni-koeln.de

Lars Möhring

Kathleen Falconer

André Bresges

The Flight Physics Concept Inventory (FliP-CoIn) provides feedback to college students, introductory physics courses and their teachers about naïve conceptions in fluid dynamics in the context of flight. FliP-CoIn was developed in English and German. The first test statistics including all 59 questions (=30min including demographic questions) resulted in a Cronbach's alpha for Reliability of ?=.81 (English version. German results to be published soon). Until the conference, the instrument will be shortened and revalidated with a big German student group. Further an automatic online scoring system will be introduced. FliP-CoIn is the first physics concept inventory which was developed concurrently in two cultures and languages. Therefore its evolution yielded many unforeseeable improvements and hurdles. FliP-CoIn was developed because the teaching of fluid dynamics was adopted by the German Physical Society (DPG) in its newest science standards recommendations (DPG 2016). DPG. (2016). DPG SchulStudie - Basiskonzepte. https://www.dpg-physik.de/veroeffentlichung/broschueren/studien/schulstudie-2016/schulstudie-basiskonzepte.pdf

PST1E02: 9:15-10:00 p.m. Preparing the Next Generation of Educators

Poster – Alexandru Maries, 345 Clifton Court, Cincinnati, OH 45220; mariesau@ucmail.uc.edu

Graduate students across the United States are currently playing an important role in the education of students as they often teach laboratories, recitations, and discussion sections. It is important to provide professional development for graduate teaching assistants (GTAs), not only because this will have a positive impact on students now, but also because it can have an impact on the students of tomorrow. This poster summarizes the important takeaways from the literature on effective TA programs along with how this literature has helped shape a particular GTA professional development program. Finally, results from over three years of implementing this program are presented, in particular, by focusing on the pedagogical practices of the GTAs.

PST1E03: 8:30-9:15 p.m. North Pole Physics: Incorporating Real World Data into the Classroom

Poster – Danielle Bugge, Rutgers University, 10 Seminary Place, New Brunswick, NJ 08901; danielle.bugge@rutgers.edu

In May 2018 I had the opportunity to travel to Svalbard, Norway as a Grosvenor Teacher Fellow. The Grosvenor Teacher Fellowship is a competitive professional development opportunity for pre-K–12 educators that is made possible by a partnership between the National Geographic Society and Lindblad Expeditions. I was immersed in a field-based experience to further my students' understanding of our interconnected planet. Reaching latitudes of almost 83 degrees North, I was able to make observations and collect data from a location few others had ventured. The resources I brought back for use in my classroom took the form of videos, pictures, audio recordings, and instrumental data. This poster shares how my involvement with the National Geographic Society has informed my instruction as well as physics lessons and activities created using authentic data.

PST1E04: 9:15-10:00 p.m. Assessing the NGSS Alignment of Next Gen PET

Poster – Meghan P. England, Tennessee Technological University, Dept. of Physics, TTU BOx 5051, Cookeville, TN 38505; mpengland21@students.tntech.edu

Paula V. Engelhardt, Steve Robinson. Tennessee Technological University

Next Generation Physical Science and Everyday Thinking (Next Gen PET) (1) is a set of research-based, guided inquiry curriculum materials for preservice and inservice elementary teachers. While the intention was to provide learning experiences aligned with the Next Generation Science Standards (NGSS), that alignment has not been formally assessed. The Educators Evaluating the Quality of Instructional Products (EQuIP) Rubric (2) was developed to provide criteria by which to measure how well K-12 instructional and instructor support materials are consistent with the intent of NGSS. In this poster, we will describe the outcome of applying the EQuIP rubric to the Next Gen PET materials, together with their associated instructor support. We will discuss to what degree the materials provide an NGSS-aligned learning experience for preservice teachers, as well as the implications for possible revisions

(1) https://nextgenpet.activatelearning.com/ (2) https://www.achieve.org/our-initiatives/equip/equip

PST1E05: 8:30-9:15 p.m. Developing Techlesson Plans for Physics Teachers: Undergrads in the Classroom

Poster – Hugo Brito Dias Santos, Universidade federal da Bahia - UFBa Avenida Dom João VI Salvador, BA 40285000 Brazil; britodiashugo@gmail.com

Katemari Rosa, Universidade federal da Bahia - UFBa

In this presentation, we share an experience of producing teaching materials exploring technology in the classroom for physics teachers in Brazil. Brazilian physics teachers face several hurdles to keep up with technology. First, our public schools rarely have working computer labs or other tech apparatus. Therefore, it is hard for teachers to update their practices when it comes to using technology in physics classrooms. Besides, a significant number of physics teachers lack proper training to integrate technology in the classroom, which leads to restricting their classes to PowerPoint presentations and traditional blackboards. Here we describe the partnership between university faculty, undergraduate students, high school teachers, and their students to promote the use of technology in a public school in Brazil. The result was a lesson plan on topics of modern physics, integrating simulations, plickers, and other resources to improve physics classes.

PST1E06: 9:15-10:00 p.m. Guided Inquiry Physical Science for Pre-Service Teachers and Explanations of Physical Phenomenon*

Poster – Roger A. Key, California State University, Fresno, 2345 E San Ramon Ave., MH37 Fresno, CA 93740; rogerk@csufresno.edu

Alvir Sangha, Dermot Donnelly, Frederick Nelson, California State University, Fresno, Chemistry Dept.

David Andrews, California State University, Fresno

Pre-service teachers continue to struggle with science instruction especially elementary teachers. The Next Generation Science Standards (NGSS) provides opportunity to reconstruct science education for future teachers. This study investigates how a redesigned guided-inquiry physical science curriculum impacts pre-service elementary teachers' explanations of scientific phenomena. Research methods quantitatively measure changes in students' explanations through pre/post assessments consisting of nine conceptual open-response items; three physics, three chemistry, and three integrated items. Initial analysis of fall 2018 and spring 2019 data provides evidence that future pre-service teachers begin physical science courses with many non-normative ideas. Findings will provide insight on students' conceptual difficulties and how a guided-inquiry curriculum supports students in developing coherent explanations of scientific phenomena. This study provides important aspects for teacher education programs to consider in restructuring science instruction in light of NGSS.

*We wish to acknowledge the support of the NSF award number 1712279 with this research.

PST1E07: 8:30-9:15 p.m. Online Graduate Certificate Program in Physics Education for In-service Teachers

Poster – James Christopher Moore, University of Nebraska Omaha, 1001 Sterling Dr., Papillion, NE 68046-6121; jcmoore@unomaha.edu

We describe an online 18 credit hour graduate certificate program in physics education that ties into the existing M.S. in Secondary Education at the University of Nebraska Omaha. Teaching physical science at the secondary-level requires deep discipline-based understanding in combination with knowledge and practice in science education methods, and specific understanding of pedagogical content knowledge (PCK). The program was designed for in-service physics teachers, with coursework based on PCK learning modules developed for the PhysTEC program, combined with new content-focused modules and research experiences. The program provides a pathway for teachers to become qualified to teach dual-enrollment and AP physics courses, while providing learning experiences directly applicable to their own classrooms. We present the framework for the program's development, the coursework and sequence, and preliminary experiences from the program's first cohort.

PST1E08: 9:15-10:00 p.m. What Thriving physics Teacher Education Programs Do: The PTEPA Rubric*

Poster – Stephanie Chasteen, Chasteen Educational Consulting, 247 Regal St., Louisville, CO 80027; stephanie.chasteen@colorado.edu

Rachel Scherr, Scherr & Associates

Monica Plisch, American Physical Society

The Physics Teacher Education Program Analysis (PTEPA) Rubric is a new instrument designed by PhysTEC to provide a specific, objective, and reliable measurement of the activities and structures that may be present in physics teacher education programs. The PTEPA Rubric was developed based on site visits to eight "thriving" physics teacher education programs (those graduating five or more physics teachers per year), and extensive validation, creating a detailed taxonomy of possible program elements (such as institutional characteristics, recruitment of teachers, and pedagogical preparation). In addition to self-reflection for program leaders, the rubric allows new research opportunities. We encourage the PER community to engage in studies using the rubric, including further validation, and using the instrument to further our knowledge about effective physics teacher education programs.

*The PTEPA Rubric is available at http://phystec.org/thriving. We acknowledge funding from NSF-0808790, NSF-1707990 and APS's 21st Century Campaign for development of the PTEPA Rubric.

PST1E09: 8:30-9:15 p.m. Successes, Trials, and Tribulations in Physics Teacher Preparation at Purdue University Fort Wayne

Poster – Matthew P. Perkins Coppola, Purdue University Fort Wayne, 2101 E. Coliseum Blvd., Fort Wayne, IN 46805; matthewperkins@hotmail.com

Mark P. Masters, Purdue University Fort Wayne

Purdue University Fort Wayne was selected as one of the first four PhysTEC Fellows sites in 2017. During the past two years this professional development opportunity has allowed us to strengthened the partnership between physics and education faculty at our institution. We tout three early successes: (1) the creation of a Teacher Advisory Group composed of local high school physics teachers from across the region, which meets monthly, (2) the beginnings of a learning assistant (LA) program, and (3) the creation of a Learning and Teaching in Physics pedagogy course for LA's and TA's. We have also identified challenges to growing the physics teaching major, including recruitment and institutional administrative challenges.

Upper Division and Graduate

PST1F01: 8:30-9:15 p.m. A New Model for Advanced Lab and Introduction to Research

Poster Todd Zimmerman University of Wisconsin - Stout 410 10th Ave E Menomonie, WI 54751 zimmermant@uwstout.edu

A new Advanced Lab course was developed to give students experience with soft skills. The advanced lab course was offered in conjunction with a freshman level introduction to research. This combination of two different levels of students was done to populate a traditionally low-enrolled course and to provide senior students with leadership experience. Each senior-level student was paired with one to two intro students to act as a team leader. Both courses had two 3-hour lab sessions that met together and a separate 1-hour lecture session for each course. The introductory course focused on basic scientific research methods, keeping lab notebooks, working as a member of a team, scientific ethics, experimental design, and scientific communication while the senior course focused on these topics at a more advanced level. The structure of the two courses and the opinions of the students' will be discussed in this poster.

PST1F02: 9:15-10:00 p.m. How Do Departmental Policies Influence Graduate Physics Students' Self-efficacy?

Poster – Diana Sachmpazidi, Western Michigan University, 1903 W. Michigan Ave., Kalamazoo, MI 49008; ntiana.sachmpazidi@wmich.edu

Charles Henderson, Western Michigan University

Graduate attrition in STEM fields is an increasingly observed and persistent phenomenon. Four out of 10 students that enroll in a physics graduate program will end up not completing their degree. Previous studies found that students' entering academic ability is not related to attrition. This study shifts the focus on the relationship of departmental supportive structures to students' self-efficacy and persistence. In addition, we examine how experiencing certain departmental structures affects graduate students' perceptions of career outcome expectations upon the completion of their degree. We collect survey and interview data from physics graduate students from multiple institutions across the U.S. The results of the study will help us identify the factors that influence persistence and career outcome expectations either directly or through the effect of self-efficacy. Our goal is to create recommendations for policymakers in physics graduate programs that can improve students' experiences and increase retention.

PST1F03: 8:30-9:15 p.m. Investigating Transfer of Learning in an Upper-Level Quantum Mechanics Course*

Poster – Alexandru Maries 345 Clifton Court Cincinnati, OH 45221 mariesau@ucmail.uc.edu

Ryan Sayer, Bemidji State University

Chandralekha Singh, University of Pittsburgh

Transfer of learning from one context to another is considered a hallmark of expertise. Physics education research has often found that students have great difficulty transferring learning from one context to another. We examine upper-level and graduate students' facility with questions about the interference pattern in the double-slit experiment with single photons and polarizers in various orientations placed in front of one or both slits. Answering these questions correctly in the context of the double-slit experiment requires transferring learning about concepts from the context of a tutorial on Mach-Zehnder Interferometer (MZI) with single photons and polarizers in various paths of MZI. We discuss the extent to which students who worked through the MZI tutorial were able to transfer what they learned in that context to another context involving the double-slit experiment.

*Work supported by the National Science Foundation

PST1F04: 9:15-10:00 p.m. Survey on Upper-Division Thermal Physics Content Coverage

Poster – Katherine D. Rainey, University of Colorado Boulder, 1550 South Evanston St., Aurora, CO 80012; katherine.rainey@colorado.edu

Bethany R. Wilcox, University of Colorado Boulder

Thermal physics is a core course requirement for most physics degrees and encompasses thermodynamics and statistical mechanics content. However, the primary foci of thermal physics courses vary across universities. This variation can make creation of targeted materials or assessment tools for thermal physics difficult. To determine the scope and content variability of thermal physics courses across institutions, we distributed a survey to over 90 institutions to solicit content priorities from faculty and instructors who have taught upper-division thermodynamics and/or statistical mechanics. We present results from the survey, which articulate key similarities and differences in thermal physics content coverage across institutions. We will discuss implications of these findings for the development of instructional tools and assessments that are useful to the widest range of institutions and physics instructors.

PST1F05: 8:30-9:15 p.m. Improving Students' Understanding of Lock-in Amplifiers

Poster – Seth T. DeVore, West Virginia University, 135 Willey St., Morgantown, WV 26506; stdevore@mail.wvu.edu

Alexandre Gauthier, Jeremy Levy, Chandralekha Singh, University of Pittsburgh

A lock-in amplifier is a versatile instrument frequently used in physics research. However, many students struggle with the basic operating principles of a lock-in amplifier which can lead to a variety of difficulties. To improve students' understanding, we have developed and evaluated a research-based tutorial which utilizes a computer simulation of a lock-in amplifier. The tutorial is based on a field-tested approach in which students realize their difficulties after predicting the outcome of simulated experiments involving a lock-in amplifier and check their predictions using the simulated lock-in amplifier.Then, the tutorial guides and helps students develop a coherent understanding of the basics of a lock-in amplifier.The tutorial development involved interviews with physics faculty members and graduate students and iteration of many versions of the tutorial with professors and graduate students. The student difficulties and the development and assessment of the research-based tutorial are discussed. Supported by the NSF.

PST1F06: 9:15-10:00 p.m. Quantifying Jargon*

Poster – Shannon D. Willoughby, MSU Physics Department, Bozeman, MT 59717; shannon.willoughby@montana.edu

Jenny Green, Leila Sterman, Bryce Hughes, Brock LaMeres, Montana State University

Determining the amount of jargon in a given piece of writing or a speech transcript can be challenging, but necessary because excessive use of jargon can hamper communication between experts and laypeople. We report on an equation, 'jargonness', which calculates the amount of jargon in any text using a logarithmic scale so one can determine how much jargon is in any written text, and directly compare one text to another. Initially developed in 2015 by Sharon and Barm-Tsabari, the researchers used text from British English. We have re-engineered the code in R to be compatible with contemporary American English, and we have calculated the amount of jargon in several classic texts, transcripts from STEM graduate students who have applied to our oral communication grant, grant proposals, and publications from several STEM disciplines. We present the freely available R code and initial comparisons of our jargonness calculations.

*Funded by NSF NRT Grant #1735124.

PST1F07: 8:30-9:15 p.m. Student Difficulties with the Basics for a System of Non-interacting Identical Particles

Poster – Christof K. Keebaugh, Franklin and Marshall College, P.O. BOX 3003, Lancaster, PA 17604-3003; christof.keebaugh@gmail.com

Chandralekha Singh, Emily Marshman, University of Pittsburgh

We discuss an investigation of upper-level and graduate students' difficulties with fundamental concepts involving a system of identical particles. The investigation was carried out in advanced quantum mechanics courses by administering free-response and multiple-choice questions and conducting individual interviews with students. We find that students share many common difficulties related to these concepts.

PST1F08: 9:15-10:00 p.m. Measuring the Activity of Radioactive Isotopes in Soil Using NaI Detector in the Advance Physics Lab

Poster – Rebekah Aguilar, California State Polytechnic University Pomona, 3801 W Temple Ave., Pomona, CA 91768-4031; rsaguilar@cpp.edu*

Peter Siegel, Nina Abramzon, California State Polytechnic University Pomona

Experiments involving nuclear radiation detection are routinely performed in the undergraduate physics curriculum. Common detectors found in many undergraduate institutions are sodium iodine (NaI) gamma detectors. These detectors are relatively inexpensive and are well suited for the teaching of basic spectroscopic techniques. For the study of environmental samples high-resolution gamma detectors are ideal however these detectors are less common. We report on the use of NaI detectors to study environmental samples. Known decay products from the higher-end energy spectrum sources were used for calibration, gamma energy peaks that were measured include: 1440 keV for Potassium-40, 1764 keV for the Uranium-238, and 2614 keV for the Thorium-232 series. A secular equilibrium was used to assume that the activity of each isotope within their decay series were the same. Our results indicate that NaI detector can be used by students to measure the activity of radioactive isotopes in a soil.

*Sponsored by Nina Abramzon

Session DA Building Professional Networks?

Location: CC - Cascade E **Sponsor:** Committee on Women in Physics **Co-Sponsor:** Committee on Educational Technologies
Time: 8:30–9:40 a.m. **Date:** Tuesday, July 23 **Presider:** Anne Cox

DA01: 8:30-9:00 a.m. STOP Collaborate and Listen: Peer Mentorship in Secondary Education

Invited – Jennifer Goetz, Harding High School, 1540 6th St. E, Saint Paul, MN 55106; jmgoetz@gmail.com

Engaging in professional networks as a high school physics teacher can be challenging. The pressures of teaching full time, lack of professional development funding, and availability of readily accessible groups limit the opportunities K-12 teachers have to reap the benefits of such networking. However, through support from the Knowles Teacher Initiative, local networks, and online communities, I have grown as an educator, physicist and teacher-leader. During this talk I will discuss how my experiences in Knowles empowered me to join and lead local collaborations, take part in an online IB Physics Peer Learning Community and engage in teacher inquiry with peers around the country. Creating space for collaboration and networking as a high school physics teacher has given me the inspiration and support I need to survive and thrive in secondary education.

DA02: 9:00-9:30 a.m. Mentoring Works! The Value of Peer Mentoring in the Lives of Scientists

Invited – Barbara Whitten, Colorado College, 14 E La Cache Poudre St., Colorado Springs, CO 80903; bwhitten@ColoradoCollege.edu

Cynthia Blaha, Carleton College

Anne Cox, Eckerd College

Beth Cunningham, AAPT

Linda Fritz, Franklin and Marshall College

Idalia Ramos Colon, University of Puerto Rico.

There is a wealth of data showing that mentors are a valuable asset to the lives and careers of young scientists. Mentors are usually thought of as an older and more experienced person who provides advice and support to a younger person, but it has been shown that peer mentors can be useful as well. Further, we have learned that mentoring is effective and important at all stages of a scientist's career, not just at the beginning. And that mentoring is particularly effective in overcoming isolation for physicists who are marginalized in some way. I will discuss two mentoring projects that we have been involved in. First, I have been a part of a peer mentoring network of senior women physicists at liberal arts colleges for more than a decade. This has become one of the most important professional activities of my career. I'll talk about how we began, how we continue, and why it's important. Second, we have been working on an NSF-funded project to create similar peer-mentoring alliances of isolated women in physics. This project is in its third year and five alliances have been created, with several more forming. I'll describe these alliances and how they formed, and talk about what we've learned from this project, with ideas for the future and for other isolated physicists.

DA03: 9:30-9:40 a.m. Building Professional Networks on Social Media

Contributed – Sarah Durston Johnson, Simon Fraser University, Dept. of Physics, 8888 University Drive, Burnaby, BC V5A 1S6 Canada sjohnson@sfu.ca

Over the past several years I have discovered that social media, especially Twitter, is a great place to grow one's professional networks. I originally joined Twitter more than 10 years ago as the manager of my son's soccer team. I had no idea that a decade later I would be using Twitter to discuss physics teaching with colleagues around the world. We share teaching ideas via the iteachphysics hashtag and provide support to each other from afar. Not only have I interacted with physics instructors at all levels, I have also made meaningful connections with many women scientists. These contacts have led to, among other things, a fund-raising campaign designed to encourage Canadian high school girls to consider a career in science. In this talk, I will describe how I built my online professional networks on Twitter and the benefits I have derived from participating in them.

Session DB PER: Student Understanding and Innovative Tools for Learning

Location: CC - Cascade D **Sponsor:** AAPT/PER **Time:** 8:30–9:50 a.m. **Date:** Tuesday, July 23 **Presider:** TBA

DB01: 8:30-8:40 a.m. Prompting Special-Case Analysis in Classical Mechanics

Contributed – Kelby T. Hahn, Oregon State University, 301 Weniger Hall, Corvallis, OR 97331; kelbythahn@gmail.com

Paul J. Emigh, MacKenzie Lenz, Elizabeth Gire, Oregon State University

One way that physics experts check and gain new insights into their answers is by performing special-case analysis. Special-case analysis involves (1) restricting the parameter space of a problem to a case where the solution is either known or can be intuited, and then (2) either making a judgement about answer correctness or gaining new insight into the problem. This research project examines how students in classical mechanics perform special-cases analysis. We present analysis of homework problems where students were either (1) explicitly prompted to perform a special-case analysis for given cases or (2) asked to make sense of their answer but the special-case-analysis strategy was not specifically prompted. We found that the cases students chose to analyze varied and that students used a variety of reasoning to defend and understand their cases. Surprisingly, few students made judgments. Of those who did, the types of judgments differed with prompting style.

DB02: 8:40-8:50 a.m. Prompted Evaluation in Second Term Calculus-based Introductory Physics

Contributed – Travis Alexander Herring, Oregon State University, 3740 NW Harrison Blvd., Corvallis, OR 97330; herrintr@oregonstate.edu

Elizabeth Gire, MacKenzie Lenz, Kelby Hahn, Paul Emigh, Oregon State University

Introductory physics instructors often ask students to make sense of their answers to problems, both in class and on written homework. This sensemaking generally includes checking for correctness and understanding the meanings of their answers. Checking for correctness - or evaluative sensemaking - can include a variety of strategies such as: checking units and dimensions, evaluating limiting or special cases, verifying correct signs, or judging the reasonableness or magnitude of an answer. We will present results from an analysis of students' responses to explicit reflection prompting on homework problems in three lecture sections of a large-enrollment second term calculus-based physics course. Our results include a description of strategies students employed, how frequently these strategies were used, and how the use of strategies varied by instructor and by physics topic.

DB03: 8:50-9:00 a.m. Measuring Conceptual Understanding Through Students' Judgments of Certainty

Contributed – Eric Kuo, University of Pittsburgh, 3939 O'Hara St., Pittsburgh, PA 15260; erickuo@pitt.edu

Nolan Weinlader, Timothy J. Nokes-Malach, Benjamin M. Rottman, University of Pittsburgh

When answering a physics question, students possess multiple, relevant ideas. Learning to reliably employ the correct physics concepts is a gradual process of re-coordinating and re-organizing one's knowledge, not a sudden, all-or-nothing leap in understanding. Yet, typical multiple-choice questions that measure conceptual understanding in physics are all-or-nothing: either the student is right or wrong. We will present initial results of a new approach to measuring conceptual thinking: asking students to judge their certainty that a response is correct (from 0% certain to 100% certain). Contrasting with simple correct/incorrect coding, the results reveal finer-grained detail and dynamics in students' conceptual thinking. We will discuss future directions for this approach to assessment and connections to existing work in conceptual change and metacognition.

DB04: 9:00-9:10 a.m. The Effectiveness of Student Diagramming for Self-reflection

Contributed – Catherine M. Herne, SUNY New Paltz, 1 Hawk Dr., New Paltz, NY 12561-2447; hernec@newpaltz.edu

Brian M. Bodnar, SUNY New Paltz

In this talk, we outline the foundational research about drawing in the science classroom and describe our own study in an introductory physics class. Studies demonstrate that students who utilize drawing and diagramming for self-reflection perform better on tests. Also, teachers can gauge their students' understanding more effectively from reflective drawing than from reflective writing. We describe the design and outcomes of our study investigating the effects of self-reflective diagramming on students' performance. We found that there was a greater increase in performance on exams for those who were asked to diagram in class in comparison to those who wrote verbal reflections in class. We also found correlations between reflective drawing in class and the number of diagrams drawn on exams. This work has implications for course design in physics teaching.

DB05: 9:10-9:20 a.m. Observing Students Revise their Conceptual Understanding Through Revision of Writing

Contributed – Robert Dalka, University of Michigan, 500 S State Street, Ann Arbor, MI 48109; rpdalka@umich.edu

In the Introduction to the Mechanics course at the University of Michigan, we have implemented Writing-to-Learn (WTL) activities that engage students in writing about physics concepts related to real-world scenarios. During these activities, there is a revision process in which students are asked to revise what they originally wrote in their First Draft and ultimately submit a Revised Draft. While students work through this revision process, they revise their own knowledge and take control of their own learning. As researchers, we are able to use this as an opportunity to witness student learning and understand how students change the ways they explain different concepts. In this talk, I will discuss this learning and revision process by examining specific concepts that students were asked to address in the activities. I will share our findings using both quantitative measures of revision and qualitative examples of student learning.

DB06: 9:20-9:30 a.m. Examining the Effectiveness of Two Methods to Improve Student Transfer

Contributed – Zhongzhou Chen, University of Central Florida, Physics Department, 4111 Libra Drive, Orlando, FL 32816; Zhongzhou.Chen@ucf.edu

Kyle Whitcomb, Chandralekha Singh, University of Pittsburgh

Matthew Guthrie, University of Central Florida

An earlier study using online learning modules found that students lack the ability to transfer learning from a problem-solving tutorial to similar new problems. The current study examines the effectiveness of two methods to improve students' ability to transfer. First, we added an "on-ramp" module developing proficiency on basic skills. Second, we added a new module containing a new problem, for which half of the students were asked to compare and contrast the new problem with a previous one, and the other half were given a tutorial on the problem. We found that the on-ramp module significantly improved students' performance on transfer tasks compared to last year, whereas neither the compare-contrast condition nor the tutorial condition had a significant impact on students' performance, nor were the performance between the two groups significantly different. The study demonstrated a flexible and sensitive new method for measuring the effectiveness of new instructional designs.

DB07: 9:30-9:40 a.m. Learning to Learn by Inquiry: Are Simulations too Challenging for Novices?

Contributed – Jonathan Massey-Allard, University of British Columbia, 2329 West Mall, Vancouver, BC V6T 1Z4 Canada; jmassall@phas.ubc.ca

Ido Roll, Joss Ives, University of British Columbia

Inductive inquiry learning activities, where students are tasked with quantitatively modelling physics phenomena with little guidance from an instructor, have been shown to have substantial conceptual learning benefits. A common implementation is an "invention activity" where students invent a general rule from patterns in instructor-provided data before receiving direct instruction on the target topic. Alternatively, students could be provided with an interactive simulation where students then have the agency to explore and collect data on their own. While this provides a promising opportunity for developing more robust inquiry process skills, it also introduces substantial challenges for novices that may, for instance, only do a shallow exploration and miss crucial features of the domain. We discuss the impact on conceptual learning outcomes and process skill development from a study that tested the impact of these different affordances in a sequence of inductive inquiry activities implemented throughout an introductory E/M course.

DB08: 9:40-9:50 a.m. Creating Comfortable and Accessible Virtual Reality Physics Education Tools

Contributed Jared Phelps Canright University of Washington Department of Physics Physics and Astronomy Building, 3910 15th Ave NE, Box 351560 Seattle, WA 98195 jpcan@uw.edu

The recent advent of affordable and mature virtual reality (VR) technology has spurred the development of educational virtual reality experiences in many fields, including physics. These experiences require special consideration of many aspects of user comfort and accessibility previously minimal or absent, such as implementing locomotion without motion sickness, visual overstimulation, and choice of hardware and user interface designs that minimize time spent teaching students how to interact with the experience. In this work, these problems are explained in context of a VR electromagnetism laboratory, and their solutions motivated and described. Examples are also drawn from VR experiences unrelated to physics education such as Tilt Brush and Fantastic Contraption, and the lessons VR physics education developers may learn from them are detailed.

Session DC Upper Division/Graduate Labs

Location: CC - Cascade C **Sponsor:** AAPT **Time:** 8:30–10 a.m. **Date:** Tuesday, July 23 **Presider:** TBA

DC01: 8:30-8:40 a.m. Using Old Equipment for New (Low Cost) Advanced Optics Labs

Contributed – Toni Sauncy, Texas Lutheran University, 1000 West Court Street, Seguin, TX 78155; tsauncy@tlu.edu

Calvin Berggren, Texas Lutheran University

New interface possibilities allow for a re-purposing of old equipment that might have been on its way to the recycling company. By using low-cost sensors, we have designed several intermediate and advanced labs that make use of otherwise obsolete instrumentation that is readily available in nearly any physics department. Examples and results of light scattering and other experiments will be discussed.

DC02: 8:40-8:50 a.m. Measuring the Lorentz Factor for Cosmic Ray Muons

Contributed – Gordon C. McIntosh, University of Minnesota, Morris, 600 E 4th St., Morris, MN 56267; mcintogc@morris.umn.edu

Liam Taylor, University of Minnesota, Morris

The relativistic nature of cosmic ray muons is well known and is often used as an example in Modern Physics texts. However it has been difficult to perform an experiment indicating the Lorentz factor, relativistic time dilation, of these muons. We have developed an experiment using Geiger counters and a coincidence counter that measures the cosmic ray muon flux vs. zenith angle. Based on several reasonable physical assumptions these measurements indicate a time dilation for the muons of at least 15±2. This project has been supported by a University of Minnesota Morris Academic Partnership.

DC03: 8:50-9:00 a.m. A Differential Scattering Cross Section Laboratory Exercise

Contributed – Michael R. Braunstein, Central Washington Universit,y Physics, MS 7422, CWU, 400 E University Way, Ellensburg, WA 98926; braunst@cwu.edu

The application of differential scattering cross section to evaluate physical models is an essential experimental tool that can be conceptually challenging for students encountering it for the first time. We have developed a laboratory exercise for students that addresses conceptual elements of differential scattering cross section with a simple optical system. Using basic principles of lens optics, students can be realistically expected to derive a reasonable model for the differential scattering cross section of the system. Measurements can then be performed to evaluate the model they have developed. The exercise thus provides a full, hands-on conceptual framework for differential scattering cross section. The system will be described in detail and representative results will be presented.

DC04: 9:00-9:10 a.m. Improving Students' Understanding of the Wave Function for a System of Identical Particles

Contributed Christof K. Keebaugh Franklin and Marshall College P.O. BOX 3003 Lancaster, PA 17604-3003 christof.keebaugh@gmail.com

Chandralekha Singh University of Pittsburgh

Emily Marshman University of Pittsburgh

We discuss an investigation of student difficulties with concepts related to the many-particle stationary state wave function for a system of non-interacting fermions or bosons in cases in which the many-particle stationary state wave function can be written as the product of the spatial and spin parts. The investigation was carried out in advanced quantum mechanics courses by administering free-response and multiple-choice questions and conducting individual interviews with students. We find that students share many common difficulties related to these concepts. Many students struggled to write a many-particle stationary state wave function consistent with the symmetrization requirements for the system (a completely antisymmetric wave function for a system of fermions or bosons).

DC05: 9:10-9:20 a.m. Constructed and Investigation on Combined Black-Body Radiation Facility

Contributed – Shihong Ma, Department of Physics, Fudan University, Room S410, Building of Physics, 2005 Songhu Road, Jiangwan Shanghai, 200438 CHINA; shma@fudan.edu.cn

Nan Zhang, Ping-jing Yang, Department of Physics, Fudan University

The black-body source, with thermal radiation detector and micro-voltmeter, can be used to set up a combined black-body radiation experimental facility. The experimental facility with good scalability has been developed completely and the operation steps by the students are simple and direct. Therefore, students can fully understand the physical model of Black-body radiation through the experiment. In this article, the author verified the basic law of black-body radiation, demonstrated the feasibility of the method and gave a future prospect of the experiment.

DC06: 9:20-9:30 a.m. How a Clueless Lab Can Help Students Learn

Contributed – David D. Allred, Brigham Young University, N265 ESC, Provo, UT 84602-4636; dda@byu.edu

Dallin S. Durfee, Nathan D. Powers, Brigham Young University

It can be very educational to give students in a laboratory class an assignment with a simple goal but no instructions. The first day of our advanced lab we hand each pair of students a silicon PIN photodiode, and with no information about what a photodiode is, or how it works, other than the fact that it detects light. We ask them, "Who can get the biggest signal?" We tell them this is a competition, and we write the highest value each team measures on the whiteboard. After the contest, we have a debriefing in which we discuss their results and how they could improve their approach to unfamiliar equipment and experimental challenges. Later in the semester, students have another similar instruction-free lab. Our observation is that they approach the second experience in a much more professional manner.

DC07: 9:30-9:40 a.m. Coherent Imaging in an Advanced Lab Techniques Course

Contributed – Dallin Durfee, Brigham Young University, N245 ESC Provo, UT 84602; dallin_durfee@byu.edu

David Allred, Nathan Powers, Brigham Young University

Coherent imaging has a wide variety of applications, including imaging transparent microbes, non-destructive measurements of quantum gases, and visualizing air turbulence, and has even been the subject of multiple Nobel Prizes. We describe our approach to teaching this subject in a lab setting, which covers imaging, laser optics and spatial coherence, interference, complex waves, Fourier optics, and Gaussian beams. The topic generates a great deal of student enthusiasm and many of the experiments can be completed on a very small budget.

DC08: 9:40-9:50 a.m. Establishing Experimental Goals Through a Competitive Proposal Development Process

Contributed – Nathan D. Powers, Brigham Young University BYU, Department of Physics and Astronomy, Provo, UT 84602; ndp5@byu.edu

Dallin Durfee, David Allred, Brigham Young University

Establishing and assessing research goals, criteria, and feasibility are among the more impactful tasks that expert scientists engage in. Project-based lab courses offer a unique space for students to develop these critical skills. Previously, we showed how a proposal competition was implemented in our project-based advanced lab to promote development of the six-period final project. The competition mirrors a real-world funding scenario and incorporates two cycles of peer-review. Students now have several opportunities to propose, execute, and report on short student team-initiated projects earlier in the course. For example, we added a one-period expansion project in the first third of the course. This is a short experiment based on the knowledge and skills they have developed in the optics or vacuum unit of the class. We note their ability to develop realistic experimental goals and report them clearly and persuasively matures with each experience of establishing goals and assessing them.

DC09: 9:50-10:00 a.m. Modelling Magneto-Optical Traps for an Undergraduate Experimental Physics Course

Contributed – Corey Gerving, United States Military Academy, Bartlett Hall Science Center, West Point, NY 10996; corey.gerving@westpoint.edu

As part of a semester-long experimental physics course for senior physics majors, we introduce computational techniques using laser cooling as the topic. The course is broken into two phases: computational physics and experimental physics. In the computational phase, students are taught the basics of coding using Python through assignments of increasing complexity. The computational portion of the course culminates with the modeling of N>>1 particles confined in a in a damped harmonic oscillator. The theory is a semi-classical approximation of the Magneto-Optical Trap (MOT). The second half of the course requires the students to build from scratch a rudimentary MOT using the parameters they modeled in their simulations.

Session DD The Discovery of Gravitational Waves: Four Years Later

Location: MH - Bryce **Sponsor:** Committee on Space Science and Astronomy **Time:** 8:30–10 a.m. **Date:** Tuesday, July 23
Presider: Toby Dittrich

DD01: 8:30-9:00 a.m. LIGO, Black Holes, and Our New View of the Universe

Invited – Joey Shapiro Key, University of Washington, Bothell, 11136 NE 180th St., Bothell, WA 98011; joeykey@uw.edu

We live in the new era of multi-messenger astronomy, with the Laser Interferometer Gravitational wave Observatory (LIGO) and Virgo gravitational wave detectors partnering with telescopes around the world to study cosmic collisions of black holes and neutron stars. This new astronomy allows us to peer deeper into the cosmos and reach farther back into the history of our Universe than ever before. In the coming decades we will explore our Universe using detectors that reach across the gravitational wave spectrum, including a world-wide network of Earth-based detectors, the European Space Agency (ESA) and NASA Laser Interferometer Space Antenna (LISA), and the galactic-scale pulsar timing arrays (PTAs) such as the North American Nanohertz Observatory for Gravitational waves (NANOGrav). We have learned from the history of astronomy to expect the unexpected when opening a new window on the Universe and we now sit on the threshold of a wealth of exciting discoveries.

DD02: 9:00-9:30 a.m. What We Have Learned from Gravitational Waves

Invited – Raymond Frey, University of Oregon, 1371 E 13th Avenue, Eugene, OR 97403; rayfrey@uoregon.edu

The last four years have been transformational to the field of gravitational wave science and astrophysics. On Sept. 14, 2015, LIGO announced the observation of a strong gravitational wave (GW) signal from a binary black hole merger. One of Einstein's most amazing predictions was confirmed. The GW discovery was just the start of a new paradigm in astronomy and astrophysics – LIGO had opened the door to a new way to observe the universe. Indeed, in 2017 this vision was realized spectacularly with the discovery of the gravitational wave signal from a binary neutron star (BNS) merger, accompanied within 2 seconds by a gamma-ray burst, and over the next hours, days, weeks, and months by observations across the electromagnetic wavelengths of the merger's afterglow. The era of "multi-messenger astronomy" involving GWs was born. In this talk, I will discuss the implications of these observations to astrophysics, fundamental physics, and cosmology, and some guesses for near-future prospects.

DD03: 9:30-10:00 a.m. "Listening" for the Background Buzz of Gravitational Wave

Invited –Gwynne Crowder, Bellevue College, 3000 Landerholm Circle SE, Bellevue, WA 98007; gwynne.crowder@bellevuecollege.edu

Long predicted but only recently observed, gravitational waves (GWs) have revealed colliding black holes and colliding neutron stars. What more is out there to discover with this exciting new approach to the universe? Theoretical models predict GWs from a multitude of sources, spanning supernovae to spinning neutron stars to early universe sources. Yet these "quieter" sources are below the current sensitivity level of operating GW detectors and cannot be individually detected. Nonetheless, every one of these potential sources emits GWs that contribute to a background "buzz" of their superposition. In this talk, I discuss prospects for observing the buzz (also known as the stochastic gravitational-wave background) and how this form of GW detection might transform our understanding of the "quieter" elements of the universe.

Session DE PER: Assessment, Grading and Feedback II

Location: MH - Birch **Sponsor:** AAPT **Time:** 8:30–9:50 a.m. **Date:** Tuesday, July 23 **Presider:** TBA

DE01: 8:30-8:40 a.m. Topical, Randomized Quizzes in Electromagnetism

Contributed – Alexander J. Shvonski, Massachusetts Institute of Technology, 22 Dearborn St., Medford, MA 02155-4315; shvonski@bc.edu

Michelle Tomasik, Byron Drury, David E. Pritchard, Massachusetts Institute of Technology

We developed five 30-minute topical quizzes in an introductory electromagnetism course (n~150) at MIT, and administered them electronically in class. For each problem on the quiz, students were given a randomized variant from a subset of three variants. We analyzed both the self-consistency of these quizzes and their correlation with other components of the course, including the final exam. We also looked at correlations between "types" of problems on both quizzes and the final. Interestingly, the quizzes exhibited a low score of consistency, as measured by Cronbach's alpha, perhaps reflecting the compartmentalized nature of the material. se. We intend to make these materials available to instructors at other institutions.

DE02: 8:40-8:50 a.m. Using Rutgers Rubrics to Optimise Learning and Instructor Workload

Contributed – Sergej Faletic, University of Ljubljana, Faculty of Mathematics and Physics, Jadranska 19 Ljubljana, 1000 Slovenia; sergej.faletic@fmf.uni-lj.si

Gorazd Planinsic University of Ljubljana, Faculty of Mathematics and Physics

Rubrics are a well known assessment tool. Well designed rubrics provide feedback to student on what they did well, and also feed-forward on what they need to improve to do even better. We introduced scientific abilities rubrics, developed at Rutgers University, NJ, into a project based course "Project Laboratory" for first-year physics students. In this course, students solve open-ended physics problems and submit a written report, which is assessed and students are allowed to improve it until it is done well enough to be accepted. Before, feedback and feed-forward were provided in the form of comments/annotations to the report. Now they are provided in the form of scores on the rubrics. We will show that the rubrics decreased the workload of the instructor, increased the quality of the reports and were very useful to provide guidance to the students during their work.

DE03: 8:50-9:00 a.m. Lab TAs Facilitate and/or Hinder Experimental Design in Learning Physics

Contributed – David R. McKenna, University of Notre Dame, 25 S Canyon Ave., Springville, UT 84663-2184; dmckenna@byu.edu

Abigail Mechtenberg, University of Notre Dame

Our 700+ students/year introductory labs implemented an experimental design (ED) pedagogy over four years for students to move from cookbook to inquiry-based labs. Three ED thought spheres scaffold all labs into pattern recognition: measurements, calculations, and variations. Three ED connection pathways teach students how to think about doing science (regression versus derivation approaches MVC versus CMV). Using Google Classroom, Lab TAs gave feedback (9,000+ comments) as well as the rubric-based grade (1,050 lab reports). We analyzed all comments in terms of total words, tone, complexity, probing level, and instructional efficacy of the Lab TA and calculate correlations between these and student evaluations of lab as well as lab final exam and rubric-based grades over time. We present these relationships between how Lab TAs communicate with students in laboratory settings using ED with 35-45 student lab sizes and how students learned and think they learned.

DE04: 9:00-9:10 a.m. Scientific Practices in Introductory Physics Labs*

Contributed – Steven F. Wolf, East Carolina University, C-209, Howell Science Complex, 10th Street, Greenville, NC 27858-4353; wolfs15@ecu.edu

Feng Li, Mark W. Sprague, Joi P. Walker, East Carolina University

This talk discusses the results of course transformation efforts in place at ECU to privilege scientific practices in our introductory physics lab courses. Transformed curricula were piloted in spring 2018 in Physics 1, and fall 2018 in Physics 2. We will discuss our curricular framework, practical assessment, and implementation challenges. In particular we will discuss how we have worked with faculty to forge a consensus around the transformed learning goals, as well as the administrative changes that are required to sustain the new curricula.

*Supported by NSF DUE-1725655

DE05: 9:10-9:20 a.m. Student Behavior and Test Security in Online Conceptual Assessments

Contributed – Bethany R. Wilcox, University of Colorado Boulder, 2510 Taft Dr. #213, Boulder, CO 80302; bethany.wilcox@colorado.edu

Steven Pollock, University of Colorado Boulder

Historically, the implementation of research-based assessments (RBAs) has been a driver of education change within physics and helped motivate adoption of interactive engagement pedagogies. Until recently, RBAs were given to students exclusively on paper and in-class; however, this approach has important drawbacks including decentralized data collection and the need to sacrifice class time. Recently, some RBAs have been moved to online platforms to address these limitations. Yet, online RBAs present new concerns such as student participation rates, test security, and students' use of outside resources. Here, we report on a study addressing the second two concerns. We gave two upper-division RBAs to courses at five institutions; the RBAs were hosted online and featured embedded JavaScript code which collected information on students' behaviors (e.g., copying text, printing). With these data, we examine the prevalence of these behaviors, and their correlation with students' scores, to determine if online and paper-based RBAs are comparable.

DE06: 9:20-9:30 a.m. Student Performance and Stress Level in Different Testing Environments

Contributed – Sarah Elizabeth Muller, University of Central Florida, 3200 N Alafaya Trail, Orlando, FL 32826; smuller@Knights.ucf.edu

Archana Dubey, University of Central Florida

This study examines how student quiz scores and behavior differ when taking quizzes in an Evaluation and Proficiency Center (EPC) vs. a studio classroom setting. The studio classroom promotes collaborative learning by having the students work in groups of about three. All focus groups have the same professor, a graduate TA, and an undergraduate Learning Assistant. Student quiz scores and stress levels will be compared in the two environments to see if one setting is more favorable than the other. Quiz scores from the EPC will be compared to paper quiz scores. A statistical analysis will be run to see the difference between the two locations. Student self-evaluation of stress levels will be analyzed via an anonymous survey given at the end of each semester. The spring 2019 data will be compared to the data to be attained in the fall 2019 semester when we will implement Personalized Adaptive Learning.

DE07: 9:30-9:40 a.m. How Can We Assess Scientific Practices? The Case of "Using-Mathematics"

Contributed – Amali Priyanka Jambuge, Kansas State University, 1600 Hillcrest Dr., Apt V26, Manhattan, KS 66502; amali@phys.ksu.edu

James T. Laverty, Kansas State University

Recently, there is an emphasis on including scientific practices into introductory-level college physics curricula, instruction, and assessments. We conducted a study to develop assessment tasks to elicit evidence of students' abilities to engage in the scientific practice, Using Mathematics. We used Evidence-Centered Design to develop these tasks and these tasks were given to students along with one on one think-aloud interviews. The students' written work was compared to the video of them solving the problem aloud to determine if what they wrote down can reliably predict whether or not they engaged in the scientific practice. In this talk, I focus on interesting aspects of the students' work that gives us evidence about how reliably we can assess students' use of mathematics. This work informs developing future classroom and standardized assessments that can assess scientific practices.

DE08: 9:40-9:50 a.m. How Can We Develop Assessment Tasks for "Planning Investigations"?

Contributed – Hien Khong, Kansas State University, 1544 International Ct. Apt 24, Manhattan, KS 66502; hienkhong@ksu.edu

James T. Laverty, Kansas State University

The Three-Dimensional Learning Assessment Protocol (3D-LAP) was introduced to transform assessments so that we can see students using their knowledge to do physics and NGSS has called them as scientific practices. This research focuses on developing assessment tasks for introductory courses where we can assess student abilities to plan investigations in physics. In order to figure out how to assess this practice, we first identified steps that go into the process of planning investigations. Then we collected data using a think-aloud protocol to identify observable in students' written work, which may provide evidences of the students engaging in the scientific practice. This will help us to design the assessments which both assess students conceptual understanding and their ability to do physics.

Session DF Introductory Courses: Approaches to Instruction

Location: MH - Amphitheater **Sponsor:** AAPT **Time:** 8:30–10 a.m. **Date:** Tuesday, July 23 **Presider:** TBA

DF01: 8:30-8:40 a.m. An Activity to Get Students to Draw Better Pictures

Contributed – Matthew Olmstead, King's College, 133 N River St., Wilkes Barre, PA 18711-0800; matthewolmstead@kings.edu

One of the most important steps in solving introductory physics problems is drawing an appropriately labeled and detailed picture. I slightly modified the game Telestrations as an activity used several times in class to help show students the value of good picture. With Telestrations, players alternate between writing down a word and drawing a word. I had the students start with a physics question, they had to draw a detailed picture representing that question, hand it to a neighbor who then tried to write what the question was based only off the picture, and then pass it to another student who would then draw the picture for this question. I will discuss specific examples of this as well as what students found useful about this activity.

DF02: 8:40-8:50 a.m. To Reflect or Not to Reflect? Reflect, Duh!

Contributed – Taoufik Nadji, 4000 Highway M-137, Interlochen, MI 49643; NADJIT@INTERLOCHEN.org

The presenter will share examples of students' reflections in their respective physics and astronomy classes. These reflections on various readings, video-watching assignments, and STEAM projects require that the students tie the physics and astronomy concepts they learned to their arts areas, to real life, or to other fields of learning. Throughout the years, these writing pieces have been exceeding beauties of STEAM and the fusion of the arts and the sciences.

DF03: 8:50-9:00 a.m. Peer-Led Team Learning on the Galactic Scale

Contributed – John D. Mason, Texas A&M University, 4242 TAMU College Station, TX 77843; masonj777@physics.tamu.edu

With over 1000 students enrolled in its entry-level mechanics course, Texas A&M University boasts one of the largest physics educational efforts in the country. To improve the quality of instruction and the student experience in the course, a peer-led team learning model was implemented in recitations. While many educational programs have implemented a peer-based model over the years, few have had to deal with the challenges of implementing a program that reaches as many students as Texas A&M. I will discuss the challenges and lessons learned from my experiences running a large scale PLTL program and how these findings can be incorporated into any educational program.

DF04: 9:00-9:10 a.m. Bringing Hands-on, Service-Learning Experience to Introductory Physics Classroom

Contributed – Tatiana Erukhimova, Texas A&M University, 4242 TAMU College Station, TX 77843-4242; etanya@tamu.edu

We will present the results of an innovative program at Texas A&M University that aims to add hands-on, teamwork, and outreach components to the learning and research experiences of undergraduate students. In this program, undergraduates taking introductory physics classes work throughout the school year in small teams led by physics graduate students on design and fabrication of exciting physics demonstration experiments: from a giant Galilean cannon to liquid sand pool, Texas-sized Tesla coil, and superconducting train. Student teams demonstrate their experiments at high-profile outreach events such as the Texas A&M Physics & Engineering Festival, Physics Shows, Just Add Science, and Game Day Physics. They film their experiments in 2-3 min video clips posted at realphysicslive.com. The demonstrations are used in regular physics classes at Texas A&M.

DF05: 9:10-9:20 a.m. Initiating Studio Physics Transformation for the Introductory Physics Courses

Contributed – Xian Wu, University of Connecticut, 2152 Hillside Road, unit 3046, Storrs Mansfield, CT 06269-0001; xian.wu@uconn.edu

Diego Valente, Jason Hancock, University of Connecticut

The physics department at the University of Connecticut is preparing to launch its own studio physics program in the 2019 fall semester. Our program is planned to bring impact to 2300 undergraduate students on a yearly basis by providing studio-based instruction to three calculus-based introductory course sequences serving physics majors, engineering, and life sciences students accordingly. Of these course sequences, two are considered as large enrollment: engineering physics and physics for life sciences. Currently, each course sequence is piloting certain aspects of a studio-style teaching approach. The engineering physics sequence is facilitating the "flipped classroom" pedagogy, while the physics for life sciences sequence is currently developing problem-solving tutorials through an iterative design cycle. Our third calculus-based course sequence, for physics majors, is taking advantage of its smaller enrollment to test out the physical infrastructure, class scheduling, and cohesion of the lectures, problem-solving, and lab components. We would like to share with the PER community our current progress on the redesign process of these courses and the evaluations of teaching effectiveness we envision for them. We hope to initiate inter-institute conversations about how interactive teaching approaches can be adopted and evaluated within the framework of a given institution's support and constraints.

DF06: 9:20-9:30 a.m. Making Physics Appealing to Non-Science Students

Contributed – Elizabeth Jane Angstmann, UNSW, Sydney School of Physics, UNSW Kensington, NSW 2052 Australia; e.angstmann@unsw.edu.au

At UNSW, Sydney, Fundamentals of Physics is a traditionally taught, algebra-based introductory physics course. A number of students, planning on sitting the medical entry exam, wanted to take this course but were unable to fit it into their packed timetables. Everyday Physics was designed to cover similar physics content in an online format aimed at non-physics students. To make it relevant students look at the physics behind how a different object works each week. Unexpectedly this course became increasingly popular with business students; it grew from 560 enrollments in 2013 to 1100 in 2018. These students freely elected to study physics, saying that they liked the flexibility offered by online delivery and the real-life applicability of the subject. Average FMCE learning gains are somewhat higher in Everyday Physics (with females gaining more than males) so students are learning at least as much from this course as Fundamentals of Physics.

DF08: 9:40-9:50 a.m. Using Ebooks to Design Your Class Syllabus

Contributed – Donald G. Franklin, Retired, 35 West Main Street, Hampton, GA 30228-2932; donfranklin8@gmail.com

With the availability of online textbooks gives educators these options: 1. Lower the cost of textbooks by using online texts. 2. Develop a multi textbook syllabus using online texts to save on buying multiple texts or copying chapters from other text. 3. Reorganize an ebook into the format that matches the syllabus you wish to use: Example -- Medical Physics has a greater relevance if one starts with the last part of the text and peak the student's interest in physics, rather than having them memorize chapters that have little value to Pre-Med Students.

DF09: 9:50-10:00 a.m. What a Validation/Confirmation Lab Looks Like When It Grows Up

Contributed – Richard A. Zajac, Kansas State University, Polytechnic Campus, 2310 Centennial Road Salina, KS 67401-8196; rzajac@ksu.edu

The reformed use of undergraduate labs for inquiry/exploration has not eliminated the traditional confirmation lab, in which a formula/theorem derived in lecture is applied by students to a real system. At their worst, these confirmation labs frequently foster the perception by students that lab results need to conform to an unimpeachable, authoritative textbook formula in order for students to get a good grade. Still, the need for corroboration and reification is unavoidable. Methods are discussed by which particular undergraduate general physics labs have been redeemed by steering them away from the conformist mentality. The evolution of these labs over decades demonstrates that simple adjustments can also be useful in giving physics back its real-world "street cred."

Session DG 30 Demos in 60 Minutes

Location: MH - Cedar **Sponsor:** Committee on Teacher Preparation **Co-Sponsor:** Committee on Physics in High Schools
Time: 8:30–9:30 a.m. **Date:** Tuesday, July 23 **Presider:** Wendy Adams

Our panel of physics teachers will present at least 30 dynamic demonstrations that will engage students in the wonder of science. Presenters will share tips on the setup, materials, procedure, and underlying science concepts so the audience can integrate these demos into their own classrooms.

Session DH TPT Favorites

Location: MH - Arches **Sponsor:** Committee on the Interests of Senior Physicists **Co-Sponsor:** Committee on Physics in Two-Year Colleges
Time: 8:30–10 a.m. **Date:** Tuesday, July 23 **Presider:** Mary Mogge

DH01: 8:30-10:00 a.m. An Editor's View of *TPT* Favorites

Invited – Gary White, AAPT and GWU Physics, One Physics Ellipse, College Park, MD 20740; gwhite@gwu.edu

After 6 years at *The Physics Teacher*, I am eager to share some of my favorite articles….but how to pick? It's like indicating favorites among children—sure, they might exist, but is it wise to admit it? So rather than suggesting a "Best of *TPT*" collection, I'll highlight favorites that stand out when examined in light of either online popularity or personal impact. With the former, I hope to showcase articles that get downloaded the most, whether classic papers from the *TPT* archives or recent additions to the literature. With the latter, I'll promote papers whose clever ideas and thoughtful approaches have ended up in my own classroom, hopefully in a way that does justice to the authors' visions. Wise or not, perhaps I'll provide some context for this session, which features authors who have been invited to tell us a little more about their recent contributions to *TPT*.

DH02: 8:30-10:00 a.m. The Two-Bullet Problem with Constant Magnitude Drag Force

Invited – Jennifer L. Burris, Appalachian State University, Deptartment of Physics and Astronomy, Boone, NC 28608; burrisjl@appstate.edu

Brooke C. Hester, Karl C. Mamola, Appalachian State University

It is common in introductory physics to show that in the absence of air drag, an object dropped from rest will reach the level ground at exactly the same time as one that is projected horizontally from the same height. However, the situation is different in the presence of a speed-dependent drag force, as either object may hit first or they may hit at the same time. Drag force is quite complex, and the dependence of the drag force on speed is related to a number of factors, some of which are beyond the scope of this talk. This talk focuses on the cases of drag forces with a magnitude dependent on an integer power (2, 1, and 0) of the speed as these are suitable for study in introductory courses.

DH03: 8:30-10:00 a.m. Classroom Simulation of Gravitational Waves from Orbiting Binaries

Invited – Jonathan Perry, Towson University, 333 Spenceola Parkway, Forest Hill, MD 21050-3160; jperry12@students.towson.edu

James Overduin, Rachael Huxford, Jim Selway, Towson University

With appropriate caveats, demonstrations using stretched spandex fabric as a stand-in for curved space-time can convey some of the wonder of general relativity to non-experts. We have extended this idea to simulate gravitational waves from orbiting binaries using a pair of caster wheels attached to a hand drill and illuminated by a strobe light. This setup reproduces the pattern of outgoing spiral ripples that has entered the public imagination through LIGO animations. We use a paperclip plumb bob to measure the amplitude of these two-dimensional spandex waves as a function of orbital frequency and diameter, as well as distance from the center of mass. We compare our results with those that hold for gravitational waves propagating in three-dimensional space. Our simulation should not be confused with a demonstration of general relativity, but does exhibit some of the same features that gravitational waves share with other forms of radiation in general.

DH04: 8:30-10:00 a.m. Responding to the Call: Addressing Equity in Physics

Invited – Geraldine Cochran, Rutgers University, 136 Frelinghuysen Rd., Piscataway, NJ 08854-8019; moniegeraldine@gmail.com

The editorial "Unique voices in harmony: Call-and-response to address race and physics teaching" was based on conversations between The Physics Teacher editor, Gary White, and me regarding submissions in response to a call for papers on race and physics teaching. In that editorial, we shared our experiences with call-and-response and our thoughts on the included papers. We expressed our appreciation for the submissions; they were unique in their content and appropriate to the theme. In a follow up article on this focused collection, "Continuing conversations on equity in the physics classroom," we discussed the impact of the work in this collection. In particular, the authors of these articles thought deeply about issues of equity and the need for social justice in physics. This moved me to begin creating spaces where physics educators and physics education researchers could continue conversations on this important topic, which I will discuss in this presentation.

DH05: 8:30-10:00 a.m. Teaching about Racial Equity in Introductory Physics Courses

Invited – Abigail R. Daane, South Seattle College, 6000 16th Ave. SW, Seattle, WA 98106; abigail.daane@gmail.com

Sierra R. Sybertz nee Decker, Redmond High School

Vashti Sawtelle, Michigan State University

Even after you decide to tackle a problem like racial inequity, it may seem daunting to broach the subject in a physics classroom. After all, the idea of an instructor tackling a sensitive topics such as social justice can be scary in any context. Not only that, but physics is typically viewed as a "culture with no culture." The physicist's quest for objectivity supports the treatment of this subject as untouched by people. Sometimes it is easier just to focus on Newton's laws. However, ignoring the striking underrepresentation of ethnic/racial minorities in both the physics classroom and field is a great disservice to all our students. We take the position that the persistence of representation disparities is evidence that culture plays a role in who and what is involved in physics. Instructors have an opportunity engage students in this effort through the Underrepresentation Curriculum, shared in this talk.

DH06: 8:30-10:00 a.m. The Importance of Physics Teachers' Recognition for Physics Identity Development*

Invited – Zahra Hazari, Florida International University, 11200 SW 8th St., Miami, FL 33199; zhazari@fiu.edu

Eric Brewe, Drexel University

Renee-Michelle Goertzen, Theodore Hodapp, American Physical Society

Cheryl Cass, SAS

In a series of two papers we published in *The Physics Teacher*, we presented: (i) evidence of the positive effect that high school physics teachers' recognition has on female students' likelihood to intend a physics career and (ii) how this recognition is enacted in a high school physics class. The first paper drew on survey data from a large sample of female students in undergraduate physics majors (N~900) while the second was a case study of one teacher and a female student in his class who felt recognized by him. This talk will summarize the results of this work as well as the implications for future research and practice.

*This material is based on work supported by the National Science Foundation under Grant No. 1346627, 0952460, and 1721021.

DH07: 8:30-10:00 a.m. Video Abstracts and Highlights from the Technology Column

Invited – James Lincoln, Youtube.com/AAPTfilms, PO Box 11032, Newport Beach, CA 92658-5016; LincolnPhysics@gmail.com

The new "Technology in the Classroom" has been around for two years now and in that time we have created several video abstracts to illustrate these and other articles. This column has seen some of the most innovative and exciting articles and in this talk I discuss the creation of these and the creation of video abstracts. Tips for successful video abstracts are discussed as well as a preview of upcoming article ideas that should tantalize our readers and viewers.

DH08: 8:30-10:00 a.m. The Joy of Solving Physics Problems

Invited – Carl E. Mungan, United States Naval Academy Physics, Mailstop 9c Annapolis, MD 21402-1363; mungan@usna.edu

The column "Physics Challenges for Teachers and Students" started appearing in The Physics Teacher in the October 2001 issue. Originally, three problems were presented per month, with solutions appearing a few months later. In the spring of 2005, weekly challenges became the basis of a World Year of Physics competition. Subsequently, the column editor (Boris Korsunsky) settled on one problem per monthly issue. For every Challenge, Boris chooses a solution (based on clarity, elegance, and originality) to be published. The problems are intended to be solvable at the advanced high school or introductory college level. I will present statistics and comments based on my experience in tackling all of the problems since the inception of this marvelous column. Members of AAPT who are not currently engaging these challenges should give it a try and they should encourage their students to do the same!

DH09: 8:30-10:00 a.m. iPhysicsLabs: A Lot of Physics with Smartphones

Invited – Martín Monteiro, Universidad ORT Uruguay, Aconcagua 5152 Montevideo, 7 11400 Uruguay; fisica.martin@gmail.com

Arturo C. Marti, Cecilia Cabeza, Cecilia Stari, Universidad de la República

Smartphones and other similar devices has spread dramatically in the last decade around the world. This revolution also impacted in the physics laboratories where several experiments are possible by the use of their built-in sensors. From a physicist's point of view, it is impressive that smartphones incorporate several sensors, including accelerometer, gyroscope, magnetometer, light sensor, microphone and many others according to the specific hardware. These sensors are not supplied for educational purpose, nevertheless they can be employed in a wide range of physical experiments, in high school or college. Moreover, experiments with smartphones can be easily performed outside the traditional laboratory. Since 2012, The Physics Teacher has been publishing the iPhysicsLabs column, where several experiments are proposed, taking advantage of the capabilities of the smartphones, covering many topics of physics, like mechanics, electromagnetism, optics, acoustics, among others. References at: http://smarterphysics.blogspot.com/

Session DI The Art and Science of Teaching

Location: MH - Canyon **Sponsor:** Committee on Teacher Preparation **Co-Sponsor:** Committee on Physics in Undergraduate Education
Time: 8:30–10 a.m. **Date:** Tuesday, July 23 **Presider:** Andy Gavrin

DI01: 8:30-9:00 a.m. Is Research on Teaching an Art or a Science?*

Invited – Paula Heron, University of Washington, Dept. of Physics, Box 351560, Seattle, WA 98195-1560; pheron@uw.edu

The PER community has made a compelling case that the teaching of physics can be regarded not only as an art, but a science. Evidence from research on student learning, attitudes, and participation have driven significant changes in how physics is taught. As in other scientific endeavors, systematic investigations and theoretical speculation, supported by publication and peer review have led to cumulative progress. However, the accumulated expertise of PER cannot be distilled into well-defined principles. Moreover, as in all scientific pursuits, creativity and insight in PER do not follow from clearly defined procedures. Researchers draw on theory where it is robust, profit from the experience of perceptive teachers, and exploit regularities, even without a clear understanding of underlying mechanisms. In this talk, I will illustrate how creativity and "clinical wisdom" play a role in the design of experiments, the development of interpretative frameworks, and the implementation of findings.

*Supported in part by the NSF.

DI02: 9:00-9:30 a.m. The Evolution of an Intro Physics Lab Reform Effort

Invited – Mats Selen, Department of Physics, 1110 W. Green St., Urbana, IL 61801; mats@illinois.edu

At the University of Illinois, we are in the process of reforming the lab component of introductory physics courses taken by over 5000 students per year. We are moving away from highly structured activities focused on concepts, and implementing ISLE-inspired open-ended activities that focus on scientific skills (enabled by the IOLab system). When we started this work several years ago we did not anticipate the interesting twists and turns we would encounter, nor did we appreciate that the most challenging aspects of the reform would have as much to do with instructors and infrastructure as with lab content and pedagogy. With the benefit of hindsight I will try to shine some light on the path that has led us to the current milestone at which all students enrolled in our algebra-based intro courses (about 700 per semester) are doing the reformed labs. I will describe the Learning Assistant program that we developed as part of this effort, and will finish by outlining our plans for the coming year as we scale this approach to include the 2000 physics and engineering majors taking our calculus-based intro mechanics and E&M courses each semester.

DI03: 9:30-10:00 a.m. Reflections and Projections: The Promises of Scholarship in Physics Education

Invited – Noah Finkelstein, University of Colorado, UCB 390 - Dept of Physics, Boulder, CO 80309; finkelsn@colorado.edu

Significant, perhaps unprecedented, attention is being paid to the need for transformation of the fields of science, technology, engineering, and mathematics (STEM) education. Building on early work and discussions in the field, this talk will examine how physics education research (PER) has grown to address many more opportunities that advance education for our students. I present examples from work at the Colorado PER Group that scale from the individual to institutional: how we have moved from introductory to advanced topics, growth of technologies in education, studies that examine more than traditional content understanding and how our environments do and do not support students from populations historically underrepresented, and models for engaging in sustainable and scalable transformation.

Session DJ Contributing to, and Using, the Living Physics Portal

Location: MH - Aspen **Sponsor:** Committee on Physics in Undergraduate Education **Co-Sponsor:** AAPT
Time: 8:30–10 a.m. **Date:** Tuesday, July 23 **Presider:** Nancy Beverly

Tuesday Morning

DJ01: 8:30-9:00 a.m. Interdisciplinary Science Teaching – How the Physics Living Portal Can Assist

Invited – Rhonda Dzakpasu, Georgetown University, 37th and O St. NW; 506 Reiss Science Building, Washington, DC 20057; rd259@georgetown.edu

The biological physics major at Georgetown University was created primarily to attract premed students who might otherwise major in biology. Many of these students will have taken physics and calculus – frequently at the AP level – in high school and are often not aware that physics can be a viable path to medical school. This talk will discuss our philosophy in developing the major and the requirements to complete the major; I will focus on the first of our two-semester course sequence in biological physics and how the Physics Living Portal and curriculum swaps in a community environment can play a role in ongoing course development and enrichment. I will also present some of the benefits as well as the challenges that we have experienced as we work to refine the major as well as what types of paths our majors take after they graduate.

DJ02: 9:00-9:30 a.m. Posting PALS on the Portal

Invited – Alice D. Churukian, University of North Carolina at Chapel Hill, 120 E. Cameron Ave., Chapel Hill, NC 27599; adchuruk@physics.unc.edu

At the University of North Carolina at Chapel Hill we completely redesigned the introductory course sequence typically taken by students of the life sciences. As part of the development of our new introductory physics course for life science (IPLS) majors, we designed more than 50 studio activities called Physics Activities for the Life Sciences (PALS). All activities address important physical principles and their applications to the life sciences, and many focus on topics that are not part of the traditional introductory physics curriculum. The introduction of the Living Physics Portal has afforded us the opportunity to not only broadly share our materials with others who are also developing and teaching IPLS courses, but also receive feedback from our peers. In this talk, I will share my experiences of uploading materials to the Community Library and the process of getting materials accepted into the Vetted Library.

DJ03: 9:30-9:40 a.m. Physics Faculty's Attitudes Towards Copyright, Licensing, and Distribution of Curricular Materials*

Contributed – Sarah McKagan, American Association of Physics Teachers, 1 Physics Ellipse, College Park, MD 20740; sam.mckagan@gmail.com

Adrian M. Madsen ,American Association of Physics Teachers

Traditionally, curricular materials for teaching physics have been developed by small groups of curriculum developers, and owned and distributed by publishing companies, often at a substantial cost to students. The Living Physics Portal provides an alternative model of an online environment where physics faculty share, discuss, adapt, and reshare free curricular materials. In order to sustain this free resource, we are exploring possibilities for working with commercial partners to also distribute materials though online homework systems, integrated online textbooks, and on-demand publishers. We conducted usability testing interviews with six physics faculty in which we asked them to pretend to contribute their curricular materials to the Living Physics Portal and assign them a copyright, license, and permission to distribute to commercial partners. The faculty in our study had a wide range of attitudes about who should own their curricular materials and how they should be distributed. We present our findings and their implications for how curricular materials should be shared and how universities and funding agencies should support their employees and grantees in addressing these issues.

*Supported by NSF DUE grant 1624185

DJ04: 9:40-9:50 a.m. Ways to Use NEXUS/Physics on the LPP*

Contributed – Edward F. Redish, University of Maryland, Department of Physics, College Park, MD 20742-4111; redish@umd.edu

EXUS/Physics is an Introductory Physics Course for Life Science (IPLS) and pre-health-care students. It has been delivered at the University of Maryland since 2011. The materials developed for the class are being shared through the Living Physics Portal and ComPADRE, hosted by the AAPT. The materials developed for NEXUS/Physics can be used at a variety of grainsizes ranging from a single item (reading or problem), to a module (time-confined unit on a single topic), to a thread (a skill-developing set of materials running through all topics), to a full year's class (with sample syllabi available). Materials on the LPP can be adopted and adapted to match the needs of a particular instructional situation. I'll present examples that are currently available and discuss possibilities for future development.

*Supported in part by grants from HHMI and the NSF.

DJ05: 9:50-10:00 a.m. SCALE-UP Physics on the Living Physics Portal

Contributed – Mark E. Reeves, George Washington University, 725 21st St. NW, Washington, DC 20052; reevesme@gwu.edu

At George Washington University, we have developed a two-semester, calculus-based sequence that mostly serves our biophysics majors and the biomedical engineers. It was developed with support from the NSF and has been delivered at George Washington University since 2008. The materials developed for the class are being shared through the Living Physics Portal (LPP), hosted by the AAPT. These materials include standard elements of the SCALE-UP model, including reading quizzes, peer-instruction clicker questions, ponderables (group problem solving), tangibles (small hands-on elements), laboratories, homework problems as well as quiz and test problems. The materials are arranged by topic and presented as a fully transferable course. Materials on the LPP can be adopted and adapted to match the needs of a particular instructional situation. In this talk, I will give examples of modules that are currently available on the LPP.

Session DK Informal Physics Education Research: An International Community Informal Physics Education Research - IPER community

Location: MH - Zion **Sponsor:** Committee on Science Education for the Public **Co-Sponsor:** Committee on Research in Physics Education **Time:** 8:30–10 a.m. **Date:** Tuesday, July 23 **Presider:** Claudia Fracchiolla

The Informal PER Community is growing. Now is the time to begin offering opportunities and supports for those who participate in this community. With this topical discussion we seek to begin the discussion about how best to address the needs of the members of this community, what do we want as a community, how can we present ourselves as a community. However, we cannot seek to address the needs of this community without directly involving the community. In this roundtable discussion at AAPT 2019. We hope to create a space for community supports and professional development that is targeted to those who are interested in IPER. We want this community to be interdisciplinary and intersectoral, that is that we want practitioners and researchers from different backgrounds.

Session DL Solo PER

Location: CC - Ballroom A **Sponsor:** Committee on Research in Physics Education **Co-Sponsor:** Committee on Professional Concerns **Time:** 8:30–10 a.m. **Date:** Tuesday, July 23 **Presider:** Steve Maier

Are you the only professional active in PER within your department? Are there only one or two colleagues in close proximity you can talk "PER shop" with? The membership of Solo PER is larger than you may think, and more diverse than most suspect. Join us for this topical discussion to connect with other Solo PER professionals and learn what is being done to help our/your endeavors. As in the past, bring questions, ideas and professional concerns to share. Consider joining the Solo PER group at PERcentral ahead of the meeting for occasional updates (https://www.compadre.org/per/programs/). Also, you can join in on live conversations using our Discord server (https://discord.gg/5fADGZr).

Session DM PER: Student Understanding, Concept Inventories, and Computation

Location: CC - Ballroom B **Sponsor:** AAPT/PER **Time:** 8:30–10 a.m. **Date:** Tuesday, July 23 **Presider:** TBA

DM01: 8:30-8:40 a.m. The Second Dimension of the FCI Is Mostly Medieval

Contributed – David Pritchard, MIT Room 26-241, MIT, Cambridge, MA 02139-4307; dpritch@mit.edu

Angel Perez Lemonche

John Stewart, West Virginia University

Byron Drury, MIT

Rachel Henderson, Michigan State University

We constructed Item Response Curves (1) for correct and distractor responses to the FCI (N=17000, eight universities) administered pre-instruction. Even students scoring below chance selected responses whose curves rose monotonically as Newtonian ability (raw correct score) decreased – indicating an absence of guessing. About a dozen 'intermediate maximum' distractors were selected by over 30% of intermediate students but by fewer low or high ability students. In addition to Newtonian ability, Two-Dimensional Item Response Theory revealed a dimension distinguishing classes of distractors. This axis differentiates intermediate maximum from dominant wrong responses. Intermediate maxima correspond to known commonsense physics ideas (2), especially the Medieval concept of impetus, and are predominantly selected by students scoring 15-50%. Lower skill students selected a wider range of more 'naively incorrect' responses. The ability to infer specific alternate conceptions of students or classes should allow development and application of effective instructional interventions for specific misunderstandings.

(1) Morris, G. A., Harshman, N., Branum-martin, L., Mazur, E., Mzoughi, T., Baker, S. D., … Baker, S. D. (2012). An item response curves analysis of the Force Concept Inventory An item response curves analysis of the Force Concept Inventory, 825(March 1995). http://doi.org/10.1119/1.4731618 (2) Halloun, I. A., & Hestenes, D. (1998). Common sense concepts about motion, 1056(1985). http://doi.org/10.1119/1.14031

DM02: 8:40-8:50 a.m. Multidimensional Item Response Theory and the FMCE

Contributed – Jie Yang, West Virginia University, 135 Willey St., Morgantown, WV 26506; jy0033@mail.wvu.edu

John Stewart, West Virginia University

Many studies have examined the structure and properties of the Force Concept Inventory (FCI), however, far less research has investigated the Force and Motion Conceptual Evaluation (FMCE). This study applied Multidimensional Item Response Theory (MIRT) to a sample of N=4528 FMCE post-tests responses. Exploratory factor analysis identified a 10-factor solution as optimal; however, much of the optimal factor structure was related to the blocking of items into a group with a common stem. A confirmatory analysis, which constrained the MIRT models to a theoretical model constructed from expert solutions, produced a model requiring only eight principles, fundamental reasoning steps. This was substantially fewer than that identified in the FCI. Correlation analysis also demonstrated that the two instruments were very dissimilar. The reduced number of principles allowed the extraction of eight single-principle subscales, seven with Cronbach's alpha greater than the 0.7 required for acceptable internal consistency.

DM03: 8:50-9:00 a.m. Evaluating Assessment Construct of Concept Inventories in Pre- and Post-test

Contributed – Yang Xiao, School of Physics and Telecommunication Engineering, South China Normal University, 367 Waihuanxi Road, Panyu District Guangzhou, Guangdong 510006 China; 20092305002@m.scnu.edu.cn*

Haoli Zhuang, Jing Han, Jianwen Xiong, School of Physics and Telecommunication Engineering, South China Normal University

Lei Bao, Department of Physics, The Ohio State University

Concept inventories (CIs) are commonly used in pre-post testing to study student conceptual change. To obtain consistent measurement, the assessment construct measured by a CI is desired to maintain invariance across pre-post tests. Using a large dataset from a Midwestern public university, Item Response Theory analysis was performed to examine the stability of the factorial structure invariance of two commonly used CIs, the Force Concept Inventory (FCI) and the Conceptual Survey of Electricity and Magnetism (CSEM), across pre- and post-test. While both CIs held a stable unidimensional configural structure between pre- and post-test, the CSEM violated more metric invariance than the FCI did. The results suggest that analysis of total score of the two CIs under unidimensional assumption can yield reliable measures. The difference in the construct changes of the two CIs also indicates possible influence from students' prior knowledge on construct invariance.

*Sponsored by Dr. Lei Bao

DM05: 9:10-9:20 a.m. How do Previous Coding Experiences Influence Undergraduate Physics Students

Contributed – Jacqueline N. Bumler, Michigan State University, 567 Wilson Rd., East Lansing, MI 48824; bumlerja@msu.edu

Paul C. Hamerski, Marcos D. Caballero, Paul W. Irving, Michigan State University

Project and Practices in Physics (P-Cubed), a section of introductory, calculus-based physics, is designed around problem-based learning. Students spend each class working in groups on a single complex physics problem. Some of these problems are computational in nature – students start with code from a visual computer program that runs without accurately accounting for the physics, and they spend the class period applying the physics concepts correctly in the program. Here we present an interview study that investigates the relationship between students' prior computational experiences and their experience with computational activities in P-Cubed. This investigation demonstrates the ways by which prior coding experience can impact how students make sense of computation within physics.

DM06: 9:20-9:30 a.m. Scientific Practices in Minimally Completed Programs

Contributed – Daniel Oleynik, Michigan State University, 2100 Daintree Ave., West Bloomfield, MI 48323; oleynikd@msu.edu

Paul Irving, Michigan State University

Computational problem solving practices are beginning to be the center of many introductory physics courses. Specifically, within P-cubed, students regularly work on computational problems situated in physics that involve minimally working programs. Currently, very little research has been done on minimally working programs in relation to curriculum design, especially with how frequently they facilitate students in engaging with computational practices. After an initial coding of student work in class, we have identified extended periods of time where students were working on aspects of the problem that were not intended by instructors, which we coded as "distractors." Throughout the course of this presentation, we examine these distractors for computational practices and pedagogical benefits.

DM07: 9:30-9:40 a.m. Visualizations of E&M Plane Waves Designed for Better Student Understanding

Contributed – Michael Wilson, North Carolina State University, 106 Willow Point Court, Durham, NC 27703; mbwilson@ncsu.edu

Robert Beichner, North Carolina State University

It is well known that plane waves in electricity and magnetism (E&M) are misunderstood. Particularly, the traditional visual representation of these plane waves is misleading and students are confused by the waves' three dimensionality. Previous work by the author suggests that students respond best to visualizations that show propagating wavefronts and visualizations that fill the entire space. Presented is a qualitative study focusing on three very different simulations designed to meet these two requirements and their effect on student understanding.

DM08: 9:40-9:50 a.m. A Method for Measuring Resource Activation in Physics Quantitative Literacy*

Contributed – Trevor I. Smith, Rowan University, 201 Mullica Hill Rd., Glassboro, NJ 08028-1701; smithtr@rowan.edu

Philip Eaton, Montana State University

Suzanne W. Brahmia, Alexis Olsho, University of Washington

Andrew Boudreaux, Western Washington University

We are engaged in a multi-year project to develop the Physics Inventory of Quantitative Literacy (PIQL): a multiple-choice assessment instrument to measure students' mathematical reasoning abilities in physics. One of our main goals is to examine the interactions between students' understanding of physics and their quantitative reasoning skills. To measure these interactions, we have included several multiple-choice multiple-response (MCMR) questions on the PIQL for which students may choose as many (or as few) responses as they think are correct. Different responses correspond with different aspects of the physics or mathematics. We present results from several MCMR questions and discuss methods for analyzing these data that allow us to examine how students' responses may correspond to different resources being activated. We also probe whether or not the assumptions of typical quantitative analyses, such as classical test theory, are appropriate for instruments that include MCMR questions.

*Supported by NSF grants DUE-1832836, DUE-1832880, and DUE-1833050

DM09: 9:50-10:00 a.m. The Progress Toward Developing an Instrument to Measure Student Reasoning*

Contributed – Brianna Santangelo, North Dakota State University, 1340 Administration Ave., Fargo, ND 58105; brianna.santangelo@ndus.edu

Mila Kryjevskaia, Alexey Leontyev, North Dakota State University

One of the goals of physics instruction is to help students develop reasoning skills in the context of physics. However, it is challenging to design instruments capable of measuring student reasoning in order to make claims about improvements. The challenges stem from two aspects. First, it is difficult to disentangle conceptual understanding from reasoning. Second, to reason productively, a certain level of conceptual understanding is required. As such, a traditional pre- and post-test methodology is not appropriate for documenting changes in reasoning. To address the challenges, we have been developing sequences of screening-target questions: screening questions probe conceptual understanding, while target questions require students to apply this understanding in situations that present reasoning challenges. The level of consistency in student performance on screening and target questions is used to make inferences about reasoning skills.

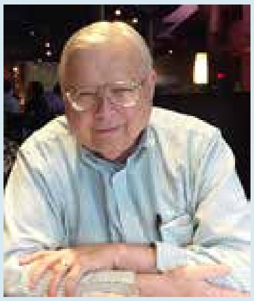
*This material is based upon work supported by the National Science Foundation under Grant Nos. DUE-1431940, DUE-1431541, DUE-1431857, DUE-1432052, DUE-1432765, DUE-1821390, DUE-1821123, DUE-1821400, DUE-1821511, DUE-1821561.

Session DN How Scientific Societies Are Addressing Harassment and Sexual Misconduct Issue

Location: CC - Soldier Creek **Sponsor:** AAPT **Time:** 8:30–10 a.m. **Date:** Tuesday, July 23 **Presider:** Beth Cunningham and Laura Greene

Recent historical events have taken the existence of harassment and sexual misconduct at the workplace to new levels of awareness. Scientific societies have taken action on how to deal with this, starting with publishing and posting codes of conduct for meetings to actually taking some action. AAAS has formed the "Societies Consortium on Sexual Harassment in STEMM." We will give short discussions on this consortium, what AAPT, APS, and other scientific societies (including maybe AGU and IUPAP) are doing in this area, and welcome ideas from the audience.

AAPT AWARDS: Millikan Medal Awarded to Tom Greenslade Jr.



Thomas Greenslade Jr.
Kenyon College

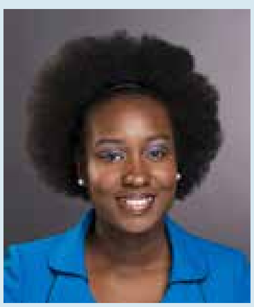
I would like to tell you some stories. The first one is about Robert A. Millikan and the apparatus that he designed for the introductory physics courses at the University of Chicago at the turn of the twentieth century. As for the rest, I would like to tell you how an interest in oscillations and waves sparked my interest and kept me going in the required first year physics course at Amherst College in the mid-1950s. After I arrived at Kenyon College in 1964, as the youngest faculty member at the College, I discovered a "back room" full of delightful physics apparatus from the nineteenth century, and learned how to use them in demonstrations of oscillatory phenomena. Later I was able to start a new course for sophomore physics majors called "Oscillations and Waves" that made full use of Tony French's text with a similar title. Here I was able to devise a full set of experiments, some old and some that I developed. As you will see, there is more than one way to swing a pendulum!

AAPT PHYSICS EDUCATION

10:30–12:30 p.m.
Tuesday, July 23

CC - Ballroom C

AAPT AWARDS: Homer L. Dodge Distinguished Service Citations



Geraldine Cochran
Rutgers University

Larry Engelhardt
Francis Marion University

Laura E. McCullough
Hamline University

Brian Pyper
BYU-Idaho

Matthew Blackman
Ridge High School

PhysTEC Teacher of the Year – Matthew Blackman

Matthew has been teaching physics and physics education for the past ten years, during which time he has made significant contributions to the physics education community at the local, state and national levels. His efforts in teaching students, training teachers, and creating web-based educational resources have made a positive impact on the physics education of many thousands of students in the U.S. over the past decade. Some of Matthew's accomplishments:

- Dramatically increased enrollment and student scores in AP Physics 1 and AP Physics 2 at both Madison and Ridge High Schools.
- Improved the ratio of female to male students taking AP Physics at Ridge High School, increasing female enrollment from under 20% to over 50% in just three years.
- Taught himself how to code and design games in his spare time, and has since built five educational physics games to help students learn kinematics, circuits, waves, and electricity.
- Created a 501c3 nonprofit – The Universe and More – to develop and distribute these games 100% free and ad-free – More at www.universeandmore.com
- Matthew's educational games have received over 6 million plays in total over the past 7 years, being used by teachers and incorporated into physics curricula in all 50 states and over 60 countries.
- Teaches graduate courses in the Physics Education Master's Program at Rutgers, consistently receiving some of the highest course evaluations in the Graduate School of Education.
- Designs and runs a highly successful summer PD workshop, which has grown from eight teachers/year to now over 20 teachers/year – More at www.teachphysics.com
- Recognized by the NJ Senate in a congressional resolution honoring his achievements in the high school and college classrooms, success coaching FIRST robotics and innovative development of educational games.

Session EA Effective Practices in Educational Technology

Location: CC - Cascade E **Sponsor:** Committee on Educational Technologies **Time:** 1:30–3:10 p.m. **Date:** Tuesday, July 23
Presider: Andy Gavrin

EA01: 1:30-2:00 p.m. The Coming Revolution in Small Ground- and Space-Telescope Research

Invited – Russell Genet, California Polytechnic State University, 1 Grand Ave., San Luis Obispo, CA 93407; rgenet@calpoly.edu

Alex Johnson, Charles Van Steenwyk, California Polytechnic State University

David Rowe, PlaneWave Instruments

Rachel Freed, Institute for Student Astronomical Research

Large telescopes excel at taking "snapshots," while arrays and networks of small, identical, robotic telescopes excel in making follow-up, time-series "movies." Capitalizing on the economies of production and robotic operation, the Fairborn Observatory operated an array of 0.8-meter robotic telescopes in the 1980s. Starting in the 1990s, Los Cumbres Observatory deployed a global network of equatorial 0.4- and 1.0-meter telescopes (10 each). Recently, PlaneWave Instruments has produced 50 alt-az 0.7-meter direct dive robotic telescopes and six 1.0-meter telescopes. Redefining what is "small," production 1.5- and 2.0-meter robotic telescopes are likely over the next decade, as are complete turn-key observatories. The CubeSat revolution is producing low-cost small space telescopes. New arrays and networks of small ground and space robotic telescopes will be available to the growing army of published undergraduate, high school, and citizen science researchers, synergistically supporting the ever-larger ground and space telescopes and their professional and graduate student researchers.

EA02: 2:00-2:10 p.m. Tracking of Student Learning in an Open-source Flipped Classroom

Contributed – Evan Thatcher, Oregon State University, 627 NW 10th St., Corvallis, OR 97333-1233; thatchee@oregonstate.edu

Recent efforts to develop an open-source, flipped classroom curriculum for the algebra-based introductory physics sequence at Oregon State University have enabled fine granularity tracking of student study habits, out of class work habits, in-class habits, and mastery of content. This talk will provide reflections on the ground-up, collaborative approach to the curriculum design, methods, and preliminary findings of the tracking, and the future of the project as it expands from a large state college, to a small satellite campus, to e-campus and a hybrid classroom.

EA03: 2:10-2:20 p.m. Building an Open Resource Flipped Classroom Structure Using Educational Technology

Contributed – Ryan Scheirer, Oregon State University - Cascades, 900 NE Warner Place, APT #226, Bend, OR 97701; ryan.scheirer@osucascades.edu

With the vast spectrum of open and for-profit resources, physics teachers have many tools at their disposal for class design. At Oregon State University we are collaboratively re-designing an introductory physics course completely around the flipped classroom model and open resources. Modular content and learning tools are coded to learning objectives and click-stream tracking allows for a build, analyze, and iterate approach to instructional design. In this talk I will reflect on this process.

EA04: 2:20-2:30 p.m. Analysis of Brain Activation Characteristics in Physics Problem Solving by Students

Contributed – Hwa Kuk, Korea National University of Education, 250, Taeseongtabyeon-ro, Gangnae-myeon, Heungdeok-gu Cheongju-si, Chungcheongbuk-do 28173 Republic of Korea; chryshwa@knue.ac.kr

Kwangsu Ryu, Korea National University of Education

Up to now, most educational researches have been using traditional methods such as evaluation, observation and interview using questionnaires. Recently, however, brain-based education research based on detailed information in the brain area has been activated. In particular, brain imaging technologies such as MEG, EEG, and fMRI are mainly used. However, since these techniques have limited motion, it is not possible to conduct brain-based research in actual education field. So, in this study, the brain activation was measured using fNIRS, a brain imaging technique with no motion limitation. By analyzing the intensity of the light reflected from the brain tissue, the fNIRS device can measure the activation state of the frontal lobe in real time. The subject of education research was selected as solving the physic problems because the frontal lobe makes plans and decisions to find problem solving in various cognitive conflicts. Specifically, we analyzed the difference in brain activation characteristics according to the type of physics problem and correct answer rate in the students' solution of the FCI questionnaire. We think that the results of this study can be used as important data for the development of brain-based education research.

EA06: 2:40-2:50 p.m. Using Google Sheets for Shared Data Collection in Student Labs

Contributed – Duane L. Deardorff, University of North Carolina at Chapel Hill, CB 3255, Chapel Hill, NC 27599-3255; duane.deardorff@unc.edu

Jennifer Weinberg-Wolf, University of North Carolina at Chapel Hill

At UNC-CH, we have been using shared Google sheets for students to report their data and results during selected introductory physics labs. This practice has been relatively easy to implement, provides an electronic record of students' experimental results, and is an effective way for students to compare their results with their peers and correct mistakes before completing the lab activity. It also provides a way for students to examine a larger collection of data and different experimental configurations. The open access also means that the document can be easily altered and is vulnerable to corruption, so this data-sharing tool should only be used in low-stakes settings; however, we have found it to be worth the risk, and we recommend its use.

EA07: 2:50-3:00 p.m. Lessons Learned from Developing and Marketing PathPlan Mechanics

Contributed –Thomas M. Foster, Foster Learning, LLC 900 Timberlake Dr., Edwardsville, IL 62025; tmfpaer@gmail.com

Eddie Ackad, Foster Learning, LLC

We developed PathPlan Mechanics as a tool to help students learn algorithmic problem solving. As a PER scholar, I have been studying, researching, and leading AAPT workshops for over 20 years. While there are people who know more than me about problem solving in physics, I would still consider myself an expert. As a physicist, I knew very little about actually bringing the PathPlan idea to fruition, but how hard could it be? I'm a physicist after all. I'll share a few of our favorite moments along this continuing journey.

EA08: 3:00-3:10 p.m. Online Discussions as Evaluations in Introductory Physics and Astronomy Classes

Contributed – Anthony Smith, Walla Walla Community College, 500 Tausick Way, Walla Walla, WA 99362; spacetime82@gmail.com

Introductory Physics and Astronomy students can often become lost in academic discussion of the class concepts, and lose sight of their applications in the world at large. Discussion assignments were added to both online Physics and in-person Astronomy classes, as an assessment of the students' knowledge and processing of class material, in which they had to either watch a brief educational video or read a webcomic, and process it in light of their previous knowledge and the material learned. These discussions were done on Canvas, with students required to submit an original post and reply to their classmates. Student feedback was positive and enthusiastic.

Session EB Best Practices for Maker Spaces

Location: CC - Cascade D **Sponsor:** Committee on Science Education for the Public **Co-Sponsor:** Committee on Educational Technologies
Time: 1:30–3:30 p.m. **Date:** Tuesday, July 23 **Presider:** Edward Price

EB01: 1:30-2:00 p.m. Promising Practices for Engaging Underrepresented Students in Makerspaces

Invited – Brooke Coley, Arizona State University, 7171 E Sonoran Arroyo Mall, Mesa, AZ 85212; bccoley@asu.edu

Audrey Boklage, University of Texas – Austin

Nadia Kellam ,Arizona State University

As making could potentially impact academic progression, through early exposure and opportunities to develop confidence through building, design, iteration and community, it is critical that we understand how all students, especially those from underrepresented groups, come to affiliate with, become alienated from and/or negotiate the cultural norms within these maker communities. It is crucial to explore the complexities of underrepresented students' identity development and how they are impacted by navigating in engineering-affiliated makerspace environment. This study investigated the experiences of underrepresented engineering students that have also engaged as makers in makerspaces. This study was conducted across seven university engineering affiliated makerspaces and interviewed a total of 65 engineering students from varying backgrounds, disciplines and class statuses. Narrative interviews were used to ascertain stories of students' personal growth and identity development which helped to elucidate promising practices for makerspaces to engage all students, and specifically underrepresented students.

EB02: 2:00-2:30 p.m. Incorporating Making into a Design Curriculum: Best Practices

Invited – Audrey Boklage, University of Texas at Austin, 204 E Dean Keeton St., Stop C2200, Austin, TX 78712; audrey.boklage@austin.utexas.edu

One of the defining characteristics of design is that there is rarely a single correct answer to an engineering problem, but rather an acceptable solution leading to a final design. Makerspaces are catalysts to innovation, confidence and design. Recent research found over a course of three-months, students who took part in a course that made use of the makerspace for a class project were positively and significantly impacted in the domains of technology self-efficacy, innovation orientation, affect towards design, design self-efficacy, and belonging to the makerspace. The Curriculum lab at The University of Texas at Austin serves as a space for professional development for faculty to leverage their expertise and incorporate the makerspace into their design curriculum. Through this work we have recognized the importance of an asset-based approach coupled with realistic learning outcomes for the students in the successful implementation of these projects.

EB03: 2:30-3:00 p.m. The Library as a Venue for Making and Learning

Invited – Victor Lee, 2830 Old Main Hill, Logan, UT 84322-2830; victor.lee@usu.edu

Mimi Recker, Aubrey Rogowski, Utah State University

There are over 100,000 school and public libraries in the United States, and they are increasingly become locations where Making is taking place. In some situations, this involves the creation of dedicated Makerspaces in the library while in others, libraries are offering new programs and experiences that put patrons in contact with STEM-oriented Making. In this presentation, I will discuss the latter and specifically the opportunities to come into contact with physics content through some common types of Maker activities that are especially amenable to library settings. The comments and accounts shared by this panel speaker are based on three years of research and design work with small town and rural serving public and school libraries funded by the Institute of Museum and Library Services. Over that time, the research and design team has launched and implemented programs that have been in use with hundreds of youth library patrons in and out of Utah and helped demonstrate to a broader public that learning in today's libraries is about much more than just books.

EB04: 3:00-3:30 p.m. A University-based Mobile Maker Space*

Invited – Charles DeLeone, California State University, San Marcos, 333 S. Twin Oaks Valley Rd., San Marcos, CA 92096-0001; cdeleone@csusm.edu

Edward Price, April Nelson, California State University San Marcos

University maker spaces hold great potential for engaging the community, but may not be easily accessible, especially for youth and underserved populations. Going out from the university to the community can address this issue and help broaden youth participation in making. Mobile Making is a university-based after-school making program that operates within local middle schools. Highly qualified and ethnically diverse undergraduate science majors and teacher candidates lead youth participants in authentic making activities during weekly sessions. Objectives include increases in the participants' interest and self-efficacy related to Making and STEM, and their perception of the relevance of STEM/making in everyday life. Evaluation has documented positive impacts on the participants and facilitators, and the programs create a sustainable maker ecology within the region. We will share outcomes, lessons learned, and our assessment methods and tools, and describe how other universities can engage in or initiate similar efforts

* This work supported by NSF DRL-1612775

Session EC NSF-Sponsored Physics and Astronomy Projects Crossing Disciplinary Boundaries

Location: MH - Zion **Sponsor:** Committee on Research in Physics Education **Co-Sponsor:** Committee on Physics in Undergraduate Education
Time: 1:30–3:30 p.m. **Date:** Tuesday, July 23 **Presider:** R. Steven Turley

EC01: 1:30-2:00 p.m. Education Researchers' Characterizations of Physics Faculty

Invited – Linda E. Strubbe, Kansas State University, 1228 N. 17th St., Manhattan, KS 66506; lestrubbe@gmail.com

Brycen Parker, Kansas State University

Adrian M. Madsen, Sarah B. McKagan, American Association of Physics Teachers, Alder Science Education Association

Eleanor C. Sayre, Kansas State University, Alder Science Education Assocation

The education research community has been studying physics teaching for over 40 years. Part of this work includes characterizing people who teach physics. The PhysPort team is conducting a review of how our community talks about university physics instructors in our published papers. Looking at the top three physics education research journals (PR-PER, AJP, PERC Proceedings), our preliminary results suggest that the dominant characterization of physics faculty follows a deficit model. A deficit model, in contrast to an asset model, focuses on faculty deficiencies and problems rather than on their strengths and opportunities. This is important because how we talk about our colleagues offers insights into how we as a field view the big-picture mission of our work; these results may encourage us to reflect critically. In this talk, I will describe our research into how the education research field characterizes physics faculty and discuss our results so far.

EC02: 2:00-2:30 p.m. Living Physics Portal - Connecting Physics Educators with Life Science Students

Invited – Dawn Meredith, University of New Hampshire, 9 Library Way, Durham, NH 03824; dawn.meredith@unh.edu

Several national policy documents about the education of future life scientists were published in late 2000's. These called for their education to be more grounded in the physical sciences and mathematics. Independently, several physics educators across the country took up the challenge to make the introductory physics course for life science students (IPLS) more relevant and appropriate for the next generation of life scientists. Each institution solved the problem in a unique way. In 2016, a group of eight such institutions formed a collaboration to create an on-line portal (funded by NSF grant) that would be both a repository of materials for this course and an on-line community to support instructors as they implemented changes. This talk will outline the challenges in creating an impactful IPLS course and the value of the on-line portal.

EC03: 2:30-3:00 p.m. Integrating Computation into Undergraduate Physics: Faculty Development for Community Transformation*

Invited – Larry Engelhardt, Francis Marion University, 4822 E Palmetto St., Florence, SC 29506; lengelhardt@fmarion.edu

Danny Caballero, Michigan State University

Marie Lopez del Puerto, University of St. Thomas

Kelly Roos, Bradley University

Norman Chonacky, Yale University

We are currently in the fourth year of an NSF-funded project to help faculty integrate computation throughout the undergraduate physics curriculum. This project is all about improving physics education, and creating and sustaining a community of faculty that have the tools and support to integrate computation. The model of transformation that we have been building should be relevant to faculty in other disciplines in the sciences, engineering, and mathematics. Integrating computation into the introductory physics sequence impacts students in all of the disciplines previously mentioned, and many of the exercise sets that have been developed as part of the project are interdisciplinary. We will discuss the current state of this project, what we have been doing, where we are going, and how this relates to other disciplines.

*This workshop is funded by the National Science Foundation under DUE IUSE grants 1524128, 1524493, 1524963, 1525062, and 1525525.

EC04: 3:00-3:30 p.m. University-wide Teamwork Minor for STEM Majors

Invited – Justin D. Fair, Indiana University of Pennsylvania, 975 Oakland Ave, Rm 143, Weyandt Hall, Indiana, PA 15705-1001; jfair@iup.edu

Anne E. Kondo, Mimi Benjamin, Rachel Desoto-Jackson, Melanie D. Hildebrandt, Indiana University of Pennsylvania

Recent employer surveys indicate employers feel many new university graduates lack interpersonal and teamwork skills, which are critical in today's market. Providing specific training in these skills is difficult because few scientific majors have room in their tech.-heavy course load. To fill this gap, Indiana University of Pennsylvania has created a focused teamwork minor that spans across a student's education, introducing the concepts in Liberal Studies courses and allowing for repeated application, practice, and evaluation of these skills in STEM courses. Social science, theater, and communication courses introduce the theory, practice, and self-assessment of skills required for good teamwork. Students enhance and reflect on their skills through team-based interdisciplinary research projects, both in science courses required for their majors and through independent research. With our curricular model, future graduates will be better prepared for the necessary future interdisciplinary collaborations the workforce needs to advance its competitive edge.

Session ED STEP UP - Take Action to Engage Women in Physics

Location: MH - Bryce **Sponsor:** Committee on Women in Physics **Co-Sponsor:** Committee on Physics in Two-Year Colleges
Time: 1:30–3:20 p.m. **Date:** Tuesday, July 23 **Presider:** Kelli Gamez Warble

ED01: 1:30-2:00 p.m. STEP UP: Examining the Impacts of Classroom Lessons on Students' Physics Identities and Career Intentions*

Invited – Zahra Hazari (presented by Geoff Potvin), Florida International University, 11200 SW 8th St., Miami, FL 33199; gpotvin@fiu.edu

Hemeng Cheng, Raina Khatri, Florida International University

Robynne M. Lock, Texas A & M University - Commerce

This talk reports on work related to the STEP UP project. In the first phase of this multi-year, multi-institutional project, we developed and tested a set of classroom materials to help teachers expose students to career options for physics majors and to discuss the underrepresentation of women in physics. The development was based on prior research on these topics and followed an initial pilot phase with one group of teachers followed by a quasi-experimental phase with another group of teachers. In this talk, we summarize the development and design logic of the lessons and present findings on their impacts on students' physics identities and future physics intentions, with a particular focus on women. These results should inform future improvements and adoption of the materials in high schools across the U.S.

*This work is supported by the National Science Foundation under Grant No. 1720810, 1720869, 1720917, and 1721021.

ED02: 2:00-2:10 p.m. STEP UP: Applying Multiple Frameworks in Curriculum Development*

Contributed – Raina M. Khatri, Florida International University, 11200 SW 8th St., Miami, FL 33199; raina.m.khatri@gmail.com

Zahra Hazari, Geoff Potvin, Ingelise Giles, Florida International University

Robynne M. Lock, Texas A&M University - Commerce

This talk reports on work related to the STEP UP project. The project had two primary criteria in creating classroom resources to support the project's goals of increasing the recruitment of women to undergraduate physics: 1) they must be based in the research literature on gender issues in physics, and 2) they must be usable across many classroom contexts. Thus, the team explicitly drew upon multiple frameworks from both gender and dissemination literature, integrating knowledge from traditionally disparate fields in the creation and revisions of the materials. This talk provides examples of the frameworks used and how they informed improvements of materials in concurrence with classroom field-testing data. This may serve as a model for other educators to promote transferability of their materials while maintaining core intervention content.

*This work is supported by the National Science Foundation under Grant No. 1720810, 1720869, 1720917, and 1721021.

ED03: 2:10-2:20 p.m. STEP UP: Analyzing Student Identity Development in Two Classroom Interventions*

Contributed – Hemeng Cheng, Florida International University, 11200 SW 8th Street, Miami, FL 33199; hchen033@fiu.edu

Geoff Potvin, Zahra Hazari, Raina Khatri, Florida International University

Robynne M. Lock, Texas A & M University - Commerce

This talk reports on work related to the STEP UP project. Based on an earlier successful pilot study, in fall 2018, a second group of teachers from three regions in the U.S. were recruited to participate in a quasi-experimental test of a set of classroom materials intended to expose students to careers in physics and a discussion of underrepresentation of women in physics. Students completed multiple rounds of attitudinal surveys that probed both physics identities and future career intentions. This talk will report on a quantitative analysis of the pre/post data for both lessons as well as the implications of these findings for future improvements of the lessons and adoption of these lessons across the country.

*This work is supported by the National Science Foundation under Grant No. 1720810, 1720869, 1720917, and 1721021.

ED04: 2:20-2:30 p.m. STEP UP: Analyzing Discussions of Underrepresentation*

Contributed – Benjamin J. Archibeque, Florida International University, 11200 SW 8th St., Miami, FL 33199; barchibeque1@gmail.com

Geoff Potvin, Zahra Hazari, Laird Kramer, Raina Khatri, Florida International University

This talk reports on work related to the STEP UP project. In previous research, in-class discussions of underrepresentation have been found to increase women's interest in physics-related careers as well as their physics identities. Understanding which facets of these conversations are important and how they affect broader classroom discussion might offer insight into what instructors can do to bolster women's physics identities and career interests. This talk will present an analysis of certain aspects of an in-class discussion of underrepresentation: how speaking time changes, and how students' hedging and warranting progresses throughout the discussion.

*This work is supported by the National Science Foundation under Grant No. 1038321, 1720810, 1720869, 1720917, and 1721021.

ED05: 2:30-2:40 p.m. STEP UP: Analyzing Student Perceptions of Physics Following a Career in Physics Lesson*

Contributed – Thomas B. Head, Texas A&M University - Commerce, 4900 Joe Ramsey Blvd. E, Greenville, TX 75401; thead2@leomail.tamuc.edu

Robynne M. Lock,Allan Teer, Texas A&M University - Commerce

Zahra Hazari, Geoff Potvin, Florida International Unviersity

In fall 2018, we conducted an experimental study on the effects of the project interventions, including the Careers in Physics lesson. In this lesson, students explored the profiles of modern day physicists and the many career options available to physics majors. The students then connected physics to their own career aspirations. In this talk, we discuss how students' perceptions of physics align with their own career goals. Students' career goals are analyzed under the framework of agentic and communal goals. We examine to what extent the lesson communicates that communal goals align with physics and how this perception varies with gender. Data collected include student open-ended survey responses, survey items, and student work such as a career profile in which students envision themselves achieving their career goals with a physics degree.

*This work is supported by the National Science Foundation under Grant No. 1720810, 1720869, 1720917, and 1721021.

ED06: 2:40-2:50 p.m. STEP UP: An Examination of Teachers' Changing Beliefs about Discrimination During the Implementation of Classroom Lessons on Women in Physics*

Contributed – Camila Monsalve, Florida International University, 11200 SW 8th St., Miami, FL 33199; cmons002@fiu.edu

Geoff Potvin, Zahra Hazari, Florida International University

Robynne M. Lock, T. Blake Head, Texas A & M University - Commerce

This talk reports on work related to the STEP UP project. STEP UP is focused on mobilizing high school teachers to inspire more female high school students to pursue physics majors in college. Participating high school teachers are asked to teach two lessons about physics careers and women's representation in physics. Teachers' own beliefs regarding women's discrimination in physics are important to understand, both in terms of how these beliefs affect the way they implement the lesson and what teachers learn from the experience. Surveys and interviews were conducted with both teachers and students in high schools in three regions of the U.S. We will present an analysis of how teachers' and students' beliefs shift after the lesson on women's representation.

*This work is supported by the National Science Foundation under Grant No. 1720810, 1720869, 1720917, and 1721021.

ED07: 2:50-3:20 p.m. STEP UP: Discussing the Implementation of Strategies with High School Physics Teachers*

Invited – Bree Barnett Dreyfuss, Amador Valley High School, 1155 Santa Rita Rd., Pleasanton, CA 94566; BreeBarnettDreyfuss@gmail.com

Colleen Epler-Ruths, Brian Kays, Susan Johnston, Dr. Jolene Johnson

The STEP UP project includes Master Teachers who participated in the initial research phase of the project and teacher Ambassadors that will prepare other teachers to implement the classroom materials. The Master Teachers helped refine and test the engagement strategies amongst their high school students to facilitate the development of students' physics identities, engage more female students, and encourage them to consider pursuing a bachelor's degree in physics. The Ambassadors will lead the projects' propagation efforts by coordinating teacher workshops and providing support to physics teachers in implementing the materials. In this moderated panel, both Master Teachers and Ambassadors will discuss their perspectives on all of these activities.

*This work is supported by the National Science Foundation under Grant No. 1720810, 1720869, 1720917, and 1721021.

Session EE Sharing Approaches to Meaningful Writing in intro Labs

Location: MH - Birch **Sponsor:** Committee on Laboratories **Co-Sponsor:** Committee on Space Science and Astronomy
Time: 1:30–3:30 p.m. **Date:** Tuesday, July 23 **Presider:** Helen Cothrel

EE01: 1:30-2:00 p.m. An Integrated Model for Teaching Writing in the Introductory Laboratory*

Invited – Scott W. Bonham, Western Kentucky University, 1906 College Heights Blvd., Bowling Green, KY 42101; Scott.Bonham@wku.edu

Because it is a challenge to learn to write scientifically, many students can benefit from a good pedagogical approach to help them master this important, complex skill. Different pedagogical strategies have been used for teaching students writing: repeated practice, instructor feedback, good—and maybe not so good—examples, explicit grading rubrics, pre-lab questions, and scaffolding where students focus on just one section at a time, building up towards a complete report. In this talk I will describe a pedagogical model that we developed to incorporate all of these elements together to support students learning to write in our introductory physics lab. I will also share evidence that demonstrates its effectiveness in improving student writing skills that we have collected from surveys, lab reports, and final exams. I will also discuss some experiments in using student peer review, results and lessons learned.

*Supported in part by the NSF through grant DUE-0942293

EE02: 2:00-2:30 p.m. Incorporating the Scientific Practice of Lab Notebook Documentation into Physics Lab Courses at All Levels

Invited – Heather Lewandowski, University of Colorado, CB 440, Boulder, CO 80309; lewandoh@colorado.edu

Jacob Stanley, University of Colorado

Documentation of plans, procedures, results, interpretations, and in-the-moment thinking while working on a physics experiment is an authentic scientific practice. We have studied how experts learn how to keep a lab notebook and their professional practices while keeping a notebook. Additionally, we have studied the outcomes from replacing lab reports with lab notebooks as the primary course artifact in both introductory and upper-division level labs. Using these data, we will present recommendations for incorporating lab notebooks into lab classes and some outcomes from our own courses.

EE03: 2:30-2:40 p.m. The Feasibility Proposal: An Alternative to Lab Reports

Contributed – Stefan A. Jeglinski, UNC Chapel Hill, 130 E Cameron Ave., Chapel Hill, NC 27599; jeglin@physics.unc.edu

A course in Physical Computing, modeled after one of the same name at the Tisch School of the Arts at NYU, has been developed. The course is project and Makerspace oriented, and focuses on sensing, computing, and interacting. In lieu of lab reports, students write and implement a feasibility proposal that parallels their physical project work. In contrast to the typical elements of Abstract, Analysis, and Discussion in a formal lab report, student focus on Abstract, Background, Significance, Technical Objectives, and How to Measure Success – all elements of real proposals submitted as SBIRs, STTRs, or requests for internal company funding. Students learn as much about written organization and communication as they would by writing a lab report, but also gain valuable knowledge about real-world scientific proposals. I will present examples of the evolution of student understanding and skill in writing such a proposal, outcomes, and student feedback.

EE04: 2:40-2:50 p.m. Exit Tickets for Formative Writing Practice

Contributed – Bradley K. McCoy, Azusa Pacific University, 901 E Alosta Ave., Azusa, CA 91702; bmccoy@apu.edu

Depending on course goals, short in-class writing exercises may be more effective for learning than longer lab reports. For example, if a course objective is for students to draw conclusions from their data, this objective can be practiced without writing all portions of a full lab report. In this talk, I describe the purpose, design, and implementation of Exit Tickets, short formative writing assignments that students complete at the end of each lab experiment.

EE05: 2:50-3:00 p.m. Reflection and Analysis of Peer Review in Junior Physics Lab

Contributed – Karen A. Williams, East Central University, 1020 E. 6th Ada, OK 74820; kwillims@mac.com

Peer review was implemented in Junior Physics Lab the last two semesters that the course was offered. The students used the rubric that was used to grade their formal lab reports to grade each other's reports before turning the reports in for grading by the professor. The effectiveness of peer review on their scores will be examined. The peer review class scores will be compared with non-peer review lab scores and non-peer review class scores.

EE06: 3:00-3:10 p.m. Supporting Claims with Evidence: Scaffolding Student Lab Writing*

Contributed – Krista E. Wood, University of Cincinnati, 9555 Plainfield Rd., Cincinnati, OH 45236; Krista.Wood@uc.edu

Kathleen Koenig, University of Cincinnati

Lei Bao, The Ohio State University

How can we get students to make valid claims supported with evidence? In our labs designed to develop students' scientific reasoning skills, we found that students struggled with stating valid claims based on evidence. In addition, students had difficulty coordinating theory with evidence. We redesigned our lab curriculum to intentionally scaffold students through this process. The redesigned lab curriculum was implemented during spring 2019. We will share how we scaffolded the writing of evidence-based claims that coordinates theory with evidence, as well as how student writing of evidence-based claims improved.'

*Partially supported by NSF IUSE DUE 1431908

EE08: 3:20-3:30 p.m. Better Lab Learning; Easier Lab Grading

Contributed – Mark Schober, Trinity School, 101 W 91st Street, New York, NY 10024; jmschober@gmail.com

In my introductory physics course, labs are used to develop fundamental science concepts, build laboratory skills, and assess laboratory skills — but not at the same time. Matching labs with particular purposes breaks down the idea of "lab" into manageable pieces for the students, and for me, too, when it comes to assessed labs. I assess several lab skills at a time according to a list of lab objectives based on the NGSS Science and Engineering Practices and the needs of my physics course. Students work in teams to demonstrate their abilities relative to selected lab objectives, and I assess their work according to the objectives. In my observation, students learn laboratory skills better, and it is easier for me to give students specific, useful feedback.

Session EF Physics Labs for Life Science Students

Location: MH - Amphitheater **Sponsor:** Committee on Apparatus **Co-Sponsor:** Committee on Educational Technologies
Time: 1:30–3:10 p.m. **Date:** Tuesday, July 23 **Presider:** Ralf Widenhorn

EF01: 1:30-2:00 p.m. Take a Deep Breath – Physics of the Respiratory System

Invited – Nancy Donaldson, Rockhurst University, 1100 Rockhurst Rd., Kansas City, MO 64110; nancy.donaldson@rockhurst.edu

The Physics of the Respiratory System Module is an NSF-funded, vetted, curricular resource on the Living Physics Portal – an online, community-sourced platform for physics for the life sciences faculty. Using hands-on active learning curriculum, this module guides students through an investigation of the mechanics of breathing and the pressure differences that guide air flow in health and disease. The target learning audience is students pursuing graduate school/careers in medicine or healthcare. Module activities address Pre-Health Competency E3 (Demonstrate knowledge of basic physical principles and their applications to the understanding of living systems) and Foundational Concept 4B (Importance of fluids for the circulation of blood, gas movement, and gas exchange) and are directed toward an application of physics to medicine. This Living Physics Portal curriculum includes complete instructor resources including pedagogy, materials, all solutions to qualitative and quantitative assessment questions, building instructions, and suggestions for use in different educational environments.

EF02: 2:00-2:30 p.m. The Drinking Bird: Converting Low-quality Energy into High-quality Energy

Invited – James P. Vesenka, University of New England, Department of Chemistry and Physics, Biddeford, ME 04005; jvesenka@une.edu

Anyssa Fisher, University of New England

The drinking bird (DB) converts low-quality thermal energy to high-quality mechanical energy, conceptually similar to energy transitions that have enabled life to develop on Earth. We interviewed a range of student and faculty participants based on a list of energy questions exploring the DB as a model for biological energy conversion. The responses indicate that the subtle energy interactions in this deceptively simple toy are difficult to disambiguate without a systematic development of energy concepts. Participant explanations occasionally included irrelevant prior knowledge (e.g. capillary action) and often excluded one of the most important elements that drive DB's motion, namely the thermal energy of dry air responsible for evaporating water from the beak. Responses have informed us of changes to be made in our instruction in order to develop a more holistic IPLS presentation of energy.

EF03: 2:30-3:00 p.m. Bodies-on Lab Activities

Invited – Nancy Beverly, Mercy College, 555 Broadway, Dobbs Ferry, NY 10522; nbeverly@mercy.edu

The algebra-based introductory physics course for pre-health students at Mercy College is run in a workshop style, allowing students to integrate hands-on and bodies-on activities in every class. As much as possible, students do activities where their own bodies are part of the experiment or demonstration. In the biomechanics portion of the course, the bodies-on activities naturally predominate, as measurements of their own movement and forces are easy to acquire, and their own kinesthetic sense can help reinforce their physics intuition. However, students' interest in their own body functioning in bodies-on activities, throughout the entire two-semester course sequence, helps motivate their exploration of underlying physical mechanisms of body senses and processes, connected to a wide range of physics concepts. Examples of these bodies-on activities, of varying time scales from 1 minute to 45 minutes, will be presented.

EF04: 3:00-3:10 p.m. Exploring Mindset and Response to Failure in Reformed IPLS Labs

Contributed – Jordan M. Gerton, University of Utah, 115 South 1400 East, RM 201, Salt Lake City, UT 84112; jgerton@physics.utah.edu

Jason May, Claudia De Grandi, Lauren Barth-Cohen, University of Utah

Lisa Corwin, University of Colorado Boulder

Shayla Shorter, Jennifer Heemstra, Meredith Henry, Emory University

Failure as a part of Learning: A Mindset Education network (FLAMEnet) is a diverse consortium of science education practitioners and researchers studying the impact of mindset interventions on student success and persistence in various instructional contexts. Through FLAMEnet, research-based interventions are co-constructed and deployed at diverse institutions. At the University of Utah, we are reforming a large-enrollment introductory physics for life sciences (IPLS) lab sequence and have implemented an intervention consisting of a sequence of short reflection prompts that students complete throughout the semester at strategic points in their investigations. These individual reflections are used by student teams to create short digital communications (e.g., YouTube videos) that discuss strategies for overcoming challenges in the course, which can then be used to help motivate future students. An overview of the FLAMEnet interventions will be presented along with a preliminary analysis of the individual reflections from the Utah IPLS labs.

Session EG Teaching and Engaging Students at HSIs

Location: MH - Cedar **Sponsor:** Committee on Diversity in Physics **Time:** 1:30–3:30 p.m. **Date:** Tuesday, July 23
Presider: Juan Burciaga

EG01: 1:30-2:00 p.m. Engaging and Empowering Students Through Promoting Change at FIU

Invited – Laird Kramer, Florida International University FIU, STEM Institute, VH 140C, Miami, FL 33199; Laird.Kramer@fiu.edu

Transformation of STEM learning at Florida International University (FIU) began in the physics department in 2003. Early efforts established Modeling Instruction, transformed labs and launched an undergraduate Learning Assistant (LA) program. Foundational to these efforts was intentional engagement of FIU's diverse students through authentic and culturally responsive mechanisms, leading to improved learning, attitudes about physics, and student success. The result of these other coordinated reforms was a dramatic increase in the number of physics majors at FIU. The early work was used to create momentum to continue and expand educational change on campus, leading to an institution-wide STEM education transformation movement that engages students, faculty and administrators. FIU is a public research university in Miami, Florida serving over 58,000 students, the majority of which come from historically underrepresented groups. The discussion will focus on the mechanisms, strategies and partnerships that are enabling FIU's students to thrive.

EG02: 2:30-3:00 p.m. Preparing Students for the Fourth Industrial Revolution at an HSI

Invited – Paul J. Walter, St. Edward's University, 3001 S. Congress Ave., Austin, TX 78704-6425; pauljw@stedwards.edu

Andrea Holgado, Raychelle Burks, Charles Hauser, Bilal Shebaro, St. Edward's University

Having received an NSF Improving Undergraduate STEM Education: Hispanic-Serving Institutions (IUSE-HSI) grant, the newly established Institute of Interdisciplinary Science at St. Edward's University in Austin, TX, aims to prepare students for the fourth industrial revolution. The institute provides an infrastructure that promotes students' workforce training, cross-sector cooperation, and interdisciplinary opportunities for faculty and students. The institute will: (i) coordinate on-campus interdisciplinary seminars in conjunction with experiential learning events that will challenge us to explore complicated problems with cross-disciplinary approaches; (ii) organize cross-sector cooperative agreements with public and private entities around the Austin, TX, area and beyond; (iii) expose STEM majors to the postgraduate landscape by networking them with employers and graduate programs through guaranteed internships; (iv) finance faculty and student professional development by offering awards to faculty and micro-credentialing scholarships to students; and (v) catalyze faculty advancement, interdisciplinary collaborations, and innovative research by offering research opportunity awards.

EG03: 3:00-3:30 p.m. Alma Project: Cultivating Cultural Capitals in Physics through Reflective Journaling

Poster – Kim Coble, San Francisco State University, 1600 Holloway Ave., San Francisco, CA 94132-1740; kcoble@sfsu.edu

Khanh Tran, Imani Davis, Arreguin Mireya, Alejandra Lopez Macha, Marissa Harris, Michaela Perez, San Francisco State University

Alegra Eroy-Reveles, University of California, Santa Cruz

Reflective journaling has been shown to promote positive, meaningful learning experiences. At San Francisco State University, the Alma Project was created to support and encourage connections to the life experiences of STEM students through reflective journaling. Pulling from frameworks in Ethnic Studies and social psychology, the Alma Project aims to make learning STEM more inclusive by affirming the intersectional identities and cultural wealth of students in STEM classrooms. In spring 2017, the Alma Project was piloted in select sections of the Supplemental Instruction (SI) program, which offers 1-unit courses that support "large lecture" STEM classes. In fall 2018, the project was expanded to all SI classes and to all introductory physics and astronomy labs. Each month, students spend 5-10 minutes responding to questions designed to affirm their values and purpose for studying STEM in college. Students also spend time in class sharing their responses, including common struggles and successes.

EG05: 3:00-3:30 p.m. Constructing STEM Mentorship Pathways to Empower Students in Low Socioeconomic Communities

Poster – Brandon Rodriguez, NASA Jet Propulsion Laboratory, 4800 Oak Grove Dr., Pasadena, CA 91101; brandon.rodriguez@jpl.nasa.gov

Shirley Yong, Malak Kawtharani, Pasadena City College

In this workshop we will explore how we have developed a science pipeline within K-12 schools. With one volunteer from NASA, we were able to train local college students on activities based on upcoming space missions. These students then in turn volunteered at a local high school, mentoring these students, who in exchange recreated these activities at a neighboring middle school. Utilizing this ripple effect from one scientist led to a passion for science and sharing that excitement down the pipeline. Now in its second year, what was once a point source, is now hundreds of students being visited a handful of times of year by familiar faces from within their community, each continuing to reaffirm their peers about their potential as future scientists. This presentation will highlight the hands-on activities we used to train the student volunteers, the data showing favorable perception of science, and highlight simple methodologies to implement similar mentorship pathways in your school.

EG06: 3:00-3:30 p.m. Report on the EUPP-HSI Conference

Poster – Juan R. Burciaga, Colorado College, 14 E. Cache La Poudre, Colorado Springs, CO 80903-3243; jburciaga@coloradocollege.edu

In January 2019 AAPT and NSHP jointly sponsored a conference on Enhancing Undergraduate Physics Programs at Hispanic Serving Institutions (EUPP-HSI). The conference report summarizes the discussions at the conference; suggests practices of physics teaching, learning and mentoring at HSIs; and provides a list of recommendations for program change initiatives for physics departments, professional societies, and funding agencies.

Session EH Professional Skills for Graduate Students

Location: MH - Arches **Sponsor:** Committee on Research in Physics Education **Co-Sponsor:** Committee on Graduate Education in Physics
Time: 1:30–3:30 p.m. **Date:** Tuesday, July 23 **Presider:** Hannah Sabo

This interactive panel focuses on developing professional skills for graduate students and other early-stage researchers. This session will address professional concerns brought up by graduate students during the past Graduate Student Topical Discussions. Topics covered may include: preparing for careers after graduate school, becoming integrated with the community, developing research skills, and disseminating your work. While this session is aimed toward graduate students, we welcome undergraduates who are interested in this professional development opportunity or curious about life as a graduate student!

Session EI Science and Society: Towards Teaching a Structural Understanding of Science

Location: MH - Canyon **Sponsor:** Committee on Research in Physics Education **Co-Sponsor:** Committee on Women in Physics
Time: 1:30–3:30 p.m. **Date:** Tuesday, July 23 **Presider:** Deepak Iyer

In this session, our goal is to connect physics educators, physicists, and physics education researchers with the community that studies the larger contexts in which science is done — power structures, socio-political issues, militarism, for example— and bring their insights into science education, physics in particular. In a sequence of invited presentations, speakers will raise and discuss questions pertaining to the ownership of science and its products, the role of capital and private corporations in science, the marginalization of indigenous knowledges and epistemologies and the corresponding strong focus on eurocentric means of "knowing," the separation of technical from social ways of knowing, and how these ideologies of individualism, meritocracy, technocracy, and eurocentrism impact ways of thinking about climate change, nuclear power, invasive technologies, data, and related issues. These will be followed by a guided discussion session with the active participation of the audience. We strongly believe that such participation is crucial to beginning and sustaining a dialogue on this subject and internalizing these notions so that it influences how we as a community think about physics and physics education.

EI01: 1:30-2:00 p.m. What Young and Aspiring Engineers Should Know About Structural Violence

Invited – David A. Banks, 46 Belle Ave., Troy, NY 12180-4802; david.adam.banks@gmail.com*

Engineers are responsible for building some of the most consequential pieces of our technological world. Much like lawyers are essential to the writing and passage of law and policy, engineers are inextricably linked to how things get built and who benefits from their existence. However, unlike lawyers (or doctors, or teachers), and with the exception of structural failure, engineers are rarely asked to consider the ethical consequences of their work. If issues like climate change or the carceral state are to be truly dealt with, engineers will have to do better than off-loading the moral dimensions of their work to the people who hired them. Engineers, instead, must be taught how to think through and integrate structural violence theory into safety pedagogy. In other words, ideals such as reparations and dignity must be just as important as tensile strength or maximum load capacity.

*Sponsored by Deepak Iyer, Ayush Gupta and Chandra Turpen

EI02: 2:00-2:30 p.m. "Service Science" and the Urgency to Reimagine How STEM Helps Communities in Need

Invited – Yanna Lambrinidou, Virginia Tech, 6687 32nd Street NW, Washington, DC 20015; pnalternatives@yahoo.com

When examining the causes of environmental injustice, we typically focus on corporations and governments that promote the interests of the few to the detriment of the many. I foreground a third institution that can contribute to the harm: 'service science.' Implemented under umbrella concepts such as 'community engagement' and 'citizen science,' 'service science' is a growing branch of STEM that brings scientists and engineers into communities in need with the purpose to 'do good.' I suggest that 'service science' is not inherently 'neutral,' 'objective,' or 'altruistic.' Rather, it is a political act, often informed by a dominant discourse that privileges the views of experts over those of the communities they aim to help. Consequently, 'service science' can systematically augment the power of STEM while replicating the very inequities at the root of environmental injustice. I posit that reimagining how STEM helps communities in need is not only necessary but also urgent.

EI03: 2:30-3:00 p.m. Re-Imagining "Western/Modern Science": "Othering" of the Non-West in the History of the Scientific Revolution

Invited – Amit Prasad, University of Missouri-Columbia, Department of Sociology, Columbia, MO 65211-6102; prasada@missouri.edu

Teaching of structural understanding of science has to confront the discursive imaginaries of "modern science" that constitute not just the non-West, but also people of color and women within the West as the "other." Such discursive imaginaries are often invisible, because, as social anthropologist Pierre Bourdieu pointed out in relation to dominant discourses that operate as doxa, they are internalized through repetition and as such become naturalized categories. Modern science is perhaps the most important constituent in the imaginary of the West and its superiority to the rest and as such this imaginary is imbibed through pedagogy and other forms of socialization. In this regard the Scientific Revolution, which is seen as marking the birth of modern science in Western Europe, becomes the point de capiton. In the presentation, I show how historical engagements with the Scientific Revolution started at a time when European colonialism was coming to an end and how they end up constituting the history and culture of the West as universal and the model for the rest of the world. I would also show how the historical framing of the origin of modern science in the West relies on "othering" of the non-West, in particular that of the Asians. The issue at stake in confronting such West-centric discursive imaginaries, I further argue, is not simply to critically interrogate the history of modern science, but to also make our students and citizens better equipped to engage with the dramatically changing global landscape of science and technology.

Session EJ Early Career Topical Discussion

Location: MH - Aspen **Sponsor:** Committee on Research in Physics Education **Time:** 1:30–3:30 p.m. **Date:** Tuesday, July 23
Presider: Daryl McPadden

Postdocs, new faculty, and other junior Physics Education Research (PER) members are invited to this topical discussion to meet and discuss common issues. As this stage in a career can be a period of significant transition, we are hoping to provide a space to facilitate community building, resources, and professional development for those starting a career in PER. The session format will be an open discussion about identifying what are the needs of early career members in the community, how can we plan strategies to address those needs, and how to build the support structures for that community. We will ask participants to discuss these topics in small groups first, then share those ideas with the room.

No abstracts submitted

Session EK Cutting-edge Physics in Developing Countries

Location: CC - Cascade C **Sponsor:** Committee on Contemporary Physics Co-Sponsor: Committee on International Physics Education
Time: 2–3 p.m. **Date:** Tuesday, July 23 **Presider:** Kenneth Cecire

EK02: 2:00-2:30 p.m. Implementing Cutting-edge Astronomy Research in Developing Countries

Invited – Anushka U. Abeysekara, University of Utah, 909 University Village, Salt Lake City, UT 84108; a.abeysekara@utah.edu

Physics research is not a widely discussed topic in many developing countries. Scientists in those countries face many issues. The prominent problems that were identified are the lack of research culture among students and educators, adequately trained human resources, and scientific isolation. Through close collaboration, the U.S. scientific community is helping these countries to overcome the issues mentioned above. Astronomy is an excellent research field to build research collaborations with developing countries because many observatories are now openly sharing data and analysis tools, and at the same time, the internet and computers are becoming affordable. The HAWC collaboration is an example of a significant scientific partnership between Mexico and the U.S. Since 2007, I collaborate with Mexican and Sri Lankan physicists in different fields. This talk summarizes our experiences in working with scientists from these two countries, how these collaborations mutually benefited both sides, and the future prospects on continuing.

Session EL Improving Student Understanding of Quantum Mechanics

Location: CC - Ballroom B **Sponsor:** Committee on Physics in Undergraduate Education **Time:** 1:30–3:30 p.m. **Date:** Tuesday, July 23
Presider: Alexandru Maries

EL01: 1:30-2:00 p.m. Improving Students' Understanding of Quantum Mechanics Using Research-validated Learning Tools*

Invited – Chandralekha Singh, University of Pittsburgh, 3941 Ohara Street, Pittsburgh, PA 15260; clsingh@pitt.edu

Learning quantum mechanics is challenging. To help improve student understanding of quantum mechanics concepts, we have been conducting investigation of the difficulties that students have in learning quantum mechanics and we are using research as a guide to develop Quantum Interactive Learning Tutorials (QuILTs) as well as tools for peer-instruction. The goal of QuILTs and peer-instruction tools is to actively engage students in the learning process and to help them build links between the formalism and the conceptual aspects of quantum physics. These learning tools focus on helping students integrate qualitative and quantitative understanding without compromising technical content. In this talk, I will discuss a framework for understanding students' difficulties with quantum mechanics and give examples of how research-validated learning tools and pedagogies can help students develop a good grasp of quantum mechanics.

*We thank the National Science Foundation for support.

EL02: 2:00-2:30 p.m. Teaching Quantum Mechanics with a Lab*

Invited – Enrique Galvez, Colgate University, 13 Oak Drive, Hamilton, NY 13346; egalvez@colgate.edu

I discuss the offering of a laboratory section of quantum mechanics. The lab experiments involve students setting up and conducting photon experiments. The setting-up phase takes two to three weeks of a three-hour lab period. Students do experiments, such as polarization Stern-Gerlachs, quantum erasing and entanglement. The goal is for students to exercise their understanding of quantum mechanics fundamentals and algebra with an apparatus that they set up from scratch. Besides the virtues of confronting issues related to experimentation, the labs provide vivid implementations of quantum mechanics, where optical elements are represented by operators, results are compared to those of bra-ket linear algebra, and seemingly counter-intuitive concepts are confirmed by real measurements that students perform. I will also present updates to our setup, which include sending entangled photons in opposite directions and a new demonstration of delayed choice involving a minor change to a standard single-photon interference experiment.

*Funded by NSF grant PHY1506321.

EL03: 2:30-3:00 p.m. Combined Simulation-tutorials to Support Visual Learning of Quantum Mechanics

Invited – Antje Kohnle, University of St. Andrews, School of Physics and Astronomy, St Andrews, KY16 9SS United Kingdom; ak81@st-andrews.ac.uk

Gina Passante California State University Fullerton

Analyzing, constructing, and translating between graphical, pictorial, and mathematical representations of physics ideas and reasoning flexibly through them is a key characteristic of expertise but challenging for learners to develop. This presentation will discuss resources intentionally designed to support the development of graphical/visual understanding and representational competence in quantum mechanics that combine interactive computer simulations and University of Washington style tutorials. We describe how learning theories have shaped the overall structure of the simulation-tutorials, whereby students first work on problems independently, constructing representations they will later see in the simulation followed by further problems with simulation support, as well as the sequencing of individual questions and the use of sketching to learn. We present results from pre-, mid- and post-tests to assess transitions in student thinking.

EL04: 3:00-3:30 p.m. Improving Student Understanding of Quantum Mechanics Using Research-Validated Clicker Question Sequences

Invited – Paul D. Justice, University of Pittsburgh, 5715 Ellsworth Ave., Pittsburgh, PA 15232; paj42@pitt.edu

Engaging students with clicker questions is a frequently used evidence-based active-engagement pedagogy in physics courses because it has a lower barrier to implementation than other pedagogical approaches. Moreover, robust validated sequences of clicker questions are more likely to help students build a good knowledge structure of physics than individual clicker questions on various topics. I will discuss the development, validation and in-class implementation of sequences of clicker questions focusing on helping students learn quantum mechanics, taking advantage of the guided inquiry-based learning sequences in interactive tutorials on some on the same topics. The extensive research in developing and validating the clicker question sequences strives to make them effective for a variety of students in upper-level undergraduate quantum physics courses. I will also discuss what we have learned through this research and development process about the bandwidth of implementation of these sequences by different instructors and how students often get stuck either in 'math mode' versus 'physics mode' when answering challenging quantum mechanics questions.

Session EM PhysTEC in 50 States

Location: CC - Ballroom A **Sponsor:** Committee on Teacher Preparation **Co-Sponsor:** Committee on Physics in High Schools
Time: 2–2:50 p.m. **Date:** Tuesday, July 23 **Presider:** David May

EM01: 2:00-2:30 p.m. PhysTEC: Building a Solution to the National Physics Teacher Shortage

Invited – Monica Plisch, American Physical Society, 1 Physics Ellipse, College Park, MD 20740; plisch@aps.org

There is a severe national shortage of qualified high school physics teachers in the U.S. Since 2001, the Physics Teacher Education Coalition (PhysTEC) project has been working to engage physics departments in establishing the infrastructure needed to address the national physics teacher shortage. The project has developed model teacher preparation programs, disseminated information on effective practices, and advocated for teacher preparation within the physics community. PhysTEC Supported Sites have more than doubled their production of highly qualified physics teachers; they have also demonstrated considerable success in sustaining their programs beyond the funding period. The project has established a national coalition of more than 300 Member Institutions located in all 50 states, which collectively educate over half of the nation's highly qualified physics teachers. PhysTEC is a project of the American Physical Society and the American Association of Physics Teachers, with support from the National Science Foundation (#1707990).

EM02: 2:30-2:40 p.m. Learning About Teacher Recruitment and Retention from Our Math Department*

Contributed – Kushal Das, Texas State University, 601 University Dr., San Marcos, TX 78667-0747; k_d252@txstate.edu

Hunter G. Close, Texas State University

At Texas State University, there are many more pre-service secondary math teachers than physics teachers, despite a successful Physics Learning Assistant Program and many other recruitment and retention activities in the physics department. Math and physics high school teaching are similar in some ways, and it seems like the numbers ought to be more similar than they are. We aim to understand from the point of view of these math teachers, what factors contribute to their recruitment and retention in their program. To learn this, we invited all of these teachers to respond to an electronic survey about their experiences in their program, and we invited a subset of those respondents to follow-up focus group discussions. We will present our findings from the surveys and interviews, emphasizing points of contrast between the physics and math teacher preparation programs.

*This work is supported by NSF DUE 1557405.

EM03: 2:40-2:50 p.m. Meaning and Purpose in the Pursuit of Physics Teaching Careers*

Contributed – Hunter G. Close, Texas State University, San Marcos, TX 78666; hgclose@txstate.edu

any factors enter into the decision to teach high school physics: scholarships and salary, working conditions and hours, professional preparation and support, job satisfaction, etc. Another element is how teaching might contribute to one's sense of meaning and purpose in life. To investigate the dynamic interplay between the path of teaching and the human spirit, I developed the "Journeys" interview protocol, which adapts archetypal forms from the Hero's Journey (Campbell, 1949) to the journey of earning a bachelor's degree in physics and pursuing teacher certification; I used this protocol as a basis for discussion with several physics teacher candidates at Texas State University. In this talk I will describe the development and content of the protocol and some of the initial results from interviews.

*This work is supported by NSF DUE 1557405.

Session EN Highlights of the PICUP Collection

Location: CC - Cascade A/B **Sponsor:** Committee on Physics in Undergraduate Education **Co-Sponsor:** Committee on Educational Technologies **Time:** 1:30–3:30 p.m. **Date:** Tuesday, July 23 **Presider:** Todd Zimmerman

EN01: 1:30-3:30 p.m. How Do You Put Python in Your Introductory Course?

Invited – Rhett Allain, Southeastern Louisiana University SLU, 10878, LA 70402; rallain@selu.edu

Solving physics problems with computer code should no longer be something reserved for upper level physics courses. With the introduction of tools like python and Glowscript, the barriers for students creating numerical calculations is very low. In this presentation, I will address the following questions: Why use python? How do you address student concerns about coding? How do you assess student understanding for numerical calculations?

EN02: 1:30-3:30 p.m. Incorporating Computational Exercise Sets into the Physics Curriculum

Invited – Deva O'Neil, Bridgewater College, 402 E College St., Bridgewater, VA 22812; doneil@bridgewater.edu

The physics program at Bridgewater College incorporates computer programming at all levels of the curriculum. By the time students reach upper-level coursework, they are expected to be able to complete assignments in python and Mathematica. Instructors have experimented with different models for incorporating computational exercise sets into Introductory Physics, Classical Mechanics, Electromagnetism, Math Methods, and Senior Capstone. Unexpected obstacles were encountered (especially at the introductory physics level), as well as noticeable benefits. Sample assignments (including exercise sets from the PICUP collection), student responses, and lessons learned will be discussed.

EN03: 1:30-3:30 p.m. Using PICUP Computational Exercise Sets in Upper-level Optics and Mechanics

Invited – Ernest Behringer, Eastern Michigan University, Department of Physics and Astronomy, Ypsilanti, MI 48197; ebehringe@emich.edu

At Eastern Michigan University, computational physics is a growing, and required, portion of physics programs. One barrier to increasing the amount of computation in the curriculum is the effort needed to develop new instructional materials that make use of computation. Fortunately, this effort can be reduced by using computational exercise sets (CES) from the PICUP collection. These CES are freely available to verified instructors and can be adapted to local student cohorts and needs. Here, the use of CES in an optics laboratory and in intermediate mechanics will be presented. The use of CES can help students learn to analyze laboratory data and quantify the limits of scientific claims. The use of CES can also help students to take on more realistic mechanical systems that cannot be treated with traditional techniques. Details regarding materials, implementation, and student response will be discussed.

EN04: 1:30-3:30 p.m. Chaos Experiments and Computer Modeling in the Advanced Lab

Invited – Eric Ayars, California State University, Chico, Campus Box 202, Department of Physics, CSU Chico Chico, CA 95929-0202; eayars@csuchico.edu

Chaos ensues in the Advanced Lab anyway, so why not model it? I will present a variety of chaotic systems: electronic simulations of the Duffing Oscillator and a bouncing ball on a vertically-driven floor, Kiers' Circuit, and a magnetic rotor in an oscillating B field. All of these systems are accessible to Advanced Lab students, and the chaotic electronic circuits are dirt cheap and easy to make. Simulation of the systems in Python requires only standard numpy/scipy libraries. Depending on the programming abilities of the students one can either give them a working program and let them explore parameter space, or turn them loose on the underlying differential equations.

EN05: 1:30-3:30 p.m. Mathematica PICUP Assignments: Examples, Support, and Assessments

Invited – Andy Rundquist, Hamline University, 1536 Hewitt Ave., Saint Paul, MN 55104; arundquist@hamline.edu

I'll talk about my experiences assigning, supporting, and assessing student projects using the Mathematica-based PICUP submissions I developed. Most are for upper-division courses ranging from Modern Physics to Theoretical Mechanics. I'll talk about the affordances of Mathematica and the decisions around whether to hide the details of built-in functions. I'll talk about using video conference software in class to allow students to help each other with their code. I'll also talk about utilizing screen recording approaches to assess student work. Most of my projects involve numerically solving differential equations. The ice-formation exercise set is a great example of taking a system that is symbolically solvable (when the outside temperature is fixed) and adding features that require numeric integration (like real temperature data).

Session EO Universal Design for Learning

Location: CC - Ballroom C **Sponsor:** Committee on Physics in High Schools **Co-Sponsor:** Committee on Teacher Preparation **Time:** 1:30–3:30 p.m. **Date:** Tuesday, July 23 **Presider:** Jacquelyn J. Chini

EO01: 1:30-2:00 p.m. What Are the Supports and Barriers in Introductory Physics Curricula for Students with Disabilities?

Invited – Erin Scanlon, University of Central Florida, 4111 Libra Drive, Orlando, FL 32816; erin.scanlon@ucf.edu

Westley James, Jillian Schreffler, Eleazar Vasquez, Jacquelyn J. Chini, University of Central Florida

To investigate how well the physics postsecondary education communities support variations in learners' skills, interests, and needs, we analyzed reformed, research-based introductory physics curricular materials through an accessibility lens, operationalized through the Universal Design for Learning (UDL) framework. The UDL framework proposes three guidelines and 31 finer-grained checkpoints which support curriculum development that provides all students equal opportunities to learn and engage with the course. Overall, we found little alignment between the physics curricula and the UDL guidelines. However, we also found ways in which the curricular materials aligned with the framework. Specifically, these curricular materials: supported planning and strategy development; fostered collaboration and community; clarified vocabulary and symbols; and highlighted patterns, critical features, big ideas, and relationships. The ways in which the curricular materials currently support learners with a variety of needs, abilities, and interests, examples of alignment and unalignment, and suggestions for future curriculum development will be discussed.

E002: 2:00-2:30 p.m. Teaching Physics: Lowering Access Barriers Using Universal Design for Learning

Invited – Amanda Lannan, 4221 Andromeda Loop N, Orlando, FL 32816-8008; amandalannan@Knights.ucf.edu

When courses are taught with a Universal Design for Learning (UDL) approach, learning opportunities are inclusive and effective for both students with and without disabilities. For many, though, the process of developing a highly rigorous course with the flexibility of UDL, may be overwhelming. By first examining the why, what, and how of our teaching, we are able to identify barriers our students frequently encounter. "Why do my students often have difficulty understanding a particular concept?" "What assignment or lesson do I receive the most questions?" "How do students engage?" Once the common obstacles are recognized, we can begin to offer students an additional way to learn and interact with the course. Practical applications, and useful resources such as accessible text, 2D/3D images, and virtual labs, will support physics instructors as they begin to facilitate the design and implementation of a flexible, responsive course.

E003: 2:30-3:00 p.m. Holistic Support for Success

Invited – Melanie Lee, 195 South Central Campus Drive, Salt Lake City, UT 84112; melanie.lee@utah.edu

Join us for an exploration of ways to support students holistically for success — in and out of the lab. We will identify tools to employ that keep you learner-centered in your engagement with students. Additionally, we will gain understanding about strategies to coach and support each student in your course.

E004: 3:00-3:10 p.m. Supporting Learner Variability in Physics Courses with a Universal Design for Learning Lens

Contributed – Westley James, University of Central Florida, 4000 Central Florida Blvd., Orlando, FL 32816; westley.d.james@knights.ucf.edu

Abdelkader Kara, Jillian Schreffler, Eleazar Vasquez III, Jacquelyn J. Chini, University of Central Florida

Students with disabilities are a significant portion of the college student population, but few instructors have received training on how to design courses to support this population. Our research team is working with instructors to address this by using a Universal Design for Learning (UDL) lens to identify barriers that could be reduced through accessible practices. This presentation will focus on a specific algebra-based introductory physics studio-mode course (taught by A.K). We will discuss how a perspective recognizing variability in learners is critical to this process. We will present strategies the instructor implemented in his class, including: providing time for students to reflect on their understanding of new concepts, incentivizing a reduced distraction environment, and providing opportunities for students to re-earn points lost on tests. We will also present how the research team disseminated these practices to a new instructor who began teaching the same course for the first time.

E005: 3:10-3:20 p.m. Accessible Interactive Simulations for Learning Physics

Contributed – Amy Rouinfar, University of Colorado Boulder, UCB 390, Boulder, CO 80302; amy.rouinfar@colorado.edu

Emily B. Moore, University of Colorado Boulder

The PhET Interactive Simulations project at the University of Colorado Boulder, a resource that includes more than 150 popular free science and mathematics simulations, has been designing and implementing multiple new accessibility features into simulations to support access for students with disabilities - including students with visual impairments. These accessibility features include alternative input, auditory description accessible using many common screen readers, and sonification (non-speech sound). In this presentation, we will share our work developing accessible interactive physics simulations. We will introduce PhET simulations, describe our design process which includes iterative user studies with students who use screen readers, demonstrate some of our accessible simulations, and share resources that can support teachers in effective use of the simulations.

PLENARY: Mid-Infrared Quantum Cascade Lasers and Applications

Claire Gmachl
Princeton University

Quantum Cascade (QC) lasers are a rapidly evolving mid-infrared and THz semiconductor laser technology based on intersubband transitions in multiple coupled quantum wells. The lasers' strengths are their wavelength tailorability, high performance and fascinating design potential. They find primarily application in trace-chemical sensing for applications in environment and health. We will first give a brief introduction into QC lasers followed by a discussion of several recent highlights, such as the quest for high performance QC lasers and the implementation of unconventional laser schemes and new materials for intersubband devices. We will also briefly touch on several applications, such as field campaigns of QC laser-based sensing, and our recent work in non-invasive in vivo glucose sensing. The work presented has been conducted in collaboration with many valued colleagues in our own research group and across MIRTHE. Time permitting, I will present our recent efforts in tailoring introductory physics instructions for a diverse population of first-year engineering students.

4:00–5:00 p.m.
Tuesday, July 22

CC - Ballroom C

Session FA PER: Assessment, Grading and Feedback

Location: MH - Zion **Sponsor:** AAPT **Time:** 5:15–6:30 p.m. **Date:** Tuesday, July 23 **Presider:** TBA

FA01: 5:15-5:25 p.m. Influence of Assessment Features on Student Epistemologies in Physics

Contributed – Kelli Shar, University of Tampa, 6727 South Lois Avenue, Apt. 809, Tampa, FL 33616; kelli.shar@spartans.ut.edu

Rosemary S. Russ, University of Wisconsin

James T. Laverty, Kansas State University

Assessment is a fundamental aspect of education and usually is considered as a route to obtain information about student learning. Instead, this project explores the ability of physics assessment questions to send information to the students about what faculty and researchers think it means to know and do physics. We focused on the effects of assessment features on how students engaged with the assignment. To do this, we analyzed recordings of students completing a variety of introductory level physics problems for Epistemological Frame and Resource use. We found that Frame shifts are rare, but they can be triggered by a shift in Resource, which can be activated by assessment feature. This work extends existing work on epistemological framing into the realm of assessment and allows us to consider the effects of assessments on our students' understanding of physics teaching and learning.

FA02: 5:25-5:35 p.m. Comparing Learning Outcomes With and Without the Use of Simulations*

Contributed – Manher Jariwala, Boston University, 590 Commonwealth Avenue, Dept. of Physics, Boston, MA 02215; manher@bu.edu

Emily Allen, Andrew Duffy, Boston University

Computer simulations and supporting instructional materials for topics in mechanics were developed and investigated in a five-section, algebra-based, studio physics class. Simulations were implemented in a lab activity on collisions for three of the five sections, taking the place of hands-on equipment. The groups were reversed for a simple harmonic motion lab. A similar A/B research design was used to evaluate discussion-based activities, with simulations supplementing either a conservation of energy or rotational dynamics exercise. We compare learning outcomes between groups, based on an array of scores from quizzes, relevant exam questions, and pre/post testing using the Energy and Momentum Conceptual Survey (EMCS).

* Funded by NSF grant DUE 1712159.

FA03: 5:35-5:45 p.m. Comparing Student Learning Behavior Under Mastery-Based vs. Traditional Online Instruction

Contributed – Matthew W. Guthrie, University of Central Florida, 4111 Libra Drive, Orlando, FL 32816-2385; matthew.guthrie@ucf.edu

Zhongzhou Chen, University of Central Florida

Mastery-based online (MBO) learning has been the focus of recent studies aimed at improving the effectiveness of online physics education. While traditional instruction, practice, and assessments are organized separately in larger units, MBO learning integrates these elements into learning module sequences, enabling students to proceed based on individual mastery level. MBO homework has been shown to improve learning outcomes while generating more interpretable and informative learning data. However, MBO systems may lead students to focus on passing assessments rather than learning. To compare student learning and behavior under MBO and traditional systems, we created two forms of modules using each design principle for the same introductory physics level content. Two module sequences were assigned as homework to classes of approximately 250 students, and the two designs were switched between the classes after the first unit. This presentation will detail what we learned by analyzing student interaction throughout the two conditions.

FA04: 5:45-5:55 p.m. Developing and Sharing Weekly Topical Assessment for Introductory Mechanics

Contributed – Byron C. Drury, MIT 77 Massachusetts Avenue, Cambridge, MA 02139-4307; bdrury@mit.edu

Dave Pritchard, MIT

We have developed a comprehensive set of online topical quizzes for calculus based introductory mechanics courses. The quizzes are designed to be administered weekly or bi-weekly and take 30 minutes to complete. They are composed of questions from research validated assessments supplemented with questions tested on hundreds of students in both MOOCs and on-campus courses. We will make the quizzes available to interested college and high school instructors for use this fall. We present analysis of results from the administration of these quizzes to approximately 250 students across five classes. The online quizzes were administered concurrently with traditional rubric-graded written quizzes. We argue that weekly online assessment presents numerous advantages over traditional written tests. The online quizzes provide more reliable measurement of student ability, timelier feedback to both students and teachers, and already electronic data for education research, as well as reducing time spent grading.

FA05: 5:55-6:05 p.m. Do We Make Students Do Too Much or Too Little? A Cognitive Load Study

Contributed – Diego Valente, University of Connecticut, 2152 Hillside Road, U-3046 Storrs, CT 06269-3046; diego.valente@uconn.edu

Xian Wu University of Connecticut

Cognitive load theory is a useful theoretical framework in founded on principles of educational research. It grants us insights on how students perceive instructional interventions and assessments. Currently, one of the biggest challenges in cognitive load theory is developing a validated measurement instrument for the different aspects of cognitive load, i.e., intrinsic, extraneous and germane cognitive load, with little to no training given to students regardless of their level, major, and the content of instructional interventions. We have adopted a likert-scale survey to measure student cognitive loads in class. Two courses were included in the present study: one is a small enrollment introductory physics course specific to physics majors, and the other a traditional large enrollment engineering physics course. Statistical analysis was facilitated to reveal how this measurement instrument differentiates between three types of cognitive load. This study may shed light on further validation of this instrument.

FA06: 6:05-6:15 p.m. Exploring the Alignment of Laboratory Learning Goals Through E-CLASS Results*

Contributed – Rachel Henderson, Michigan State University, 567 Wilson Rd., East Lansing, MI 48824; hende473@msu.edu

Kelsey Funkhouser, Marcos D. Caballero, Michigan State University

Recently, the Michigan State University (MSU) physics department has transformed its introductory physics laboratory curriculum. In line with the AAPT Recommendations for the Undergraduate Physics Laboratory Curriculum, this newly transformed course, Design, Analysis, Tools, and Apprenticeship (DATA) Lab, emphasizes the development of experimental skills and laboratory practices and provides students with an authentic physics laboratory experience. In this presentation, we will discuss the differences in Colorado Learning Attitudes and Science Survey for Experimental Physics (E-CLASS) data between the context of the traditional laboratory course and the newly developed DATA Lab. Results showed a significant difference in post-test scores between the traditional laboratory and the transformed DATA Lab with the transformed course having a higher percentage of expert-like responses. Item-level statistics were also analyzed and results showed the largest post-test difference between the two courses for the E-CLASS items that were directly aligned with the DATA Lab learning goals.

*This work was supported by the Howard Hughes Medical Institute.

FA07: 6:15-6:25 p.m. Impact of Lab Curricula on Students' Critical Thinking Skills

Contributed – Cole J. Walsh, Cornell University, 118 Prospect St., Ithaca, NY 14850-5645; cjw295@cornell.edu

N.G. Holmes, Cornell University

Physics lab instruction has been receiving increased attention of late, with a larger emphasis being placed on developing students' experimentation and critical thinking skills. We investigate student responses to a diagnostic assessment aimed at evaluating students' critical thinking skills in a physics lab context --- the Physics Lab Inventory of Critical thinking. We compare student performance based on lab type, particularly to gauge the impact of labs taught using curricula transformed to teach experimentation and critical thinking. We also address variations in the effect of instruction across various student-level variables, as well implications of these results for future research and undergraduate physics lab transformations. Data used in this study are part of a growing dataset of student responses that includes over 4000 students from more than 30 institutions.

FA08: 6:02-6:35 p.m. Understanding Informal Physics Efforts Through Organizational Theory

Contributed – Dena Izadi, Michigan State University, 567 Wilson Rd., East Lansing, MI 48824; izadiden@msu.edu

Julia Willison, Michigan State University

Claudia Fracchiolla, University College Dublin

Noah Finkelstein, University of Colorado Boulder

Kathleen Hinko, Michigan State University - East Lansing, MI

We are undertaking a nationwide effort to develop a systemic understanding of the landscape of informal physics, including how informal physics programs are facilitated and assessed. We have collected initial survey and interview data along with some site visit field-notes for several different informal physics activities sponsored by physics departments in academic institutes and physics national labs. At this stage of the project, we are operationalizing existing organizational assessment tools and adapting them to our data. By making modifications to frameworks used to understand the functionality of the non-profit organizations, we have developed a codebook that could be used for large-scale data analysis. Here, we share findings from the responses of a number of institutes, as well as the challenges faced in data collection and methodology. Additionally, we invite facilitators, practitioners, and groups to contribute to the study.

Session FB PER: Student Understanding about Upper-Division Physics

Location: MH - Canyon **Sponsor:** AAPT/PER **Time:** 5:15–6:45 p.m. **Date:** Tuesday, July 23 **Presider:** TBA

FB01: 5:15-5:25 p.m. Student Interpretation of Eigenequations in Mathematics and in Quantum Mechanics*

Contributed – Megan Wawro, Virginia Tech, 1008 Willard Dr., Blacksburg, VA 24060; megan.wawro@gmail.com

John Thompson, University of Maine

Kevin Watson, Virginia Tech

Linear algebra, and eigentheory in particular, plays an important role in modeling quantum mechanical systems. Our research project investigates students' reasoning about eigentheory in quantum mechanics and how their language for eigentheory compares and contrasts across mathematics and quantum physics contexts. We discuss students' interpretations of a canonical mathematical 2x2 eigenequation and a spin-1/2 operator eigenequation. The data consist of video, transcript, and written work from individual, semi-structured interviews with 9 students from a quantum mechanics course. Students were first asked to explain what the equations meant to them and then asked to compare and contrast how they conceptualize eigentheory in the two situations. Results characterize students' nuanced imagery for the two eigenequations and highlight instances of both synergistic and potentially incompatible interpretations.

*This material is based upon work supported by the National Science Foundation under Grant Number DUE-1452889.

FB02: 5:25-5:35 p.m. Students' Connections between the Hamiltonian, Energy Eigenstates, and Eigenvalues

Contributed – Gina Passante, California State University Fullerton, 800 N. State College Blvd., Fullerton, CA 92831; gpassante@fullerton.edu

Zong Yu Wang, California State University Fullerton

Solving the time-independent Schrödinger equation in quantum mechanics involves finding the energy eigenvalues and eigenstates of a system, either by solving a differential equation (in the case of a position-space problem such as the infinite square well) or a matrix equation (in the case of spin-1/2 particles in a magnetic field). Despite the context, the relationship between the Hamiltonian, the energy eigenstates, and the energy eigenvalues is crucial to describing the time evolution of quantum systems. We present the results of surveys administered to students at two different points in the semester to probe their understanding of the connections between these three concepts. We find that while students appear to understand these topics on individual questions, when slight changes are made to the Hamiltonian, many students have difficulty recognizing the resulting changes to the eigenstates and eigenvalues. The results are being used to inform instruction on topics where understanding.

FB03: 5:35-5:45 p.m. Student Sense Making of Expectation Values in Different Quantum Mechanical Contexts

Contributed – Benjamin P. Schermerhorn, California State Polytechnic University Pomona, 3801 W Temple Ave., Pomona, CA 91768; schermerhorn@cpp.edu

Homeyra Sadaghiani, California State Polytechnic University Pomona

Gina Passante, California State University Fullerton

Steve Pollock, University of Colorado Boulder

Given the wide range of quantum mechanical systems (discrete and continuous) in which expectation values can be calculated, students' understanding and sensemaking of expectation values is a rich area for study. During one semester, 32 interviews were conducted across two universities with students enrolled in an upper-division spins-first quantum mechanics class. The first round of interviews involved a spin state in the y-basis and were given during the spins-half of the course. The second round followed during the wave functions portion of the course and asked about expectation values for a wave function composed of energy eigenfunctions and a parabolic wave function. This talk explores the portions of the interview protocol focused on students' sense-making of their calculated answer and on eliciting students general understanding of the expectation value. We seek to describe and compare student responses to questions of expectation value across the three different contexts.

FB04: 5:45-5:55 p.m. Bases and States: Student Learning of Perturbation Theory in Quantum

Contributed – Charles Joseph DeLeone, California State University, San Marcos, 1035 Honeysuckle Drive, San Marcos, CA 92096-0001; cdeleone@csusm.edu

Upper-division physics students often struggle with quantum concepts. Previous research has shown that student understanding of a phenomenon in one quantum basis does not always map to other quantum bases. Perturbation theory in quantum mechanics is another topic where mastery requires students to easily move between first-order energy terms represented as discrete matrix elements in the energy basis and as integrals in the position basis. Despite encountering the topic of switching bases earlier in their coursework it is not clear whether student can successfully apply this to perturbation theory. This talk will present the results of a pilot study that probes student understanding of first order perturbation theory as presented in different quantum mechanical bases. The talk will also discuss the pedagogical challenges associated with the teaching perturbation theory more generally.

FB05: 5:55-6:05 p.m. Student Difficulties with the Corrections to the Energy Spectrum of the Hydrogen Atom for the Zeeman Effect*

Contributed – Chandralekha Singh, University of Pittsburgh, 3941 Ohara St., Pittsburgh, PA 15260; clsingh@pitt.edu

Christof Keebaugh, Emily Marshman, University of Pittsburgh

We discuss an investigation of student difficulties with the corrections to the energy spectrum of the hydrogen atom for the Zeeman effect using the degenerate perturbation theory. The investigation was carried out in advanced quantum mechanics courses by administering free-response and multiple-choice questions and conducting individual interviews with students. We find that students share many common difficulties related to relevant physics concepts. In particular, students often struggled with mathematical sense-making in this context of quantum mechanics which requires interpretation of the implications of degeneracy in the unperturbed energy spectrum and how the Zeeman perturbation will impact the splitting of the energy levels. We discuss how the common difficulties often arise from the fact that applying linear algebra concepts correctly in this context with degeneracy in the energy spectrum is challenging for students..

*We thank the National Science Foundation for award PHY-1806691.

FB06: 6:05-06:15 p.m.. Advanced Students' and Faculty Members' Reasoning About the Double-Slit Experiment with Single Particles

Contributed – Ryan T. Sayer, Bemidji State University, 1500 Birchmont Dr. NE, Bemidji, MN 56601; Ryan.Sayer@bemidjistate.edu

Alexandru Maries, University of Cincinnati

Chandralekha Singh, University of Pittsburgh

We describe an investigation focusing on advanced students' and faculty members' understanding and reasoning about two questions related to the double-slit experiment with single particles. One of the questions posed was a standard double slit question while the other was more speculative. First, undergraduate and graduate students in advanced quantum mechanics courses were asked the questions in written form and six students were interviewed individually using a think-aloud protocol in which they were asked follow up questions to make their thought processes explicit regarding their responses to the questions. We also interviewed five faculty members who had taught modern physics, quantum mechanics and/or solid state physics to understand their reasoning and thought processes. All faculty members provided interesting responses to the more speculative question related to the double slit experiment with single particles and their responses shed light on what it means to think like a physicist. Student responses varied greatly in their correctness and sophistication of reasoning and suggested that while some advanced upper-level undergraduate and graduate students have come a long way in learning to think like a physicist, others need guidance and scaffolding support in order to develop the problem solving and reasoning skills characteristic of an expert physicist.

FB07: 6:15-6:25 p.m. Instructional Moves to Shift Upper Division Students' Epistemic Frames

Contributed – Christopher A. Hass, Kansas State University, 1701 Hillcrest Dr., Apt. 06, Manhattan, KS 66502; chris.hass@shaw.ca

Qing Ryan, California State Polytechnic University, Pomona

Eleanor C. Sayre, Kansas State University

We connect upper division students' use of mathematics and physical concepts using epistemic framing. Looking at classroom discourse and student problem solving, we use epistemic frames to find instructional moves that teachers use to shift students from unproductive frames to productive frames. Using qualitative analysis of video data of an upper division electromagnetism course, we analyze and catalog several moves used by teachers to help students during problem solving. In this talk we present these instructional moves, and the observed frameshifts they induce.

FB08: 6:25-6:35 p.m. Student's Conceptual Resources of Spherical Unit Vector in Upper-division E&M

Contributed – Ying Cao, Drury University, 900 N Benton Ave., Springfield, MO 65802-3791; ycao@drury.edu

Brant Hinrichs, Drury University

The resources framework has been applied in physics education research in many different contexts. Results have indicated that students can draw upon rich conceptual resources to make sense of difficult physics concepts with the help of appropriate instructional prompts. It is well-recognized that students have great difficulty understanding non-Cartesian unit vectors. However, the resources framework has only limitedly been applied to this problem. In this study, we applied the resources theoretical lens to analyze student interview data while they are solving problems involving non-Cartesian unit vectors in the context of upper-division E&M. We report our preliminary results and draw implications for possible instructional strategies.

FB09: 6:35-6:45 p.m. Identifying Student Ideas on Coordinate Systems from Calculus III Course

Contributed – Brian D. Farlow, North Dakota State University, 1211 Albrecht Blvd., Fargo, ND 58108; brian.farlow@ndsu.edu

Chaelee Dalton, Pomona College

Jordan Brainard, Warren M. Christensen, North Dakota State University

Our broad research goal is to develop research-based instructional materials to help students more effectively translate across the math-physics interface in the middle- and upper-divisions in the context of some vector concepts in various spatial coordinate systems. A portion of that effort is to understand and define the associated instructional gap between math and physics curricula. Thus, we began a study to analyze both the curricula and student understanding of that curricula in both calculus and upper-division physics courses. Previous analysis of popular calculus textbooks found that approximately 95% of their content is based on Cartesian coordinates with much of the remaining 5% being curvilinear content presented at a surface level (see Dalton et al). A follow-up survey of Calculus III students revealed an emerging understanding of vector concepts across coordinate systems. We report on this survey and how its results will inform future curriculum development.

Session FC PER: Attitudes/Beliefs about Students or Teaching

Location: MH - Arches **Sponsor:** AAPT/PER **Time:** 5:15–6:45 p.m. **Date:** Tuesday, July 23 **Presider:** TBA

FC01: 5:15-5:25 p.m. Faculty's Reasoning about Life Science Students: Varying Between Assets and Deficits*

Contributed – Adrian Madsen, American Association of Physics Teachers, 1100 Chokecherry Lane, Longmont, CO 80503; adrian.m.madsen@gmail.com

Mary Chessey, Chandra Turpen, University of Maryland at College Park

There is a growing body of literature that establishes that highly effective educators orient positively toward their students. This positive stance toward students may play out through acknowledging students' expertise and seeking to understand where students are starting from and supporting their growth. To better support physics faculty in teaching interdisciplinary physics courses, we can help faculty become more aware of their stances toward their students. We analyzed the ways that faculty reasoned about their life science students, documenting more asset-oriented and more deficit-oriented stances at different moments. For example, one faculty talked about his students' lack of preparedness with trigonometry as a constraint on what physics he can teach his life science students, while at other moments, he highly valued the physiology and biology knowledge they bring to his physics class. This analysis suggests ways of broadening the narratives that faculty use to understand their life science students.

*This work was supported under NSF grants #1624185 and #1624478.

FC02: 5:25-5:35 p.m. Situational Factors that Shape Faculty's Reasoning About Life Science Students

Contributed – Mary K. Chessey, University of Maryland College Park, 4150 Campus Dr., College Park, MD 20740; mchessey@umd.edu

Adrian Madsen, American Association of Physics Teachers

Chandra Turpen, University of Maryland College Park

As physics classrooms grow more varied in format from traditional lecture, college faculty interact with students across many different situations, including clicker responses, peer discussions, and concept inventory results. Similarly, the development of stronger interdisciplinary ties in some physics classes for life science majors also exposes physics faculty to interactions where students sometimes hold greater expertise in a subject area than their instructor. At the same time, institutional and environmental pressures, including class size, course structure, and instructional colleagues shape faculty's interactions with and understandings of their students. We analyzed the ways that physics faculty reasoned about their life science students, documenting more asset-oriented and more deficit-oriented stances at different moments. We report on how these situational factors related to faculty's reasoning about their life science students in patterned ways across episodes of storytelling in interviews.

*This work was supported by NSF#1624185 and #1624478.

FC03: 5:35-5:45 p.m. How Faculty Perceptions of Three-Dimensional Learning Change Over Time

Contributed – Lydia Bender, 1228 N 17th Street, Manhattan, KS 66502-4160; lgbender@phys.ksu.edu

James T. Laverty, Kansas State University

The Next Generation Science Standards aim to improve K-12 science learning through the implementation of Three-Dimensional Learning (3DL). 3DL was designed to increase student understanding of science by combining core ideas, crosscutting concepts, and scientific practices into science curricula, instruction, and assessment. In response to calls to bring 3DL to college courses, the 3DL for Undergraduate Science (3DL4US) collaboration created a fellowship to support faculty adoption of 3DL. During the fellowship, faculty members participate in discussions and activities during monthly meetings and in an online forum. The conversations between the fellows provide insight into how faculty think about and view 3DL, and how these views change over time. We analyzed these conversations to identify changes and the factors that led to those changes in order to improve future faculty development.

FC04: 5:45-5:55 p.m. The Baseline Data of the PTaP and FPTaP*

Contributed – Richard L. Pearson, Colorado School of Mines, 1523 Illinois St., Golden, CO 80401; rlpearson@mines.edu

Savannah L. Logan, Wendy K. Adams, Colorado School of Mines

Initial scoring results of the first, large data collection of two perceptions surveys will be presented here: the (student-facing) Perceptions of Teaching as a Profession (PTaP) survey and Faculty Perception of Teaching as a Profession (FPTaP). Both surveys measure each group's interest in and view of teaching as a career. Data has been collected across the United States in various types of institutions and disciplines. These initial results set the baseline of perceptions of teaching across the United States as we begin our efforts to transform those perceptions by getting the facts out about teaching as a profession.

*This project is supported by NSF DUE-1821710.

FC05: 5:55-6:05 p.m. Instructional Change of Physics Faculty

Contributed – Dina Zohrabi Alaee, Department of Physics, College of Arts and Sciences, Kansas State University, Manhattan, KS 66502; dindinzalaee@gmail.com

Linda E. Strubbe, Eleanor C. Sayre, Department of Physics, Kansas State University

Adrian M. Madsen, Sarah B. McKagan, American Association of Physics Teachers

As part of research on developing resources to support faculty change, we investigate how physics faculty approach changes to their teaching. The PhysPort team interviewed 23 physics faculty at diverse U.S. institutions about their instructional practices. Our research takes a faculty-centered perspective: what are the ways in which faculty think and talk about their teaching practice? In this talk, we report on a phenomenographic study of faculty approaches to and motivations for change. Our phenomenography explored six different themes: how faculty approach their teaching; their motivation to make changes; their assessment practices for change; resources that they use; how they use those resources; and challenges they experience in the term.

FC06: 6:05-6:15 p.m. Survey of Physics, Mathematics and Chemistry Faculty

Contributed – Melissa H. Dancy, University of Colorado, Department of Physics, Boulder, CO 80309; melissa.dancy@gmail.com

Naneh Apkarian, Charles Henderson, Western Michigan University

Jeff Raker, University of South Florida

Estrella Johnson, Virginia Tech

Marilyne Stains, University of Nebraska

We report initial findings from a survey of a representative sample of physics, mathematics and chemistry instructors in the United States. Faculty who recently taught an introductory course were asked about their instructional practices, knowledge of research based instructional strategies, local context, beliefs about teaching and learning, and personal background. The survey design allows us to document the extent to which faculty know about and use research-based pedagogies and to connect this use to correlating factors and to compare across disciplines.

FC07: 6:15-6:25 p.m. What Factors Influence Pedagogical Methods in Informal Learning Spaces?

Contributed – Michael B. Bennett, University of Colorado Boulder, 440 UCB, Boulder, Boulder, CO 80309; michael.bennett@colorado.edu

Brett Fiedler, Noah D. Finkelstein, University of Colorado Boulder

Informal physics education environments, such as the University of Colorado Boulder's Partnerships for Informal Science Education in the Community (PISEC) program, present unique opportunities to study instructors' pedagogical methods. Previous studies have observed that PISEC "University Educators" (UEs) tend to employ three broad pedagogical "modes" as they engage with PISEC students and that training in these modes influences UEs' stated pedagogical preferences. To complete an analysis of the factors that may influence UEs' pedagogy, we recorded in-situ video of their teaching and conducted semi-structured interviews involving, in part, stimulated recall of that video. These data were analyzed for examples of coordination and discoordination between UEs' stated and enacted preferences, as well as insight into the factors, both structural and emergent, that influence UEs' choices among the modes. We will present findings and discuss implications both for improving teacher preparation in PISEC and for connections to the formal sector.

FC08: 6:25-6:35 p.m. Personas of Undergraduate Physics Researchers

Contributed – Tra Huynh Kansas State University 116 Cardwell Hall, 1228 N. 17th St. Manhattan, KS 66506 trahuynh@ksu.edu

Adrian M. Madsen American Association of Physics Teachers

Eleanor C. Sayre Kansas State University

Engaging in undergraduate research supports students' professional development in physics. However, many departments struggle with how to pitch research projects to increasingly diverse student populations. In our research, we develop personas to help departments design appealing, fruitful undergraduate research programs. Creating personas is a common user-centered design technique where a rich set of qualitative data is synthesized into person-like archetypes. Personas represent the key characteristics and motivations of the students and feel like real people yet protect students' identity better than pseudonyms and anonymized case studies. In this talk, I will present personas as a methodology and a set of personas of undergraduate researchers developed from interviews with undergraduate physics students.

FC09: 6:35-6:45 p.m. Framing the Undergraduate Physics Experience as a Hero's Journey*

Contributed – Gabriel R. Mestas, Texas State University, 601 University Dr., San Marcos, TX 78666; g_m204@txstate.edu

Hunter G. Close, Texas State University

In an historical period in which students face a reality of ever increasing chaos, direction can be difficult to attain, especially in the murk of pursuing a degree as rigorous and attention-demanding as physics. Our project aims to frame the journey toward a physics degree as a heroic journey ("The Hero with a Thousand Faces", Campbell, 1949) in order to present discussion points for undergraduates to reflect upon their experience in a manner that connects them with the timeless mythological forms in which which they participate. We also coordinate stages of this journey with various observed subjective experiences for undergraduate STEM students, as reported in "Talking About Leaving", (Seymour, 1994). Our goal is to help students understand their experiences studying physics in a manner that promotes productive, responsible, prideful, and mentally healthy engagement in their own adventure of accomplishment.

*This work is supported by NSF DUE 1557405.

Session FD PER: Diversity, Equity & Inclusion

Location: MH - Bryce **Sponsor:** AAPT/PER **Time:** 5:15–6:45 p.m. **Date:** Tuesday, July 23 **Presider:** TBA

FD01: 5:15-5:25 p.m. Values Affirmation Study at the University of Illinois

Contributed – Tim J. Stelzer, University of Illinois, 1110 W Green St., Urbana, IL 61801, tstelzer@illinois.edu

Brianne Gutmann University of Illinois

A study from the University of Colorado at Boulder showed they were able to eliminate the gender gap through the use of two short writing activities. Inspired by these results, we conducted a replication study in two large introductory physics courses at the University of Illinois, Urbana Champaign. This talk will review the results from Boulder and describe the existing courses, population and relative performance before introducing the affirmation activities.

FD02: 5:25-5:35 p.m. Values Affirmation Study at the University of Illinois: Results/Discussion

Contributed – Brianne Gutmann, Texas State University at San Marcos, 749 N. Comanche St., San Marcos, TX 78666; brianne.gutmann@gmail.com

Tim Stelzer, University of Illinois at Urbana Champaign

A study from the University of Colorado at Boulder showed they were able to eliminate the gender gap through the use of two short writing activities. Inspired by these results, we conducted a replication study in two large introductory physics courses at the University of Illinois, Urbana Champaign. This talk will present results from the replication which were statistically different from the Colorado results and discuss possible reasons for the differences.

FD03: 5:35-5:45 p.m. Improving Physics Students' Self-Efficacy with a Brief Mindset Intervention

Contributed– Ian D. Beatty, UNC Greensboro, PO Box 26170, Greensboro, NC 27402-6170; idbeatty@uncg.edu

Stephanie J. Sedberry-Carrino, William J. Gerace, Michael J. Kane, UNC Greensboro

Jason Strickhouser, Florida State University

Helping more university students, especially under-represented minorities, complete STEM degrees and enter the STEM workforce has proven to be surprisingly difficult. Those most at risk benefit least from innovations addressing only pedagogy or curriculum. Research shows that we must influence students' self-efficacy: their belief that they can overcome setbacks and ultimately succeed. Our NSF-funded project is developing and validating a short, inexpensive, easily-used intervention to improve students' self-efficacy, suitable for any university STEM course. It builds on two different kinds of research-based intervention: "attributional retraining," about ascribing successes and failures to internal rather than external factors; and "growth mindset," about becoming smarter and more successful through perseverance and conscious attention to thinking and learning strategies. While interventions of demonstrated efficacy exist for each, none address both attribution and mindset, and none are suitable for widespread use in university-level STEM instruction.

FD04: 5:45-5:55 p.m. How Engineering Majors Reproduce and Challenge Meritocratic Ideologies*

Contributed – Hannah C. Sabo, University of Maryland, 3942 Campus Dr., College Park, MD 20742; hsabo13@gmail.com

Jennifer Radoff, Chandra Turpen, Ayush Gupta, Andrew Elby, University of Maryland

Meritocracy, a problematic worldview, conveys that "worth" accrues with an individual based solely on their own accomplishment. In physics culture, meritocracy is often paired with a technocratic ideology, which draws a line between technical and "soft" (e.g., social) skills and assigns more worth to the technical. Cultures of meritocracy and technocracy negatively affect equity and inclusion in STEM. Yet, students are steeped in these values during college, and PER interventions are rarely designed to disrupt the culture of meritocracy/technocracy. To inform such designed disruptions, we examine how STEM majors' views align and don't align with meritocratic/technocratic ideologies. Specifically, we present an example of undergraduate engineering students discussing the validity of adages such as "Some people are just superior to other people." Using tools of discourse analysis, we document how meritocratic and technocratic stances are reproduced or challenged in their talk.

*Work supported by NSF Grant 1733649.

FD05: 5:55-6:05 p.m. Research on Holistic Support of University STEM Students

Contributed – Angela Little, Michigan State University, Biomedical and Physical Sciences Bldg., 567 Wilson Rd., East Lansing, MI 48824; angie.little@gmail.com

Vashti Sawtelle, Michigan State University

There are a number of scholars programs at universities across the country that work to build supportive communities for students historically underrepresented in STEM fields. We will highlight one such program at a large primarily white midwestern research university. The staff who run this program have a number of innovative structures in place to support students holistically. We will share out research from interviews with these staff members. Lessons learned from this research are applicable to anyone interested in the work of supporting students holistically, particularly students who are navigating a transition to a new university environment.

FD06: 6:05-6:15 p.m. The Reproduction and Challenging of Technocracy in Peer-educators' Discourse*

Contributed – Ayush Gupta, University of Maryland, College Park, Room 1320 Toll Building, University of Maryland, College Park, MD 20740; ayush@umd.edu

Chandra Turpen, Jennifer Radoff, Hannah Sabo, Andrew Elby, University of Maryland, College Park

Ideologies of technocracy (distinguishing the social from the technical and valuing the latter more) and meritocracy have been mechanisms of reifying inequities within engineering education (and a version of this argument likely applies to physics education, too). We have been iteratively redesigning a pedagogy seminar for engineering peer educators working within a college-level introduction to engineering design course. Peer educators are uniquely positioned to do harm if ideologies of meritocracy and technocracy aren't challenged, and, likewise, to do good if they disrupt these ideologies in the introductory engineering design course. Using tools of discourse analysis, we analyze how technocratic stances are reproduced or challenged in engineering peer educators' talk within particular pedagogy seminar discussions. While situated in engineering, the discourses we document are likely prevalent in physics learning environments, too. We discuss implications of our findings for peer educator preparation programs in physics.

*This research is sponsored by NSF Award #1733649

FD07: 6:15-6:25 p.m. Role of Elite Universities in Improving Diversity Among Physics Faculty

Contributed – Lindsay Owens, Rochester Institute of Technology, 84 Lomb Memorial Drive, Rochester, NY 14623; lmosch@rit.edu

Jacob Mekker, Benjamin M. Zwickl, Scott V. Franklin, Casey W. Miller, Rochester Institute of Technology

The physics community is striving to encourage greater racial and gender diversity among graduate students and faculty. According to the APS, approximately 50% of students in physics graduate programs envision themselves as future faculty. We collected data from over 6500 current faculty and determined that one in six PhD graduates from the top 10% of programs (top 18 as ranked by NRC) secure a faculty position compared to an average of one in 29 from all remaining programs (programs 19-216). Our findings suggest that institutions disproportionately hire faculty who received their doctoral degree from elite institutions. Increasing diversity in elite programs cohorts has the potential to dramatically influence the diversity of future physics faculty. We strongly suggest the need for utilizing holistic practices in elite programs because of their equitable nature in terms of race and gender. (Supported by NSF-1633275)

FD08: 6:25-6:35 p.m. Can We Foster Autonomy within Communities of Practice?

Contributed – Claudia Fracchiolla, University College Dublin, 11 Obelisk Ave., Blackrock, Dublin Co A94 T2X3 Ireland; claudia.fracchiolla@ucd.ie

Brean Prefontaine, Kathleen Hinko, Michigan State University

Previous research shows that engaging in science outreach activities benefits academics in different ways, one of which is reinforcing their excitement about science. This, it is believed that this comes is in large part due to the fact that in the social space that provided by outreach provides, allows scientists to feel connected to their science community and experience a strong sense of purpose and enjoyment while engaging others in science activities. A person's physics identity is deeply related to one's perceived self-association with the field, therefore excitement about the field, connection with members of that community, and feeling that you are contributing to that community are strong indicators of identity development. In this project, we explore the development of physics identity, through participation in informal physics program by testing a blended-framework that incorporates the perception of the self (Self-Determination Theory), as well as a social context (Community of Practices).

FD09: 6:35-6:45 p.m. Scientific Modeling Instruction about Magnetism: Scaffolding for Equity

Contributed – Lauren Barth-Cohen, University of Utah, College of Education, 1721 Campus Center Drive, SAEC 3220 Salt Lake City, UT 84112-1107; Lauren.BarthCohen@utah.edu

Sarah Braden, Utah State University

Given the importance of scientific practices in Next Generation Science Standards, we implemented a middle school magnetism curriculum that forefronts scientific modeling. Students first explored an unexpected magnetic phenomenon, generated initial models, then collected data about magnetic properties and fields, and then revised their models. Finally, the students engaged in a series of small-group consensus building discussions to collaborate and revise their final models. In this presentation, participants will learn about how they can implement scientific modeling consensus building activities. Furthermore, drawing from our experiences, we will discuss how this approach can be used with English language learners to support those students in participating in meaningful scientific discourse. We will present scaffolds used to support students model revision and show examples of student work.

Session FE Interactive Video, Simulations, Gamification, and VR

Location: MH - Birch **Sponsor:** AAPT **Time:** 5:15–6:35 p.m. **Date:** Tuesday, July 23 **Presider:** TBA

FE01: 5:15-5:25 p.m. Interactive Video AND Simulations: A Powerful Combination

Contributed – Peter H. Bohacek, Henry Sibley High School, 14675 Afton Blvd. S, Afton, MN 55001; peter.bohacek2@gmail.com

Interactive video and computer simulations have both been shown to be effective tools for teaching science. We'll explore how simulations can be combined with interactive videos to create a new method with new advantages. Interactive video allows students to explore macroscopic effects, while simulations show particle-level interactions. Using this combination, we'll show examples of intermolecular forces affecting physical properties, motion of charge in RC circuits, and the mechanisms underlying greenhouse effect, and others. In each case, we'll see how interactive video can be combined with computer simulation to help students develop a powerful mental models for these phenomena.

FE02: 5:25-5:35 p.m. What's Interactive Video and How Can it Help Students Learn

Contributed – Matthew Ted Vonk, University of Wisconsin River Falls, 410 S 3rd. S River Falls, WI 54022; matthew.vonk@uwrf.edu

Peter Bohacek, ISD 197

Interactive video is a relatively new educational technology that lets students carefully observe high-resolution video of real phenomena. It's called interactive because students can manipulate online tools to make measurements for themselves and characterize the event depicted in the video. It's also interactive because students can change important parameters in the video. For example, when observing waves on a spring, students can independently change the frequency of the waves, the amplitude of the waves, or the tension in the spring. This freedom allows them to ask their own questions: "I wonder if the wave speed will increase if I speed up the frequency?" or "I wonder if the wave speed will decrease if I decrease the amplitude of the driver?" Another group of students in the same class might be curious about how the wavelength of the wave depends on the frequency of the wave. In each case, students can design and execute an experiment to answer their own questions. They can collect and analyze their own data, and draw data-driven conclusions.

FE03: 5:35-5:45 p.m. Teaching Science with Interactive Video Tutorials*

Contributed – Robert B. Teese, Rochester Institute of Technology, 54 Lomb Dr., Rochester, NY 14623; rbtsps@rit.edu

Kathleen M. Koenig, University of Cincinnati

Michelle Chabot, Rochester Institute of Technology

Alexandru Maries, University of Cincinnati

Interactive Video Vignettes (IVVs) were designed as short, ungraded, single-topic, online activities for physics students. However, the Vignette Studio software developed for them is also being used to make longer, more complicated activities. One project created 14 classroom modules for teaching biology. Each module included an IVV to be used as a pre-class priming activity. Another project made six pre-lab exercises for advanced-lab courses in physics. A current project is making Interactive Video-Enhanced Tutorials (IVETs) for teaching problem-solving in physics. Each IVET will lead the student through a solution using an important problem-solving approach (e.g., energy conservation) in physics. IVETs are based on multimedia learning principles and research on human learning and memory. They will also be affect-adaptive, which means that targeted help will be offered to students who report confusion, frustration, or other difficulties while working through the tutorial.

*Supported by NSF grants DUE-1821391 and DUE-1432286.

FE04: 5:45-5:55 p.m. Gamificiation of Learning: Circuit Games

Contributed – Gerd Kortemeyer, ETH Zurich Haldenbachstr. 44, Zurich, 8092 Switzerland; gerd.kortemeyer@let.ethz.ch

We describe the development and use of Kirchhoff's Revenge, a freely available computer game designed to teach circuit laws in introductory physics courses at the high school and undergraduate level. We share design principles, effort involved in developing and testing the game (using the Unity 3D platform), as well as experiences and player feedback. We also report on concept test results for time-independent scenarios (batteries, wires, and lightbulbs), where we find that learning gains are similar to those in traditional instruction, but inferior to investigative, physical laboratory experiments.

FE05: 5:55-6:05 p.m. Examining Interactive Simulation Use in an Informal Physics Program

Contributed – Brett Fiedler, University of Colorado at Boulder, 440 UCB Boulder, CO 80309-0440; brett.fiedler@colorado.edu

Emily Moore, University of Colorado at Boulder

Informal physics programs construct unique environments to introduce students to scientific practices, including hands-on experimentation. The programs often seek to promote science interest and reasoning with an emphasis on tangible exploration of physics concepts. Interactive simulations are designed with a similar goal to promote interest and deeper science reasoning of concepts connected to the real world. Therefore, simulation use presents an opportunity to supplement hands-on experimentation in informal settings. We investigate the impacts of using interactive simulations in informal physics programs by implementing PhET Interactive

Simulations into the Partnerships for Informal Science Education in the Community (PISEC) after school physics outreach program. We focus on how students engage with and use the simulations in a program designed around student agency and hands-on activities. Video data of group use of the simulations, including screen capture, are analyzed for student behavior and group discourse.

FE06: 6:05-6:15 p.m. Middle-School Student's Spatial Skill Influence on Understanding 3D Computer Visualization

Contributed – Colleen M. Epler-Ruths, Pennsylvania State University, 345 Epler Road, Northumberland, PA 17857; cmeruths@gmail.com

Spatial skills are predictors of a student's ability to understand science content such as force diagrams. With more computer availability in classrooms, teachers have access to computerized 3D visualizations that have previously been taught through flat models. Through mixed-methods, I investigated the hypothesis that 3D computer models will assist middle school learners with low spatial skills to better understand science content. Participants of various spatial skill level (57 female, 57 male) worked with embedded computer visualization where I collected demographic information, pre- and post-test content scores, spatial scores, classwork and marking period grades. Students (n=8) at far extremes of spatial scores were interviewed while using the 3D visualization to understand what they noticed. Findings indicate that student spatial skill level will influence the noticing-interpreting cycle used to comprehend the computer visualization. This presentation will highlight what educators can do to help students of various spatial skill levels learn from 3D computer visualization.

FE07: 6:15-6:25 p.m. Bringing the Virtual Universe into the Classroom

Contributed – Jackie Bondell, ARC Centre of Excellence for Gravitational Wave Discovery (OzGrav) / Swinburne University, (H74), P.O. Box 218, Hawthoren, VIC 3122, AUSTRALIA; jbondell@swin.edu.au*

The ARC Centre of Excellence for Gravitational Wave Discovery (OzGrav) is committed to bringing cutting-edge STEM content to the public and to schools as part of its Education and Public Outreach Program. OzGrav educators have developed a program called Mission Gravity which combines scientific modeling with interactive virtual reality (VR). This program was piloted in 2018 and is now being delivered in classrooms in Australia. In this program, students collaborate in teams, creating models of stellar evolution via collecting and analysing data from virtual trips to stars. Students use Physics and VR to model how stars evolve using virtual scientific tools. To develop this program, OzGrav focused on designing a science lesson that effectively incorporates VR into student-centred activities while aligning with curriculum standards. In this talk, participants will learn about the design process used and choices made to: maintain pedagogical integrity, value the scientific process, and embrace VR technology.

*Sponsored by Amber Strunk

FE08: 6:25-6:35 p.m. Virtual Reality Implementation for a Scanning Electron Microscope

Contributed – Scott A. Kaiser, Utah Valley University, 800 W University Parkway, MS-179 Orem, UT 84058; paul.weber@uvu.edu

Matthew Meyers, Daniel Rodriguez, Paul Weber, Reza Kamali-Sarvestani, Utah Valley University

We have developed a virtual reality simulation of a scanning electron microscope (SEM) for training students in its proper use. This simulation enables students to have full access to a scanning electron microscope in the classroom, to develop their understanding of its physics and prepare them to work efficiently before they encounter the instrument in the laboratory. We discuss the processes used to create this pedagogical tool for the classroom, and demonstrate its use as well as its fidelity in representing the real instrument. The simulation uses hand motions via virtual reality controllers in an environment that simulates a complete electron microscopy experiment. This tool will benefit institutions who do not have access to a scanning electron microscope and better prepare students in advance to work safely, effectively and efficiently with this sensitive instrument.

Session FF PTRA: Gravitational Waves

Location: CC - Ballroom B **Sponsor:** AAPT **Time:** 5:15–6:45 p.m. **Date:** Tuesday, July 23 **Presider:** TBA

Join us for an engaging session where we share hands-on resources to help students understand gravitational waves and LIGO. You can easily help students make connections between this cutting edge topic and traditional physics concepts by using resources that are inexpensive and yet provide visual models. Some materials used during the session will be given to participants and electronic resources are available online.

Session FG Physics for Refugees & Street Children

Location: MH - Amphitheater **Sponsor:** Committee on Teacher Preparation **Co-Sponsor:** Committee on International Physics Education
Time: 5:15–6:45 p.m. **Date:** Tuesday, July 23 **Presider:** Florian Genz

FG01: 5:15-5:45 p.m. Physics for Refugees and Street Children in Germany and Colombia

Invited – Manuela Welzel-Breuer, University of Education Heidelberg, Keplerstrasse 87 Heidelberg, 69120 Germany; welzel@ph-heidelberg.de*

Elmar Breuer, Gymnasium Englisches Institut Heidelberg

As part of the international collaboration project "Patio 13- school for street children" in Colombia, we are developing ways to educate so called street children who are used to living disconnected from the official school system. We are cooperating with a teacher training institution in Colombia and linking cultural aspects of education with previous experiences in pedagogy for street children and modern ways of teaching science. Together with advanced teacher students we could develop and implement different ways to teach physics as part of a curriculum for street children using an inquiry-based science education (IBSE) approach, simple experiments and material. Meanwhile, the existence of vulnerable children became visible as a worldwide increasing problem. Hence, we adapted these ideas for two series of physics experiments for refugees in Germany and qualified multipliers. Within this presentation we will report on the approaches, activities, and results and draw conclusions for further work.

*Sponsored by Kathleen Falconer

FG02: 5:45-6:15 p.m. Physics for Refugee Children in Germany

Invited – Dan MacIsaac, State Univ of NY (SUNY), Buffalo State College, SAMC278, Buffalo, NY 14222; macisadl@buffalostate.edu

Florian Genz, Institut fur Physikdidaktik, Universitat zu Koln

Michael Resvoll, Stadtisches Gymnasium Thusneldastraße, Koln-Deutz

Physik fur Fluchtlinge: We report on recent initiatives led by the German Physical Society to improve the welfare of refugee children in German refugee centers and grade schools using physics and physical science experiments. We plan to lead through a typical simple small group activity with discussion.

FG03: 6:15-6:45 p.m. Developing Physics Kits for Use in Non-Formal Refugee Settings*

Invited – Erika S. Gillette, Science United project, 3627 Greystone Ave., Bronx, NY 10463; erikagillette@gmail.com

Brian M. Gillette, Science United Project

Science education supports socio-scientific decision making and scientific problem solving and is important to support true scientific literacy for global citizenship. Children around the world who have experienced interrupted education often come from conflict-affected areas and have not had the opportunities to engage in science instruction. Also, many of them have recently arrived in refugee camps and community centers that provide them with some of their first experiences with education. Through the teaching of Physics, refugee children get to explore phenomena and learn about force and motion through multiple inquiry-based activities. This paper will present the development of the Physics kits for refugees and responses from volunteer educators about the value of Physics instruction in non-formal refugee classrooms.

*Blossom Hill Foundation provided the funding for the project

Session FI Innovations in Teaching Astronomy

Location: CC - Cascade E **Sponsor:** Committee on Space Science and Astronomy **Time:** 5:15–6:45 p.m. **Date:** Tuesday, July 23

Presider: TBA

FI01: 5:15-5:45 p.m. Gaming Your Students – The Research into Fluency Inspiring Activities

Invited – Edward Prather, University of Arizona, Department of Astronomy, 933 N Cherry Ave., Tucson, AZ 85719; eprather@as.arizona.edu

Rica French, MiraCosta College

For two decades researchers at the Center for Astronomy Education (CAE) have been investigating how best to teach difficult topics to introductory students in a variety of STEM disciplines and courses. From developing activities for Life in the Universe courses to bring Gravitational Lensing to non-science majors – we have been experimenting on which combinations of representations and tasks can motivate learners to deeply engage in developing discipline fluency. From a gamming perspective we have been investigating how to foster the right combo of Enticement, Mystery, Action, Risk, Challenge, Uncertainty, and with any luck Mastery. In this talk I will share how our research project to uncover which representations are most commonly used by faculty in Think-Pair-Share questions has evolved into a new framework that generates a new class of Fluency Inspiring Questions/Activities, (a.k.a The Boss Fight!), and how this work is being used to inform the Astronomy Majors Project (AMP).

FI02: 5:45-6:15 p.m. A Thematic Sequence in Astronomy for Non-Majors

Invited – Jennifer Blue, Miami University, 500 E Spring Street, Oxford, OH 45056; bluejm@miamioh.edu

As part of the liberal education requirements at Miami University, each student without a second major or minor must complete a Thematic Sequence. This is a set of related courses outside the student's home department.[1] One of the Thematic Sequences offered in the Department of Physics is about astronomy. It is called Our Place in the Universe, and consists of these three courses: Introduction to Astronomy and Space Science, Observational Foundations of Astronomy, and Contemporary Astronomy. The first, introductory, course is taught in a large auditorium, but the second and third are capped at 24 and mostly taken by students in the thematic sequence. Students get no credit for completing a thematic sequence in their own major; therefore, almost no students in these courses are physics majors. This talk will describe these courses and highlight the fun activities the students get to do.

[1] http://miamioh.edu/liberal-ed/current-students/2015current-students/index.html

FI03: 6:15-6:45 p.m. The Importance of Engaging with "Real Data" in Astronomy Courses

Invited – Kimberly Coble, San Francisco State University, 1600 Holloway Ave., San Francisco, CA 94132-1740; kcoble@sfsu.edu

I will discuss the importance, implementation, and impact of general education astronomy students' participation in two different course-based undergraduate research experiences (CUREs). In both curricula, our goal was to engage students with realistic practices used by professional astronomers and to examine the effects of those experiences on students' attitudes toward science. In one project, students completed a multi-step observing project with the robotic Global Telescope Network (GTN), where they focused on observation planning, proposal writing, and peer review. In the other, the Research-Based Science Education (RBSE) Project, the focus was on analysis of data taken at national observatories: nova searches, asteroid tracking, stellar and AGN spectroscopy, and photometric redshift. RBSE was developed at the University of Alaska Anchorage and tested at four different universities. Students' experiences and perceived impacts of participation in both projects were examined through iterative thematic coding analyses of interviews and essays.

Session FJ Methods vs. Topics: Scaffolding & the 3-Legged Stool

Location: CC - Cascade D **Sponsor:** Committee on Physics in Undergraduate Education **Co-Sponsor:** Committee on Apparatus
Time: 5:15–6:45 p.m. **Date:** Tuesday, July 23 **Presider:** Gabriel Spalding

This panel session discusses the distinction between TOPICS associated with a single course within the major (Statistical Physics, AstroPhysics, etc.), and foundational METHODS that should be distributed throughout the major. Failure to make this distinction is one reason why many programs fail to "scaffold in" a developmental set of experiences that, overall, co-values the foundational METHODS often described as the "three-legged stool" of the major: (1) the formalisms of physics; (2) the many ways in which computers are used in physics (integrated into offerings within the department); and (3) hands-on instruction in (and grappling with) experimentation and troubleshooting, offering exposure to a wide range of high technologies. Regarding the last of these, AAPT engaged in more than a decade of focused conversation about the broad range of goals embedded in hands-on lab instruction, followed up by a research-based document, namely, the "AAPT Recommendations for the Undergraduate Physics Laboratory Curriculum," which unpacks these goals, making a clear case that no single course can meet all of these developmental goals in 15 weeks. Similar statements can be made of each of the three legs.

FJ01: 5:15-6:45 p.m. Overhauling a Laboratory Curriculum to Focus on Methods

Panel – Ashley R. Carter, A122 Science Center, Amherst, MA 01002-5000; acarter@amherst.edu

Overhauling a laboratory curriculum is a daunting process for a department. Here, I describe a four-step process our department used to overhaul our laboratory curriculum so that it would focus on METHODS (theoretical, experimental, and computational methods) rather than TOPICS (mechanics, electromagnetism, etc.). The four-step process for overhauling the curriculum included: 1) identifying learning goals, 2) describing current practices, 3) making changes, and 4) planning for assessment. In addition, I describe how we updated experiments in a single course within the curriculum to meet our curriculum goals. This involved creating a set of "plug and play" experiments. These are experiments that can be "plugged" into a METHODS-based course because they have theoretical, experimental, and computational goals, and they can be "played" in a variety of ways since their laboratory manuals are organized by METHOD rather than TOPIC.

FJ02: 5:15-6:45 p.m. Preparing Students for Many Futures: Caltech's Introductory Physics Lab

Panel – Eric Black, Caltech MC 264-33 Pasadena, CA 91125; blacke@caltech.edu

Caltech requires all of its undergraduates to take two introductory labs, one of which must be chemistry. About half of our students opt for physics as their other lab. Fortunately, most of the skills that prepare physics majors for more advanced lab courses in their specialty are also extremely useful in other STEM fields. In this talk I will describe how we serve both populations in what is by nature a very "methods"-heavy course.

FJ03: 5:15-6:45 p.m. Effective Undergraduate Programs: Career Inspired Courses, Tools, and Resources

Panel – Brad R. Conrad, Society of Physics Students, 1 Physics Elipse, College Park, MD 20740; brad.r.conrad@gmail.com

As faculty aim to build thriving undergraduate programs, developing course sequences and content that both serve and recruit undergraduates for a broad array of career outcomes is vital for a successful department. Course sequences and material can be made to include tools that serve students aiming for both graduate school and careers immediately after graduation. This session aims to tie educational outcomes within course sequences to career objectives through specific examples and tools. By empowering a broad range of students to manage their career goals and objectives, departments can both self-evaluate and promote an inclusive environment for a diverse student population. The findings, results, and suggestions from a wide variety of source will be touched on. Special attention will be given to the SPS careers toolbox and comprehensive course design that compliments department education objectives.

FJ04: 5:15-6:45 p.m. Balancing Methods and Content: Good for Everyone and for Inclusion

Panel – Catherine H. Crouch, Swarthmore College, Department of Physics, 500 College Ave., Swarthmore, PA 19081; ccrouch1@swarthmore.edu

Although several reformed instructional and curricular approaches have sought to prioritize supporting students' mastery of methods at the same level as content, structural challenges inherent to academia make it more difficult to prioritize methods than content. In my own department at Swarthmore College, our increasingly diverse population of students and our commitment to inclusion and equity in our major has heightened our awareness of both the challenges and the importance of supporting students to develop deep skills in methods as well as content. We believe that modifying our curriculum to achieve this goal is good for all students, not only for those coming from backgrounds not well represented among physicists. I will share examples from our very early stage efforts to balance choices about teaching content with cultivating the skills and practice of physics in a manner that supports a diverse population of physics majors.

FJ05: 5:15-6:45 p.m. Successes and Challenges Balancing the Three-legged Stool at UWRF

Panel – Earl D. Blodgett, University of Wisconsin-River Falls, 410 S 3rd St., River Falls, WI 54022; earl.d.blodgett@uwrf.edu

The physics program at the University of Wisconsin – River Falls intentionally embraced the idea of distributing foundational methods of experimental physics across the curriculum in the early 1970s. At that time, computational methods were viewed as a tool of the experimental physicist. As a result, our physics majors have been required to take at least one programming course ever since 1975. Our emphasis on experimental methods has tended towards concentrating computation in several laboratory courses and only a few theory classes. To use the analogy of the three-legged stool, we have a very sturdy leg representing experimental physics, a strong leg representing the formalisms of physics and a slender leg for computational physics. I will share our successes and challenges in attempting to balance the three-legged stool over the past several decades.

FJ06: 5:15-6:45 p.m. Technical Competencies in Undergraduate Physics Education

Panel – Randall Tagg, Univ of Colorado - Denver, Dept of Physics CB-157, Denver, CO 80217; randall.tagg@ucdenver.edu

An initiative is under way to create a working group within the AAPT Area Committee on Laboratories to foster development of learning materials for technical competencies. Such competencies span a range of practical knowledge, including design (e.g., mechanical or circuit design), procedures (e.g., machining or soldering), and instrumentation (e.g., use of digital oscilloscopes or lock-in amplifiers). By pooling expertise across the physics education community, we can offer a rich resource for students to expand their skills for research, technical innovation, and employment.

Session FK Quantitative Methods in PER: A Critical Examination

Location: CC - Ballroom A **Sponsor:** Committee on Research in Physics Education **Co-Sponsor:** Committee on Educational Technologies
Time: 5:15–6:45 p.m. **Date:** Tuesday, July 23 **Presider:** John Aiken

FK01: 5:15-6:45 p.m. Neither an Elixir nor a Heresy: Quantitative Methods in Physics Education Research

Panel – Lin Ding, Department of Teaching and Learning, The Ohio State Universit,y 1945 N. High St., Columbus, OH 43210-1358; ding.65@osu.edu

As with many other social sciences, physics education research (PER) is a field where investigators use various methods to make empirical inquiries. The general category of quantitative methods, commonly known as practices of quantifying and interpreting numerical information, is perhaps one of the most frequently applied genres in PER. Despite its regular use and long history, quantitative PER is often misjudged. It can be either idolized as the only objective approach to PER or demonized as statistical lies created by researchers to make a point. In this talk, I argue that quantitative PER is neither an elixir nor a heresy. Instead, it should be evaluated, at least in part, within the norms and traditions of quantitative paradigm. To that end, I discuss paradigmatic underpinnings of quantitative methodologies, including their ontological assumptions, epistemological commitments and practical implications.

FK02: 5:15-6:45 p.m. Comparing the FCI and FMCE with Multidimensional Item Response Theory

Panel – Cabot Zabriskie, West Virginia University, 135 Willey Street, Morgantown, WV 26506; cazabriskie@mix.wvu.edu

John Stewart, Jie Yang, West Virginia University

Constrained Multidimensional Item Response Theory (MIRT) is a powerful tool to understand the detailed structure of a multiple-choice instrument. A detailed model of the conceptual solution of the instrument developed by experts in the field can be mapped onto the MIRT model and the degree to which the expert solution models student thinking can be evaluated. Small, theoretically motivated, changes to the model are then explored to find an optimal model of student thinking. This process was applied to the FCI and FMCE, two instruments used interchangeably to characterize Newtonian thinking. Under the lens of MIRT, the two instruments are shown to be dramatically different with differing coverage and connectivity. Further, which the FCI is unidimensional, the FMCE demonstrates some subscale structure, but far less connection between concepts. This suggests the two instruments may be complementary with the FCI measuring an integrated Newtonian force concept and the FMCE components of that force concept.

FK03: 5:15-6:45 p.m. Reconsidering the Encoding of Data in Physics Education Research

Panel – R. Padraic Springuel, St. Anselm's Abbey School, 4501 S Dakota Ave., NE, Washington, DC 20017; rpspringuel@gmail.com

Micahel C. Wittmann, John R. Thompson, University of Maine

In performing quantitative analysis, the data collection method and the data analysis method are often well considered choices. However, data encoding, which forms the connection between the two, is often taken for granted. Either the chosen data collection method leads to an "obvious" encoding method, or the chosen data analysis method's demands on the encoded data that dictate an "obvious" choice of encoding. Researchers seldom publish their reasoning about this process and consider whether these two "obvious" choices are the same or how differences between them might affect their ability to draw conclusions and generalize them. We propose that encoding practices and decisions need to be be made explicit in conducting quantitative research. In this fashion, PER will be able to have more productive discussions about how these decisions are made, how they can be made well, and what sort of effect they have on research.

FK04: 5:15-6:45 p.m. Using Machine Learning to Understand the Retention of STEM Students

Panel – John Stewart, West Virginia University, 235 White Hall, Morgantown, WV 26506; jcstewart1@mail.wvu.edu

Cabot Zabriskie, West Virginia University

Retention of STEM students is a critical national problem. Introductory physics classes play a key role in the retention of these students. This talk will first explore retention through survival analysis to show the critical role of time in understanding retention. Machine learning algorithms including logistic regression, decision trees, and random forests are then applied to understand the variables important in predicting retention through the first year of college. This analysis identifies being a successful student in high school and arriving on campus "calculus-ready" as critical predictors of success. The student's progression through the network of introductory science and mathematics courses is then explored. Machine learning algorithms are applied to understand a student's risk factors as they matriculate from Calculus 1 and Chemistry 1 through Physics 1 and Physics 2. This will show students who matriculate through the network along different paths have different risk factors and chances of success.

Session FL PER: Diverse Investigations

Location: MH - Aspen **Sponsor:** AAPT/PER **Time:** 5:15–6:45 p.m. **Date:** Tuesday, July 23 **Presider:** TBA

FL01: 5:15-5:25 p.m. Epistemology, Sense Making, and Social Dynamics in Group Work

Contributed – Jessica R. Hoehn, University of Colorado Boulder, 390 UCB, Boulder, CO 80309; jessica.hoehn@colorado.edu

Julian D. Gifford, Noah D. Finkelstein, University of Colorado Boulder

Ayush Gupta, Andrew Elby, Brandon James Johnson, Erin Ronayne Sohr, University of Maryland

We often ask our physics students to work in groups—on tutorials, during in-class discussions, and on homeworks, projects, or exams. Researchers have documented the benefits of group work for students' conceptual mastery and problem solving skills, and have worked to optimize the productivity of group work by assigning roles and composing groups based on performance levels or gender. However, it is less common for us as instructors and researchers to attend to the social dynamics and interactions among students within a collaborative setting. In this talk, we identify an epistemological element of group work---students' stances towards what it means to generate knowledge in a group—and investigate how these stances interact with the sense making and social dynamics in one group problem solving session. Understanding these fine-grained interactions is one way to begin to understand how to support students in engaging in productive and equitable group work.

FL02: 5:25-5:35 p.m. Hogwarts Houses as a Substitute for Learning Styles

Contributed – Paul W. Irving, Michigan State University, biomedical physical sciences, East Lansing, MI 48824; pwirving@msu.edu

Marcos D. Caballero, Daryl McPadden, Michigan State University

Learning styles or by proxy personality types are frequently used as a tool to place students into bins to account for performance. Tests such as the Myers-Briggs are frequently used in the formation of learning groups with the idea that different personalities can complement each other. We asked ourselves, what if we substitute Hogwarts houses for learning styles or personality types? Does belonging to a particular Hogwarts house predict performance in coursework? Does identifying as a Hufflepuff mean you will achieve a higher normalized gain on a conceptual evaluation such as the FMCE. How many Gryffindor's can actually spell Gryffindor correctly? Spanning multiple years and encompassing both upper division and introductory physics we present our study examining the role of the sorting hat in predicting student performance in physics.

FL03: 5:35-5:45 p.m. Impact of the Next GEN PET Curriculum on Science Identity*

Contributed – Robynne M. Lock, Texas A&M University-Commerce, Department of Physics and Astronomy, PO Box 3011, Commerce, TX 75429; robynne.lock@tamuc.edu

William G. Newton, Texas A&M University-Commerce

Ben Van Dusen, California State University-Chico

Steven Maier, Northwestern Oklahoma State University

The Next GEN Physical Science and Everyday Thinking (PET) curriculum was designed for physical science courses for future elementary teachers. However, this curriculum may also be used in general education conceptual science courses. The materials are aligned with the Next Generation Science Standards and use a guided-inquiry approach. Next GEN PET is currently being implemented at many universities nationwide. We examine the impact of this curriculum on students' science identities at a subset of these universities. The identity framework consists of three dimensions. Recognition is the extent to which a student believes that parents, peers, and professors view them as a science person. Interest describes their enjoyment of science. Finally, performance/competence represents a student's belief in their abilities to understand science and complete science related tasks. The shift in science identities was measured with items adapted from a previously developed physics identity instrument.

*This work is supported by the NGP FOLC project (NSF DUE-1626496).

FL04: 5:45-5:55 p.m. Measuring Students' Emotional Engagement with Physics Experiments

Contributed – Aesha Bhansali, University of Sydney, 5-7 Campbell St., PARRAMATTA, NSW 2150 Australia; bhansali.aesha@gmail.com

Manjula Sharma, University of Sydney

Students' emotional engagement is one of the important factors to be considered in Physics Education Research. Yet no instruments have been developed to measure the emotions of students studying physics. We have adapted and validated the Achievement Emotion Questionnaire, developed by Pekrun, for first year physics experiments. We constructed an 'intervention' experiment on thermal physics. This was a guided inquiry experiment with clear instructions. We included a colorful story on the 'History of Heat' in the introduction of the experiment. The 'control' experiment on 'ultrasound waves' was written in a standard manner and was not modified. Our pilot study was done over three weeks of first semester laboratories. Surveys were collected from 320 students. The same cohort of students was surveyed for the intervention and for the control. We found more emotional engagement of students for the Intervention compared to Control.

FL05: 5:55-6:05 p.m. Perceptions of the Teaching Profession at Universities Across the U.S.*

Contributed – Savannah Logan, Colorado School of Mines, 2329 S Eldridge St., Lakewood, CO 80228; sllogan@mines.edu

Richard L. Pearson, Wendy K. Adams, Colorado School of Mines

Recent research in STEM teacher preparation has identified strongly held beliefs about the teaching profession, many of which are misperceptions. These misperceptions discourage STEM undergraduates from exploring teaching as a viable career option. To measure perceptions among university faculty and students, six universities of varying sizes and demographics were visited during spring 2019. Focus groups were used to qualitatively measure perceptions of the teaching profession among students and faculty from physics, chemistry, and mathematics departments at these institutions. Results will be shared.

*This project is supported by NSF DUE-1821710.

FL06: 6:05-6:15 p.m. Physics Road Trip as Increasing Membership in Community of Practice

Contributed – Brean Elizabeth Prefontaine, 300 N Hayford Ave., Lansing, MI 48912; prefont4@msu.edu

Caleb Rispler, Kathleen Hinko, Michigan State University

Claudia Fracchiolla, University College Dublin

We are interested in how different levels of involvement within informal physics experiences can shape or transform students' physics identities. Science Theatre is a student group at Michigan State University that offers outreach opportunities for university students to interact with physics outside of classes and research. We analyzed interviews from undergraduate students before and after they engaged in an intense outreach trip over spring break using the Communities of Practice (CoP) framework. Analysis using the CoP framework indicates that the greater level of accountability a student has to the group, the more integral their role becomes within Science Theatre, such as taking an officer position. We also find the spring break trip acts as a mechanism for allowing members to become more central in the community by 1) increasing meaningful interactions with other members of the Science Theater community, and 2) facilitating their skill in presenting physics demos.

FL07: 6:15-6:25 p.m. Practice-based Identity Survey for Physics Labs: From Design to Validation

Contributed – Kelsey M. Funkhouser, Michigan State University, 567 Wilson Rd., East Lansing, MI 48824-2320; kfunkh@msu.edu

Rachel Henderson, Marcos Caballero, Vashti Sawtelle, Michigan State University

We have worked to develop a survey to measure students' physics identity in lab classes. We assert that the survey development process we have undergone to produce a practice-based identity survey, has ensured that the survey accurately represents how students interpret these practices and how they identify with them. The process has used three distinct steps. We started by examining students' alignment with specific physics lab practices. From there we developed a closed- and free-response pilot survey. From the pilot survey analysis we determined the common themes in the identity statements that students made. These themes and the practice questions were combined to create a new fully closed-response pilot survey, which was distributed to a variety of courses and institutions. In this talk, I will summarize each part of the process and how they lead to the practice-based identity survey.

FL08: 6:25-6:35 p.m. Students' Understanding of Perceived Types of Forces Within Circular Motion

Contributed – Moa Eriksson, Lund University, Sölvegatan 14 Lund, Lund 22362 Sweden; moa.eriksson@fysik.lu.se

Urban Eriksson, Ann-Marie Pendrill, Lassana Ouattara, Lund University

Cedric Linder, Uppsala University

An integral, yet challenging, part of introductory physics courses is circular motion. An important part of these challenges is investigated using video data of students who, working in interactive tutorials, need to correctly specify the relevant forces on a given vertical-motion system in order to solve a tutorial problem. The reasoning that these students use to attempt to convince one another what the relevant forces are will be used to illustrate two things: (1) how the concept of centripetal force needs much more unpacking than may be apparent; and (2) how students' personal commitments to particular pieces of understanding can present major stumbling blocks to interactive group learning (which teachers may find hard to detect). Discussion will draw on the variation theory of learning.

FL09: 6:35-6:45 p.m. What Group Exam Performance Tells Us About Forming Effective Groups

Contributed – Joss Ives, University of British Columbia, 6224 Agricultural Road, Vancouver, BC 6224, Agricultural Road, Canada; joss@phas.ubc.ca

Jared Stang, University of British Columbia

Two-Phase (or two-Stage) Collaborative Group Exams are an easy to implement technique that leverages students' desire to discuss challenging exam questions with each other immediately after an exam. This instructional technique adds an additional group phase immediately after a regular solo exam. Based on over 1200 student-groups, we have developed a model that predicts how a group will perform on the group phase, based on their individual scores from the solo exam. This model has allowed us to investigate factors (based on demographic and survey information) that may result in groups under- or over-performing relative to the model.

Session FN Labs Beyond the First Year (BFYIII): One Year Later

Location: CC - Soldier Creek **Sponsor:** Committee on Laboratories **Co-Sponsor:** Committee on Physics in Undergraduate Education

Time: 5:15–6:45 p.m. **Date:** Tuesday, July 23 **Presider:** Eric Ayars

FN01: 5:15-5:45 p.m. Preparing Students for Research and the Workplace

Invited – Daniel Borrero-Echeverry, Willamette University, 900 State St., Salem, OR 97301; dborrero@willamette.edu

Over the last five years the physics department at Willamette University has taken significant steps to update our advanced laboratory curriculum. The goal of this push has been to prepare students to successfully contribute to faculty research, while providing them with skills that are transferable to the workplace. In this talk, I will discuss how we have created engaging laboratory experiences integrating experiment, theory, and computation based on faculty research. This coursework serves as an apprenticeship, reducing the time that faculty spend training students to work in their labs and allowing students to make significant research contributions in their senior projects. I will discuss how these efforts have been influenced by faculty participation in the 2018 Conference on Laboratory Instruction Beyond the First Year (BFY III), the Advanced Laboratory Physics Association's (ALPhA) Immersions program, and the Partnership for Integration of Computation into the Undergraduate Physics (PICUP) Faculty Development Workshop.

FN02: 5:45-6:15 p.m. From Student-Built NMR to MRI

Invited – Steven W. Morgan, University of Minnesota Morris, 600 E. 4th St. Morris, MN 56267; morgans@morris.umn.edu

In 2016 the students in our advanced lab course built a low-cost Earth's field nuclear magnetic resonance spectrometer. During the fall semester of 2018 students in the same course added one-dimensional imaging capabilities to the existing spectrometer and made other improvements to the spectrometer. In addition to the magnetic resonance work, this year some new experiments were added to our lab courses based upon workshops at the Third Conference on Laboratory Instruction Beyond the First Year (BFY III) held last summer. I will discuss these and other modifications or additions to the advanced lab and electronics courses this year that stemmed from interactions at the BFY Conference.

Session FO Teacher Training/Enhancement

Location: MH - Cedar **Sponsor:** AAPT **Time:** 5:15–6:35 p.m. **Date:** Tuesday, July 23 **Presider:** TBA

FO01: 5:15-5:25 p.m. Construction of National Excellent Course for Chinese Pre-service Physics Teachers

Contributed – Wei Yang, College of Teachers Professional Development/Shenyang Normal University, Liaoning 110034 China; yangweibnu@163.com*

Yanjie Chi, College of educational sciences/Shenyang Normal University

Yuying Guo, Chunmi Li, Department of Physics/Beijing Normal University

Lin Ding, Department of teaching and learning/The Ohio State University

As one of the only four courses for pre-service physics teachers in China, "Teaching Design of Physics in Middle school", which I was in charge of, was approved by the Ministry of Education of China to build "High-Quality Teacher Education Course" in 2013 and named "National Excellent Course" in 2017. It is now freely available on the website. Course adopts question mode and develops 10 modules gradually--the learning process is also a process of problem solving. Learners carry out practical training alternately as teachers and students emphasize the cultivation process of special ability, and diversified texts and dynamic resources more than 2200. Team members include teachers from different universities, outstanding middle school teachers, teaching and research staff and educational technology professionals. By setting up group tasks to build the dual-track learning time and space inside and outside class, and combining with the activities of teachers entering and entering the middle school classroom, the interactive training channels between middle schools and colleges are integrated. It is not only used for pre-service teachers' learning and practical guidance, but also for in-service teachers.

*Sponsored by China Scholarship Council

FO02: 5:25-5:35 p.m. Using Guitars as a Vehicle for Problem-based Learning

Contributed – Debbie A. French, Wilkes University, 84 W. South St., Wilkes-Barre, PA 18766; frenchd14@yahoo.com

Sean Hauze, San Diego State University

Richard M. French, Purdue University

Doug Hunt, Southern Wells High School

Tom Singer, Sinclair Commuity College

The STEM Guitar Project is a National Science Foundation-funded program designed to enable teachers to integrate STEM activates into their curriculum through guitar building. The STEM Guitar Project supports guitar building programs in 307 schools in 48 states. To increase student understanding of STEM concepts, the STEM Guitar Project team worked with business and industry partners to develop 12 learning activities aligned with STEM workforce skills. Faculty professional development institute participants implement this problem-based curriculum in their classrooms, through which student mastery of the 12 MLA concepts is achieved via the guitar building process. In addition to building their own custom instrument over the course of the semester, students complete the course with STEM skills and knowledge related to the guitar and aligned to workforce skills. This presentation will focus on the problem-based learning activities associated with the guitar building process.

FO03: 5:35-5:45 p.m. NextGenPET Curriculum in Integrated Science Course for Preservice Elementary Teachers*

Contributed – Nicole Gugliucci, Saint Anselm College, 100 Saint Anselm Drive, Manchester, NH 03102-1310; ngugliucci@anselm.edu

Next Generation Physical Science and Everyday Thinking (NextGenPET) curriculum is an NGSS-aligned curriculum for preservice elementary teachers that covers topics in physics and chemistry. It is fully supported with powerpoints, worksheets, answer keys, extensions, quizzes, and more, making it straightforward for new educators to adopt. At Saint Anselm College, preservice elementary teachers are required to take a one-semester integrated science course that covers all science topics in preparation for their work as educators. Similar curricula for biology and earth science exist or are in preparation, but they do not have has much supporting material as the NextGenPET. This talk will describe how NextGenPET was used and extended with these supporting materials as part of the NextGenPET Faculty Online Learning Community to create a cohesive, integrated science course for preservice elementary teachers called "Science and Everyday Thinking."

*This work is supported by the National Science Foundation DUE-1626496.

FO04: 5:45-5:55 p.m. Correlating Teacher Preparation Program Admission Standards with Classroom Outcomes

Contributed – Jill A. Marshall, The University of Texas, STEM Education, Austin, TX 78712; marshall@austin.utexas.edu

Brett Westbrook, Michael Marder, Bernard David, The University of Texas

Graduates of the UTeach secondary STEM teacher certification programs have been shown to go into teaching in larger numbers, stay in the classroom longer, and succeed with students from all demographics compared with graduates of other programs producing teachers in Texas. We predict this success has come, in part, from recruiting broadly and removing barriers to entry in the admission process. I will present a statistical analysis modeling admission variables, such as GPA and scores on our admission rubric, with outcomes such as likelihood of entering and remaining in teaching.

FO05: 5:55-6:05 p.m. Applied Physics Workshop and PhysFESTT: Teacher and Student Teams

Contributed – Matthew P. Perkins Coppola, Purdue University Fort Wayne, 2101 E. Coliseum Blvd., Fort Wayne, IN 46805; matthewperkins@hotmail.com

Mark P. Masters, Purdue University Fort Wayne

In summer 2018, teachers from across the United States met in Indiana for a week-long Applied Physics Workshop. A broad call went out to find teams of teachers and students interested in building apparatus to take home and investigate over the course of the next school year. These teacher-student teams were invited to present their demo research at PhysFESTT (FEstival of Student-Teacher Teams) in March 2019. We will share about our experiences recruiting and training student-teacher teams, what we have learned, and what our students and teachers have learned.

FO06: 6:05-6:15 p.m. Training and Supporting In-service High School Physics Teachers: An Online MS Physics Program

Contributed – William G. Newton, Texas A&M University-Commerce, Department of Physics and Astronomy, Commerce, TX 75429-3011; William.Newton@tamuc.edu

Robynne Lock, Bahar Modir, Texas A&M University-Commerce

It is well documented that significantly less than 50% of physics teachers received their primary training in physics or physics pedagogy. I will report on the progress of a new online Master's in Physics designed specifically to train in-service high school physics teachers with little previous physics background and create a community of practice to support those teachers. Piloted as six face-to-face courses to an initial cohort of seven in 2014-15, there are currently over 60 students enrolled from 16 different states and three countries. The program is intended to help physics teachers by reinforcing their content knowledge, introduce them to advanced physics topics, enhance their teaching by studying the content through the lens of physics education research, and provide access to teaching resources and a community of fellow physics teachers with whom to share ideas and support. In this talk we discuss the challenges of creating a physics Master's program to meet the needs of the physics teachers and cater to a variety of backgrounds, give an overview of the content of our classes, and report on the successes of the program.

FO07: 6:15-6:25 p.m. Modeling Instruction at Arizona State University: Update

Contributed – Jane C. Jackson, Arizona State University, Department of Physics, Box 871504, Tempe, AZ 85287-1504; jane.jackson@asu.edu

Modeling Instruction* is the research-based foundation of an ASU summer graduate program in physics and chemistry education that is primarily for lifelong professional development but can lead to a Master of Natural Science degree in physics. Since inception in 2001, the program has served 1200 teachers. Each summer, 60 Arizona teachers and another 15 nationwide participate. Singapore has sent 54 physics and chemistry teachers in 12 years. Teachers choose from 20 rotating courses (7 each summer), including contemporary physics, interdisciplinary science, and eight distinct Modeling Workshops in physics and chemistry. I will update you on our work and on recent supportive legislation in Arizona.

* http://modeling.asu.edu

FO08: 6:25-6:35 p.m. Meta-curricular choices in a Professional Development Workshops

Contributed – Dedra N. Demaree, 105 Pear Tree Lane, Franklin Park, NJ 08823; dedra.demaree@gmail.com

In August 2018, Eugenia Etkina at Rutgers University led a week-long professional development (PD) workshop for teachers interested in learning more about the Investigative Science Learning Environment (ISLE). Teachers returned for half-day workshops on four different Saturdays over the next six months. In addition to facilitating the teacher's progression through ISLE cycles, Eugenia demonstrated many skills including techniques and teacher habits that go beyond the physics content. These skills were integrated into the PD as a meta-curriculum, teachers reflected on what they saw, and Eugenia was deliberate in discussing the pedagogical choices she made. These choices are rooted in theories of educational psychology, and are important for shaping teaching philosophies that promote student learning, such as growth mindset.This talk will focus on a few of these meta-curricular goals, their theoretical foundations, and why they are critical for teacher success in any physics classroom.

AAPT Awards: 2019 Klopsteg Memorial Lecture Award

Jodi Ann Cooley
Southern Methodist University

Fantastical Dark Matter and Where to Find It

Only a small fraction of the universe is made from ordinary, visible matter. A much larger portion remains dark, its existence known to us only by its interactions through gravity. The first evidence of this dark matter originates from studies of celestial bodies in the late 1920s and early 1930s. Since that time, astrophysicists and astronomers have determined that it constitutes the bulk of matter in our universe. Despite this fact, the composition still remains unknown. In this talk, I will discuss the history of dark matter research and how scientists are trying to uncover the properties of this evasive matter.

AAPT PHYSICS EDUCATION

8:30–9:30 a.m.
Wednesday, July 24

CC - Ballroom C

Persons with odd-numbered posters will present their posters from 9:30 to 10:15 a.m.; those with even-numbered posters will present from 10:15 to 11 a.m. Posters will be available until 12 p.m.

PST2A01: 9:30-10:15 a.m. Daltonic Cybernetic Eye

Poster – Marcio Velloso Silveira, UFRJ, Av. Athos da Silveira, Ramos, 149 - Centro de Tecnologia - Bloco A Rio de Janeiro, 21941-972 Brasil; marcio.vs@oi.com.br

Antonio Santos, Ricardo Barthem, UFRJ

In this work an experiment is presented that seeks to simulate human chromatic vision through electronic components in an attempt to construct, together with the students, a cybernetic eye. The limitation of the cybernetic eye developed here in relation to standard human chromatic vision, which makes it a "colorblind" eye, is an argument to be explored by the teacher to discuss this predominantly genetic anomaly widely, raising awareness and discussion about the need for public policies aimed at the inclusion of colorblind individuals, being able to be treated in an interdisciplinary way, bringing physics closer to biology. Making use of electronic components that are easy to acquire and inexpensive, the experiment produces data that, when treated, evidences the possibility of using the RGB LED as a light receiver, as well as its limitations in discerning colors.

PST2A02: 10:15-11:00 a.m. Experimental Didactic Proposal for Inclusive Teaching of Waves in High School

Poster – Marcio Velloso Silveira, UFRJ, Av. Athos da Silveira, Ramos, 149 - Centro de Tecnologia - Bloco A Rio de Janeiro, 21941-972 Brasil; marcio.vs@oi.com.br

Antonio Santos, Ricardo Barthem, UFRJ

The models available for teaching waves, especially in high school, do not consider the stage of real development in which the vast majority of students are. Allied to this, the difficulty in presenting frequencies, either of electromagnetic or sonorous nature, different from the bands that we can interpret through our senses, tends to constitute a huge epistemological obstacle. In an attempt to shed some light on this problem, we have developed two experiments that have relations between invisible and inaudible frequencies but which, through processing with Arduino platform, can be converted into audible frequencies. Thus, we intend to unveil this invisible world, bringing to the classroom experiments that can be used, even by students with blindness or deafness

PST2A03: 9:30-10:15 a.m. FL-AAPT IOLab Workshop Supported by Bauder Fund

Poster – Shawn A. Weatherford, University of Florida, PO Box 118440, Gainesville, FL 32611-8440; sweatherford@ufl.edu

Robert DeSerio University of Florida

The 2018 FL-AAPT fall meeting featured a workshop that provided participants the opportunity to progress through introductory physics labs designed for the IOLab. The IOLab is a multi-sensory dynamics cart with wireless USB connectivity to a personal computer. UF Physics utilizes the IOLab in its online introductory physics lab course offerings for the UF Online program. The workshop received significant support from the AAPT Bauder Fund. This poster presents the details and outcomes of the workshop.

PST2A04: 10:15-11:00 a.m. Hermione and the Secretary: Toward Gender Equity in Introductory Labs

Poster – Danny Doucette, University of Pittsburgh, 504 Coal St., Apt 3, Pittsburgh, PA 15221; danny.doucette@pitt.edu

Russell Clark, Chandralekha Singh, University of Pittsburgh

The introductory physics lab is a culturally rich environment in which students often adopt an inequitable division of labor. Beyond being ethically unacceptable, inequities may negatively affect the identity formation of future scientists, starving our field of talent. Through ethnographic observations and interviews, we seek to identify how mixed-gender pairs of students adopt stereotypical gender roles in the introductory physics lab. We identify two (likely common) modes of work in which women experience lab-work in different and less-beneficial ways than their male partners. We then present and analyze strategies to address this issue, including developing a novel approach to the lab curriculum.

PST2A05: 9:30-10:15 a.m. Modeling Spatial and Temporal FFT of Experimentally Superimposed Mechanical Waves

Poster – James P. Vesenka, University of New England, Department of Chemistry and Physics, Biddeford, ME 04005; jvesenka@une.edu

Jake Todd University of New England

The superposition of waves is a concept touched upon in most undergraduate physics courses. It is key in the understanding of constructive and destructive interference and the transfer of energy along mediums. Superimposed waves can be easily simulated by graphing programs, but an actual experiment can make for an even more convincing demonstration. A simple experiment can be carried out using two wave generators, flexible string, strobe light, and high-speed cell phone camera to highlight wave superposition. Furthermore, FFT analysis of video temporal and spatial data allows for the identification of the frequency and wavelength components of these real waves making FFT analysis more transparent.

PST2A06: 10:15-11:00 a.m. What's Happening in Introductory Labs? An Integrative Analysis

Poster – Danny Doucette, University of Pittsburgh, 504 Coal St., Apt 3, Pittsburgh, PA 15221-3588; danny.doucette@pitt.edu

Russell Clark, Chandralekha Singh, University of Pittsburgh

Introductory lab courses have long been an essential component of physics instruction, but questions have been raised about their curricular role and value. As a first step toward reform, it is essential to understand the dynamics of what happens in the lab. Using an integrative approach that includes ethnography, surveys, assessments, and other tools, we mapped out the thinking, instruction, and social dynamics that take place in traditional and inquiry-based labs at a large public university. Findings will be discussed.

PST2A07: 9:30-10:15 a.m. The Fourier Spectrum of the Sound Emitted by a Singing Wine Glass

Poster – Ralf Widenhorn, Portland State University, Portland, OR 97201; rwidenhorn@hotmail.com

Reuben Leatherman, Justin C. Dunlap, Portland State University

The tone produced by a finger run along the rim of a wine glass is a sound that is familiar to most. What may be less familiar, however, is that these vibrations exhibit a beating, rather than constant-amplitude signal. To investigate and explain the reason for this phenomenon, we use experimental data as well as a simple model

to compare three cases. The first involves the steady tone produced by a stationary finger pressed to the rim of a rotating wine glass. The second produces a beating tone from a finger run along the rim of a stationary glass. The third case analyzes the decaying beating produced by a glass that is struck as it rotates. The comparison between these three cases reveals insights into acoustics, wave interference, Fourier analysis that can be instructive in intermediate level undergraduate physics laboratory courses.

PST2A08: 10:15-11:00 a.m. A Modified Boyle's Law Experiment to Estimate Salt Crystal Density

Poster – Joel D. Krehbiel, Hesston College, 301 S Main Street, Hesston, KS 67062; joel.krehbiel@hesston.edu

Kenton N. Schroeder, Harune Suzuki, Nelson Kilmer, Hesston College

A common experiment in a college physics class is to show the inverse relationship between pressure and volume predicted by Boyle's law. Students connect a syringe to a pressure sensor and record the volume of the syringe and the pressure in the system. However, a systematic error exists if the volume between the syringe and the pressure sensor is ignored. We find that it is possible to calculate this headspace volume by fitting the pressure-volume data to a modified Boyle's law equation. This modification allows us to find the volume of many different objects connected to a pressure sensor and syringe. Here we find the volume of salt crystals and thus accurately determine their density. Our experiments of five different salts show that this method has an average percent error of 1.29 percent, providing a simple and accurate way to estimate the density of salt crystals.

PST2A09: 9:30-10:15 a.m. Comparing the Muscular Efficiency of Going Up and Down Hills

Poster – Carl E. Mungan, United States Naval Academy, Physics, Mailstop 9c, Annapolis, MD 21402-1363; mungan@usna.edu

Austin R. Comeford, United States Naval Academy

Nathaniel R. Greene, Bloomsburg University

Elementary formulas for gravitational potential energy, heat capacity, and Newton's law of cooling can be used to measure and compare the efficiencies of a person traveling uphill and downhill. Good agreement is found for their ratio with more sophisticated experiments in the literature made by measuring respiration to determine metabolic power. A simple argument explains why human muscles are less than 50% efficient at converting chemical into mechanical energy.

PST2A10: 10:15-11:00 a.m. Safety and Medical Context in a Ionizing Radiation Lab Curriculum

Poster – Jan Beks, Utrecht University, Eyckenstein 46 Vleuten, 3452 JE; jan.beks@gmail.com

Ad Mooldijk, Rob van Rijn, Utrecht University

The Ionizing Radiation Lab (ISP) based at the University of Utrecht has provided visits with three mobile ionizing radiation labs to secondary schools for almost five decades now. From a selection of 22 lab experiments, students learn about ionizing radiation. All experiments contain context about safety regarding ionizing radiation and students continuously have to implement safety rules. We will describe and discuss the safety aspect with its eye-openers, and exposure awareness. Some years ago content in the Dutch Physics Ionizing Radiation curriculum started to move towards medical context. Why do hospitals choose generators to provide the radioactive substances in nuclear medicine? What is the exposure while an X-ray is taken? We will describe some particular experiments and discuss (i) how the experiments support the Dutch Physics curriculum, and (ii) how the experiments support medical context.

PST2A11: 9:30-10:15 a.m. "Choose Your Own Adventure" Project-based Labs for Introductory Physics

Poster – Dan Roth, 3600 Chester Ave., Bremerton, WA 98337; droth@olympic.edu

I have been dissatisfied with my traditional laboratory exercises using a cookbook-style approach and following a "flavor of the week" schedule which often does not align with content in the lecture. I did not feel that my students were learning the course material (an opinion that has been backed up by some research) or gaining an understanding of the experimental process, including measurement uncertainty. Simply paring down on instructions in an effort to encourage more critical thought did not seem to improve outcomes, and a single lab period is not enough time for students to fully develop an experiment, take preliminary data, consider uncertainty, and revise their experiments. So, I have developed what I call "choose your own adventure" lab projects in which the students work on over the course of several lab sessions to develop and revise their own experiments.

PST2A13: 9:30-10:15 a.m. A PSoC Coincidence Counting Unit for Single Photon Investigations

Poster – Mark F. Masters, Purdue University Fort Wayne, 2101 Coliseum Blvd. E, Fort Wayne, IN 46805; masters@pfw.edu

The coincidence counter is critical to single photon investigations. We have developed a low-cost coincidence counter (less than $50) based on a Cypress Programmable System on a Chip (PSoC). The PSoC is quite flexible. It has a microcontroller as well as FPGA like capabilities which enable us to build the coincidence detection and the counter. The design process and several investigations will be presented. The PSoC CCU can count eight channels at 24 bits. It has an onboard D/A converter for driving an interferometer. It has sub 10ns windows and is capable of counting at up to 10MHz.

PST2A14: 10:15-11:00 a.m. Apparatus for Measuring the Speed of an Electrical Signal in a Coaxial Cable

Poster – Mark F. Masters, Purdue University Fort Wayne, 2101 Coliseum Blvd. E, Fort Wayne, IN 46805; masters@pfw.edu

Anna Patterson, Purdue University Fort Wayne

In our instrumentation class, students build several apparatuses for performing various investigations. This investigation was measuring the speed with which signal traveled through a coaxial cable. The purpose of the investigation was to teach students about transmission line models, unterminated cables, and then use measurements to estimate the material of the cable. The instrument itself was built using a Cypress Semiconductor PSoC microcontroller that generated both the short pulse and measured the speed of the signal.

PST2A15: 9:30-10:15 a.m. Chalkboard Presentations in an Intermediate Physics Lab

Poster – Jennifer Delgado, University of Kansas, 1251 Wescoe Hall Dr., Lawrence, KS 66045; j743d550@ku.edu

We compare two semesters of an intermediate physics lab, one semester with a traditional format and one semester that uses example reports and chalkboard presentations to focus on argumentation. The same labs were used both semesters. In the transformed lab students used chalkboards to compose a presentation on the example report they've been given and what issues they would like to address in their own experimentation. These sample reports often contained flaws known to the TAs. Students were then tasked with presenting their findings to another group or the TA for discussion using their chalkboards as their poster. After this "conference" students chose to collect data, and analyze it as needed to address issues in the example report before writing their own report. We compare the pre/post results on the CLASS, PLIC and our own assessments between the two semesters.

PST2A17: 9:30-10:15 a.m. FAN-C Circuits: RC Circuits Using Computer Fans

Poster – Robert C. Ekey, University of Mount Union, 1972 Clark Ave., Bracy Science Hall, Alliance, OH 44601-3993; ekeyrc@mountunion.edu

Brandon Mitchell, West Chester University

Recently, small computer fans have been demonstrated to be an effective method for teaching simple resistive circuits both qualitatively [1] and quantitatively [2]. The current through the fans is related to the rotational speed of the fans and allow multiple senses to be engaged (touch, sight, and hearing). The linear relationship between the operational current and applied voltage, provides a nearly constant effective resistance for the fan. This suggests that fans can also be used to explore RC circuits both qualitatively and quantitatively, where the fans act as the resistive elements as well as the indicator. In this poster, we will demonstrate that computer fans can be used to qualitatively explore the charging and discharging times for RC circuits. By monitoring the voltage across the capacitor as a function of time, we will also show that fans can be used for quantitative RC analysis. Fans, capacitors and battery packs will be available for playing with the FAN-C circuits for those that prefer a hands-on approach.

1. Robert Ekey, Andrea Edwards, Brandon Mitchell, Roy McCullough, and William Reitz, "A fan-tastic alternative to bulbs: learning circuits with fans," Phys. Teach. 55, 13 (2017). 2. Brandon Mitchell, Robert Ekey, Andrea Edwards, Roy McCullough, and William Reitz, "A fan-tastic quantitative exploration of Ohm's law," Phys. Teach 56, 75 (2018).

PST2A18: 10:15-11:00 a.m. Flow Theory: Students' Mental State During Physics Labs

Poster – Anna F. Karelina, 42 Broadmoor ct., San Ramon, CA 94583; anna.karelina@gmail.com

Students' emotions during labs are important for effective learning and for students' attitude towards the class. Here we describe an attempt to measure students' mental state within the framework of flow theory [1]. For our measurements we used a Likert scale survey with 7 questions we have developed before [2]. The questions relate to the conditions of flow and to the students' attitude towards the labs. We used this survey in labs in different institutions and with various cohorts of students. We analyzed students' answers to this survey to find whether this method consistently describes students' mental states during the labs. [1] M. Csikszentmihalyi, "Flow: The Psychology of Optimal Experience", (Harper and Row, New York, NY, 1990) [2] A. Karelina, "Laboratories' assessment in terms of flow theory", AAPT Summer Meeting, Washington, DC, 2018

PST2A19: 9:30-10:15 a.m. How Long Was that Light on Anyway?

Poster – Roger A. Key, California State University, Fresno, 2345 E San Ramon Ave., MH37 Fresno, CA 93740; rogerk@csufresno.edu

John Walkup, Patrick Talbot, California State University, Fresno

A lab activity for teaching physics students the fundamentals of statistical analysis during the first few weeks of instruction is described. This activity involves students timing a pulse of light generated by an Arduino device of fixed duration with individual timers (e.g., stopwatch, iPhone timer). Because students are not informed of the true pulse duration until after they turn in their lab reports, they must express the estimated duration of the light pulse in terms of confidence intervals. This activity arises from a need for students to leverage the power of statistics to (1) optimize lab procedures through data-driven decision-making, (2) correct for bias through calibration, and (3) gauge the quality of their work in terms of confidence rather than correctness. We conclude that this three-step process aligns lab procedures closer to industry practices and elevates cognition and engagement among students.

PST2A21: 9:30-10:15 a.m. Low Cost Spectrographs and Spectral Radiance

Poster – Timothy Todd Grove, Purdue University Fort Wayne, 2101 E. Coliseum Blvd., Fort Wayne, IN 46805; grovet@pfw.edu

Low cost spectrographs (a device used to take pictures of spectra) can easily be made from inexpensive parts [for example, see Grove, et. al. "Using a shoebox spectrograph to investigate the differences between reflection and emission", American Journal of Physics, 86, pp. 594 – 601 (2018)]. Using simple methods, one can easily calibrate these devices with regards to wavelength. It is much more difficult to calibrate the device with regards to spectral radiance (a necessity for student investigations examining Planck's Law). Among the problems are the data compression of common color picture formats (which includes jpg), the non-uniform spectral reflection/diffraction of DVD fragments (which are commonly used as diffraction gratings), and the "measured light intensity" of low cost digital cameras can vary based upon pixel location (center of the screen vs. the edges of the screen). We will present information regarding these issues as well as possible ways to defeat these difficulties.

PST2A22: 10:15-11:00 a.m. Measuring the Activity of Radioactive Isotopes in Soil Using NaI Detector in the Advance Physics Lab

Poster – Rebekah Aguilar, California State Polytechnic University Pomona, 3801 W Temple Ave., Pomona, CA 91768-4031; rsaguilar@cpp.edu

Peter Siegel, Nina Abramzon, California State Polytechnic University Pomona

Experiments involving nuclear radiation detection are routinely performed in the undergraduate physics curriculum. Common detectors found in many undergraduate institutions are sodium iodine (NaI) gamma detectors. These detectors are relatively inexpensive and are well suited for the teaching of basic spectroscopic techniques. For the study of environmental samples high resolution gamma detectors are ideal however these detectors are less common. We report on the use of NaI detectors to study environmental samples. Known decay products from the higher-end energy spectrum sources were used for calibration, gamma energy peaks that were measured include: 1440 keV for Potassium-40, 1764 keV for the Uranium-238, and 2614 keV for the Thorium-232 series. A secular equilibrium was used to assume that the activity of each isotope within their decay series were the same. Our results indicate that NaI detector can be used by students to measure the activity of radioactive isotopes in a soil.

PST2A24: 10:15-11:00 a.m. Refining a Rubric for Assessing Student Laboratory Work on Whiteboards

Poster – Benjamin T. Spike, University of Wisconsin - Madison, Department of Physics, 1150 University Ave., Madison, WI 53706-1390; btspike@wisc.edu

In our recently redesigned introductory lab environment, each student group submits a digital photograph of their whiteboard in place of a traditional laboratory report. Because students are limited in the amount of detail they can reasonably include on their 2'x3' whiteboard, we have devised a rubric to outline essential features of their "report" and clearly communicate how they will be assessed. Students are expected to include a diagram of the experimental setup, a concise description of their approach, relevant numerical calculations, and a summary of results with attention to uncertainty and assumptions. We will present the complete grading rubric, evaluate its success at capturing students' experimental thinking, and discuss future modifications.

PST2A25: 9:30-10:15 a.m. The "Klein-Gordon string" for Teaching Dispersion and Anisotropic Wave Phenomena

Poster – Sergej Faletic, University of Ljubljana, Faculty of Mathematics and Physics, Jadranska 19, Ljubljana, Slovenia 1000 Slovenia; sergej.faletic@fmf.uni-lj.si

Gorazd Planinsic, University of Ljubljana, Faculty of Mathematics and Physics, Slovenia

Marisa Michelini, Physics Education Research Group, DMIF, University of Udine, Italy

Daniele Buongiorno, Physics Education Research Group, DMIF, University of Udine, Italy

Mojca Cepic, University of Ljubljana, Faculty of Education, Slovenia

A wave, propagating on a springs-and-beads string hanging on elastic strings is described by the Klein-Gordon equation. The medium is dispersive and many phenomena related to dispersion can be shown using it: the different phase velocities depending on frequency, the difference between phase and group velocities, the deformation of a pulse. Additionally, a medium as described above is anisotropic, so phase velocities for a vertically polarized wave and a horizontally polarized wave are different, so a source linearly polarized at 45° produces a wave whose polarization state depends on the position, i.e. the polarization can be either linear, elliptical or circular, depending on the distance from the source. We also present a teaching and learning sequence using the apparatus and the results of various implementations.

PST2A26: 10:15-11:00 a.m. The "Klein-Gordon string" for Teaching Quantum Mechanics

Poster – Sergej Faletic, University of Ljubljana, Faculty of Mathematics and Physics, Jadranska 19, Ljubljana, Slovenia 1000 Slovenia; sergej.faletic@fmf.uni-lj.si

In learning quantum mechanics, students are often told not to compare wavefunctions with waves. But the brain always compares, and the similarities are undeniable, so a better approach would be to compare and contrast the two. Therefore, I set out to explore which behavior of the quantum wavefunction can be observed also in classical waves and which cannot. Exponential tails, tunneling, the change of wavelength, and point-like energy transfer are all phenomena observed in classical waves. The question then becomes, which are the specifically quantum aspects that cannot be reproduced with classical waves? And this is the goal: to focus the teaching of quantum mechanics on the specifically quantum aspects, while dealing with wave aspects separately. A teaching and learning sequence using this approach is also suggested and some results of a pilot implementation are presented.

PST2A27: 9:30-10:15 a.m. Using Staggered Post-Testing to Improve Targeted Scientific Reasoning Skills*

Poster – Larry J. Bortner, University of Cincinnati, Physics Department, ML11, Cincinnati, OH 45221; bortnelj@ucmail.uc.edu

Kathy Koenig, Krista Wood, University of Cincinnati

Lei Bao, The Ohio State University

Over the past several years, in order to foster scientific reasoning (SR), we have been developing lab curricula and an associated assessment (Inquiry for Scientific Thinking and Reasoning [iSTAR]). The requisite SR skills include systematic exploration of a problem, hypothesis formulation and testing, variable manipulation and isolation, and consequence observation and evaluation. Of these, the control of variables (COV) is the basic subset that we focus on. COV is further broken down into nine operationally defined sub-skills that indicate developmental progress (low, intermediate, and high). Our lab courses are sufficiently populated (500-800) that we can give the post-iSTAR to random groups at strategic times over the 14-week semester to gauge statistically significant COV progress. Curriculum changes spurred by past results will be discussed.

*Partial support from NSF DUE 1431908

Physics Education Research II

PST2B01: 9:30-10:15 a.m. Assessing Multi-variable Reasoning*

*Poster – Anthony Crawford,** University of Cincinnati, 2600 Clifton Ave., Cincinnati, OH 45221; crawfoab@mail.uc.edu*

Kathleen Koenig, University of Cincinnati

Lei Bao, The Ohio State University

Krista Wood, University of Cincinnati

Scientific reasoning abilities are a common learning outcome across physics courses. One critical dimension that is under studied is students' ability to consider how multiple factors jointly impact an outcome. In a preliminary study, we sought to establish college student abilities in this area. This presentation will showcase the assessment task provided to students and the range of student thinking that resulted. These findings are important for developing and evaluating curriculum that addresses student shortcomings in this area of reasoning.

*Work supported by the NSF IUSE Program (DUE #1821396) **Sponsored by Kathleen Koenig

PST2B02: 10:15-11:00 a.m. Attitudes and Approaches to Problem Solving: Applicable to Pre-Post Measurement?

Poster – Andrew J. Mason, University of Central Arkansas, Department of Physics and Astronomy, Conway, AR 72035-0001; ajmason@uca.edu

The Attitudes and Approaches towards Physics Problem Solving (AAPS) Survey has been designed, validated, and administered as a post-test evaluation of students' attitudes towards problem solving for student populations in multiple studies. However, there is also potential for examining the AAPS' applicability towards pre-post measurements, as has been established with other attitudinal surveys. As a preliminary exploration of this idea, pre-post data is examined from a single section of first-semester introductory algebra-based physics students (~50-70 students). Items for discussion include whether or not a pre-post shift is detectable for this population, as well as considerations for establishing validity of the AAPS as a pre-test for this population.

PST2B04: 10:15-11:00 a.m. Bringing Physics into the Art Venue: Connecting Physicists and Artists

Poster – Dena Izadi, Michigan State University, 567 Wilson Rd., East Lansing, MI 48824; izadiden@msu.edu

Mohammad Maghrebi, Kathleen Hinko, Michigan State University

Physics can often be intimidating for the general public, which is rather unfortunate. Our goal is to break this barrier and create a medium that public can understand and even communicate the language of physics. We seek to achieve this through a rich, familiar medium such as art. We organize a series of workshops that brings together physicists, artists and the public in the Art Lab venue (Eli and Edythe Broad Art Museum - Michigan State University). The goal is for the audience to be able to visualize complicated concepts through creating art work. At the end of the session, participants engage in an open discussion of how art can act as a powerful medium to visualize science. In this poster, we describe the design of the activities, how the event went, and challenges of attempting to bridge art and physics.

PST2B05: 9:30-10:15 a.m. Circular Motion Revisited – Static Solution to a Dynamic Problem?

Poster – Moa Eriksson, Sölvegatan 14 Lund, Lund 22362 Sweden; moa.eriksson@fysik.lu.se

Cedric Linder, Uppsala University

Urban Eriksson, Ann-Marie Pendrill, Lassana Ouattara, Lund University

Circular motion is a part of introductory physics courses that often present difficulties for students. These difficulties are especially seen when students are asked to specify appropriate forces acting on the object in circular motion and we will present such difficulties using a case study looking at students' problem solving in small, interactive groups. Students' discussions were video recorded and analyzed through a social semiotics lens. From the data analysis we could identify certain disciplinary-specific challenges students encounter in this situation which may be linked to what aspects of the problem they are able to discern. The students' strategies for specifying these forces was also compared to strategies used by teachers.

PST2B06: 10:15-11:00 a.m. Classifying Learning Opportunities in Faculty Online Learning Community Meetings

Poster – Alexandra C. Lau, University of Colorado Boulder, 390 UCB Boulder, CO 80309; alau693@gmail.com

Adriana Corrales, Fred Goldberg, San Diego State University

Chandra Turpen, University of Maryland

Faculty Online Learning Communities (FOLCs) are a unique professional development environment for physics and astronomy instructors where they engage in sustained pedagogical reflection and growth. FOLC participants meet via a videoconferencing platform to discuss their teaching. In order to capture the breadth and depth of learning that can occur by participating in a FOLC, we have developed a taxonomy to characterize the opportunities to learn (OTLs) in a FOLC meeting. In this poster we will present our taxonomy and discuss its development based on meetings from a FOLC centered around the Next Generation Physical Science and Everyday Thinking curriculum. In order to accurately characterize the OTLs in our FOLCs, we needed to consider both the content of the conversations as well as how participants engaged in the conversations. We will present how our taxonomy captures both of these dimensions. We will also discuss the broader utility of this framework.

PST2B07: 9:30-10:15 a.m. Conversation Networking

Poster – Marshall Adkins, East Carolina University, 30 Magnolia Ave., Pinehurst, NC 28374; marshalladkins64@gmail.com

Steven Wolf, East Carolina University

Austin McCauley, Elenor Close, Texas State University

In interactive learning environments, conversations are an important medium whereby ideas are shared and understanding is constructed. In this study, we describe the behaviors and conversation patterns of Learning Assistants (LAs) engaged in small-group discussions during weekly preparation sessions. LAs are undergraduate students who work with course faculty to support active learning pedagogies. We coded LA behavior according to the following categories: socializing, separate work, group discussion, group discussion with instructor, and socializing with instructor. We coded video in these categories for each 15 second increment. After this initial coding pass, we created conversation maps which identify the speaker and all listeners in each of those 15 second segments. All analyses have been carried out in the statistical programming language R, utilizing packages including 'igraph' and 'sna' to allow for characterization of the conversation maps.

PST2B08: 10:15-11:00 a.m. Describing Collaborative Exams Using Random Graphs

Poster – Aaron M. Bain, East Carolina University, 8033 kalmia ln., Hope Mills, NC 28348; aaronbain16@gmail.com

Timothy M. Sault, Steven F. Wolf, East Carolina University

Humans are social creatures who learn as a unit in their communities. The goal of this research is to model these interactions and better describe and understand the individual interactions within the community. Through a better understanding of how these interactions take place we can better understand the connection between the cognitive and social domains of learning. Interactions between students taking collaborative exams are quantified using the framework of Network Analysis. Network Analysis has many models that can be used to describe different types of networks. We compare student collaboration networks to these different random Network Analysis models.

PST2B09: 9:30-10:15 a.m. Developing and Validating a Closed Response Practice-Based Identity Survey

Poster – Kelsey M. Funkhouser, Michigan State University, 567 Wilson Rd., East Lansing, MI 48824; kfunkh@msu.edu

Rachel Henderson, Marcos Caballero, Vashti Sawtelle, Michigan State University

This poster will describe the development of a survey to measure students' physics identity. Using a Communities of Practice lens, we examine laboratory classes with a specific emphasis on students' experiences with physics practices. From a robust understanding of students' ideas about these practices, we can get information about how students situate themselves with respect to the practices as an indicator of their physics identity. We have combined qualitative and statistical analyses to reduce the items and overall dimensions of the survey. The poster will highlight the survey development process with specific focus on turning open-ended responses into closed-form survey questions that combine practices and identity.

PST2B10: 10:15-11:00 a.m. Developing Reflective Practitioners: A Case from Faculty Online Learning Communities

Poster – Alexandra C. Lau, University of Colorado Boulder, 390 UCB, Boulder, CO 80309; alau693@gmail.com

Melissa Dancy, University of Colorado Boulder

Charles Henderson, Western Michigan University

Andy Rundquist, Hamline University

One of the main goals of the New Faculty Workshop Faculty Online Learning Community (NFW-FOLC) program is to develop the reflective practices of our participants. By increasing the reflective teaching practices of our new physics and astronomy faculty, we hope to promote the sustained adoption of research-based instructional strategies and a dedication to continuous teaching improvement. One of the ways we try to achieve these goals is by guiding our FOLC participants through the completion of Scholarship of Teaching and Learning (SoTL) projects. In this poster we report on our analysis of participants' conversations about their SoTL projects, from the beginning stages through final presentations, documenting their trajectories through different levels of reflectiveness. Additionally, we identify mechanisms in the FOLC that seem to support participants through the stages of reflection. This work illustrates in detail one impact of FOLC participation and it offers implications for similar professional development efforts.

PST2B12: 10:15-11:00 a.m. Do I Belong Here?: Understanding Participation and Non-participation in Whole-Class "Board" Meetings

Poster – Brant E. Hinrichs, Drury University, 900 n benton Ave., Springfield, MO 65802; bhinrichs@drury.edu

Jared Durden, Ozarks Technical Community College

In University Modeling Instruction, students work in small groups on a problem and then hold a student-led whole-class discussion to develop consensus. While this kind of interactive-engagement has been shown to help students learn, evidence suggests not all students have the same experience or feel equally included. We have developed a preliminary coding scheme based on Wegner's framework from "Communities of Practice", which identifies student modes of belonging through participation and non-participation. In this talk, we present initial results from coding and analyzing reflective student writing assignments on a particularly contentious mid-semester whole-class discussion. Using this lens, we identify students' varying perceptions of the whole-class discussion and how it influenced their participation. By developing a descriptive model of student engagement, we seek to create a predictive model to inform professional development for instructors who teach in student centered classrooms.

PST2B13: 9:30-10:15 a.m. Effectiveness of Modified Fluid Flow Diagrams for Student with and without Prior Instruction

Poster – Josh R. Love, Illinois State University, 23 West 466 Greenbriar Drive, Naperville, IL 60540; jlove6898@gmail.com

Colton Brucks, Amber Sammons, Raymond Zich, Illinois State University

Rebecca Rosenblatt

Diagrams are ubiquitous in STEM. These diagrams serve a range of purposes, such as problem-solving tools, displaying data, and communicating a concept. This study investigated modifications to pressure and fluid speed gauges and their effects on students' ability to rank fluid pressures or speeds. We presented students with fluid flow diagrams for incompressible fluid flowing through pipes with varying diameters and depths. These diagrams used pressure gauges and arrows to indicate fluid pressure and speed. We modified these gauges based on theories of visual attention and affordance and investigated the effects on student responses and student learning for students with and without prior instruction on fluid flow. Findings indicate that these visually modified images were more effective than standard images for teaching students about pressure and fluid speed independent of prior student instruction. Also, we observed interesting interactions between prior instruction and student learning with the different diagram types.

PST2B14: 10:15-11:00 a.m. Engage Students' Attention with Clickers in Active Learning Lectures

Poster – Jacqueline Y. Bao, The Ohio State University, 191 W Woodruff Ave., Columbus, OH 43210; bao.224@osu.edu

Shaona Zhou, South China Normal University

Joseph Fritchman, The Ohio State University

In large lectures, clickers have been popularly used as a method to deliver active engagement instruction with proven effectiveness on improving student learning. One possible factor contributing to the success of the active learning approach is the engagement of students' attention during teaching and learning. Using video based face tracking, this research investigates how the use of clickers in lectures engages students' attention to the learning materials and activities, and how variation in the attention impacts learning outcomes. The results of a controlled study demonstrate that the use of clickers engages students with longer period of attention to teaching and learning compared to the control. The results also show a positive correlation between students' attention and their learning performances. The outcomes of this study can help to gain a deeper insight into the cognitive mechanisms underlying the active learning approach.

PST2B15: 9:30-10:15 a.m. Examine Physics Students Views on Ethics and the Atomic Bomb

Poster – Egla Ochoa-Madrid, Texas State University, 1701 Mill Street, Apt. 42103, San Marcos, TX 78666; e_o144@txstate.edu

Alice Olmstead, Texas State University

The societal implications of technology developed through physics research are not always clear. Physicists need to use ethical reasoning skills to maneuver through morally ambiguous situations. For this reason, curricula for physics students should also be geared towards developing these skills. Research can be found on the effects of structured ethical discussions in similar fields like engineering education, however, little research can be found on their effects in physics education. Our research listens in on student conversations in a Modern Physics class at Texas State University as they are asked to discuss the ethics of the atomic bomb development over several weeks. We present themes found in students' reasoning during this unit. Our preliminary analysis shows how students both learn to better support their already established opinions and struggle to see different points of view.

PST2B16: 10:15-11:00 a.m. Examining the Effects of Testwiseness Using the FCI and CSEM

Poster – Seth T. DeVore, West Virginia University, 135 Willey St., Morgantown, WV 26506; stdevore@mail.wvu.edu

John Stewart, West Virginia University

Testwiseness is generally defined as the set of cognitive strategies used by a student and intended to improve their score on a test regardless of the test's subject matter. To improve our understanding of the potential effect size of several well-documented elements of testwiseness we analyze student performance on questions present in the Force Concept Inventory (FCI) and Conceptual Survey on Electricity and Magnetism that contain distractors, the selection of which can be related to the use of testwiseness strategies. Additionally, we examine the effects of the position of a distractor on its likelihood to be selected in five-option multiple choice questions. We further examine the potential effects of several elements of testwiseness on student scores by developing two modified versions of the FCI designed to include additional elements related to testwiseness. Details of the effect sizes of these various aspects of testwiseness will be discussed.

PST2B18: 10:15-11:00 a.m. Exploring Students' Understanding of the Conceptual Knowledge Behind Problem Solving

Poster – Shih-Yin Lin, National Changhua University of Education, 1 JinDe Rd., Changhua, 500 Taiwan; hellosilpn@gmail.com

Ting-Chi Yang, National Changhua University of Education

Understanding the conditions under which a physics principle is applicable is essential in problem solving. However, our experience suggests that students may not necessarily understand the conceptual underpinnings behind the equations they use in their solutions. Even for students who are competent in recognizing which principle(s) or concept(s) should be used to solve a given problem, they may have difficulty providing a good justification for why the particular physics principle(s) or concept(s) can be applicable based on the underlying physics involved. We conducted a study to explore students' understanding of the conditions of applicability required for five basic concepts in introductory mechanics, including the kinematics equations, Newton's second law, conservation of momentum, conservation of mechanical energy, and conservation of angular momentum. Findings will be reported.

PST2B19: 9:30-10:15 a.m. Exploring Thinking Patterns in Electromagnetism*

Poster – Orlando M. Patricio, Laredo College, West End, Washington St., Laredo, TX 78040; orlando.patricio@laredo.edu

Educational researchers in STEM fields strive to explore ways to improve the students' understanding of electromagnetic concepts and principles. Most physics concepts in electromagnetism are difficult for many students to grasp. They are not visual and often not easy to visualize. Hence, this study employed Sense-making Activities to map out the students' thinking patterns and understanding of electromagnetic concepts and principles. The students were provided sense-making tasks and required to write explanations as they answer thought-provoking questions and problems about electromagnetism. Their responses were analyzed using a thematic approach to provide meaningful interpretation of the students' thinking patterns. The students were also interviewed by the researcher to validate the results of their responses in the activities and probe deeper description of their answers. The best thinking patterns and practices will be useful in developing lessons and in teaching electromagnetic courses to improve students' understanding.

*With permission from Pearson in using some Sense-making Activities.

PST2B20: 10:15-11:00 a.m. Extending the Usability of the C3PO Problem-solving Coaching System

Poster – Evan Frodermann, Missouri State University, 901 South National, Springfield, MO 65897; efrodermann@missouristate.edu

Hayden Stricklin, Missouri State University

Starting in 2010, the physics education research group at the University of Minnesota has been developing online computer coaches intended to aid students in developing problem-solving skills in physics. The original pre-prototype coaches were given at the University of Minnesota in calculus-based introductory physics courses and were found to usable by the students and contributed to improving problem-solving. These coach studies were in courses led by PER faculty at a large-scale research institution. The research presented here examines the student usability of the coaches at Missouri State University (MSU), a primarily undergraduate granting public institution. These studies explore usability of the coaches with a different student population demographic. Both PER and non-PER faculty at MSU utilized the coaches in their courses to explore possibility of instructor bias. There is a difference in coach usability for the students, specifically in expectation for the coaches and the applicability to their course work.

PST2B21: 9:30-10:15 a.m. Helping Students Learn the Math They Need to Succeed in Physics

Poster – Jeff Saul, nex+Gen Academy, 12200 Academy Road NE # 312, Albuquerque, NM 87111; scaleup13@gmail.com

Marila Mancha-Garcia , Krystal Irby, nex+Gen Academy

This year, looking to reduce our students' failure rate in the 11th grade physics course, Irby (Physics) and Mancha-Garcia (Algebra) developed the STEM Bootcamp for our Algebra II and Precalculus courses and all physics students (and some non-physics students) were required to take it. The five online modules help students master mathematical order-of-operations (MDAS, fractions, parentheses, exponents, and mixed). Students were introduced to STEM Bootcamp in their math course and given one class period to work on it. Then students worked on it when they finished their class activity early or at home. The program succeeded. The failure rate for first semester physics was significantly reduced from previous years.) Nex+Gen Academy is a small community school with a capacity of 400 students in grades 9–12 with an emphasis on project-based learning. We formally teach, assess, and grade students on content knowledge, agency, collaboration, communication, and inquiry & analysis.

PST2B22: 10:15-11:00 a.m. High School Student Perspectives on Computation in Different Classroom Contexts

Poster – Paul C. Hamerski, Michigan State University, 567 Wilson Rd., East Lansing, MI 48824; tallpaul@msu.edu

Daryl McPadden, Marcos D. Caballero, Paul W. Irving, Michigan State University

For many of today's educators and researchers, computation goes hand-in-hand with science education. Integrating computational practices with STEM classrooms gives learners a more realistic view of what science is, and better prepares students for pursuing careers in a world where computation is ubiquitous. This study examines one instance of such integration in the physics classroom of a suburban, racially diverse high school. The students whose perspectives we investigate have multiple formal computation experiences – both in their physics class and their computer science class. Using interviews, in-class recordings, and field notes, we produce a case study on the dual experience that some high school students have with computation, and from this case study we provide an in-depth, organic perspective on the difference between learning computation inside and outside of the physics classroom.

PST2B23: 9:30-10:15 a.m. Highlighting Earlier Time-to-Degree from Preparation through Transfer Courses

Poster – Alyssa C. Waterson, Michigan State University, 567 Wilson Rd., East Lansing, MI 48824-2320; waterso8@msu.edu

John M. Aiken, University of Oslo

Rachel Henderson, Marcos D. Caballero, Michigan State University

Earning a bachelor's degree is expensive and time-consuming. Many undergraduate students pursue Advanced Placement (AP) courses in high school or transfer coursework from other degree-granting institutions. However, the effect of those transfer courses on the time it takes students to graduate (time-to-degree) is currently not well understood. In this work, we will investigate how incoming transfer courses impact students' time-to-degree. In addition, we will explore how demographic features (e.g., students' majors, gender, ethnicity, average grade) may impact the effect of transfer courses on time-to-degree. We have identified three subsets of degree earning students: those entering with college level transfer courses, those entering with only AP level transfer courses, and those entering without any transfer credit. Results suggest that earlier graduation is a direct result from having transfer courses in one's repertoire. Students who enter with college level transfer courses graduate the earliest, though not at the traditional four-year expectation (eight semesters).

PST2B24: 10:15-11:00 a.m. How Can We Assess Scientific Practices? The Case of "Using-Mathematics"

Poster – Amali Priyanka Jambuge, Kansas State University, 1600 Hillcrest Dr., Apt V26, Manhattan, KS 66502; amali@phys.ksu.edu

James T. Laverty, Kansas State University

Recently, there is an emphasis on including scientific practices into introductory-level college physics curricula, instruction, and assessments. We conducted a study to develop assessment tasks to elicit evidence of students' abilities to engage in the scientific practice, Using Mathematics. We used Evidence-Centered Design to develop these tasks and these tasks were given to students along with one on one think-aloud interviews. The students' written work was compared to the video of them solving the problem aloud to determine if what they wrote down can reliably predict whether or not they engaged in the scientific practice. In this poster, I focus on interesting aspects of the students' work that gives us evidence about how reliably we can assess students' use of mathematics. This work informs developing future classroom and standardized assessments that can assess scientific practices.

PST2B25: 9:30-10:15 a.m. How Can We Develop Assessment Tasks for "Planning Investigations"?

Poster – Hien Khong, 1544 International Ct. Apt 24, Manhattan, KS 66502; hienkhong@ksu.edu

James T. Laverty, Kansas State University

The Three-Dimensional Learning Assessment Protocol (3D-LAP) was introduced to transform assessments so that we can see students using their knowledge to do physics and NGSS has called them as scientific practices. This research focuses on developing assessment tasks for introductory courses where we can assess student abilities to plan investigations in physics. In order to figure out how to assess this practice, we first identified steps that go into the process of planning investigations. Then we collected data using a think-aloud protocol to identify observable in students' written work, which may provide evidences of the students engaging in the scientific practice. This will help us to design the assessments which both assess students conceptual understanding and their ability to do physics.

PST2B26: 10:15-11:00 a.m. How do Previous Coding Experiences Influence Undergraduate Physics Students?

Poster – Jacqueline N. Bumler, Michigan State University, 567 Wilson Rd., East Lansing, MI 48824; bumlerja@msu.edu

Paul C. Hamerski, Marcos D. Caballero, Paul W. Irving. Michigan State University

Project and Practices in Physics (P-Cubed), a section of introductory, calculus-based physics, is designed around problem-based learning. Students spend each class working in groups on a single complex physics problem. Some of these problems are computational in nature – students start with code from a visual computer program that runs without accurately accounting for the physics, and they spend the class period applying the physics concepts correctly in the program. Here we present an interview study that investigates the relationship between students' prior computational experiences and their experience with computational activities in P-Cubed. This investigation demonstrates the ways by which prior coding experience can impact how students make sense of computation within physics.

PST2B27: 9:30-10:15 a.m. How Faculty Perceptions of Three-Dimensional Learning Change Over Time

Poster – Lydia G. Bender, Kansas State University, 1228 N 17th Street, Manhattan, KS 66502-4160; lgbender@phys.ksu.edu

James T. Laverty, Kansas State University

The Next Generation Science Standards aim to improve K-12 science learning through the implementation of Three-Dimensional Learning (3DL). 3DL was designed to increase student understanding of science by combining core ideas, crosscutting concepts, and scientific practices into science curricula, instruction, and assessment. In response to calls to bring 3DL to college courses, the 3DL for Undergraduate Science (3DL4US) collaboration created a fellowship to support faculty adoption of 3DL. During the fellowship, faculty members participate in discussions and activities during monthly meetings and in an online forum. The conversations between the fellows provide insight into how faculty think about and view 3DL, and how these views change over time. We analyzed these conversations to identify changes and the factors that led to those changes in order to improve future faculty development.

PST2B29: 9:30-10:15 a.m. Implications for Graduate Student Advising Based on Faculty Hiring Data

Poster – Lindsay Owens, Rochester Institute of Technology, 84 Lomb Memorial Drive, 3355 Gosnell Hall, Rochester, NY 14623; lmosch@rit.edu

Jacob E. Mekker, Benjamin M. Zwickl, Scott V. Franklin, Casey W. Miller, Rochester Institute of Technology

According to the APS, approximately 50% of physics graduate students envision themselves as future faculty, however, only ~11% of PhDs in physics find a permanent faculty position in a research university. We collected data on over 6,500 current faculty and found that the top 25% of physics and astronomy programs (ranked by NRC score) produce 58% of all faculty in PhD granting programs and comprise ~74% of faculty positions at these top institutions. The lower ranked (26-100%) programs accounted for 18% of overall faculty. While obtaining a faculty position is always possible, it is important that graduate students have a realistic picture of faculty employment data and the diverse range of employment options for PhDs. Career advising from the earliest stages of graduate education is critical so that students can build their networks, professional skills, and technical skills to be equipped for a successful career. (Supported by NSF-1633275)

PST2B30: 10:15-11:00 a.m. Improving Physics Students' Self-Efficacy with a Brief Mindset Intervention

Poster – Ian D. Beatty, UNC Greensboro, PO Box 26170, Greensboro, NC 27402-6170; idbeatty@uncg.edu

Sedberry-Carrino J. Stephanie, William J. Gerace, Michael J. Kane, UNC Greensboro

Jason Strickhouser, Florida State University

Helping more university students, especially under-represented minorities, complete STEM degrees and enter the STEM workforce has proven to be surprisingly difficult. Those most at risk benefit least from innovations addressing only pedagogy or curriculum. Research shows that we must influence students' self-efficacy: their belief that they can overcome setbacks and ultimately succeed. Our NSF-funded project is developing and validating a short, inexpensive, easily used intervention to improve students' self-efficacy, suitable for any university STEM course. It builds on two different kinds of research-based intervention: "attributional retraining," about ascribing successes and failures to internal rather than external factors; and "growth mindset," about becoming smarter and more successful through perseverance and conscious attention to thinking and learning strategies. While interventions of demonstrated efficacy exist for each, none address both attribution and mindset, and none are suitable for widespread use in university-level STEM instruction.

PST2B31: 9:30-10:15 a.m. Increasing Active Learning Effectiveness Using Deliberate Practice: A Homework Transformation

Poster – Kristina Callaghan, University of California, Merced; Harvard University 1340 Cormorant Dr., Merced, CA 95340; kcallaghan@ucmerced.edu

Kelly Miller, Logan McCarty, Louis Deslauriers, Harvard University

We show how learning can be improved in actively taught classrooms by transforming homework using the principles of deliberate practice. We measure the impact of transforming the homework on student learning in a course in which an active learning approach had already been implemented. We compare performance on the same final exam in equivalent cohorts of students over three semesters of an introductory physics course; the first taught with traditional lectures and traditional homework, the second taught with active instruction coupled with traditional homework, and the last taught with both active instruction and transformed homework. We find students in the semester where both active teaching and transformed homework are used score 20% better on the final exam than the students taught actively but with traditional homework. This learning gain achieved by transforming the homework is comparable to that achieved by replacing traditional lectures with active teaching strategies in-class.

PST2B32: 10:15-11:00 a.m. Introductory Physics II Lab Practical Exam Development: Investigation Design*

Poster – Annalisa Smith-Joyner, East Carolina University, East 5th Street, Greenville, NC 27858; smithann14@students.ecu.edu

Feng Li, Dr. Mark W. Sprague, Dr. Joi P. Walker, Dr. Steven F. Wolf, East Carolina University

This study reports the development and validation of an instrument used to assess science practices in the second semester of an introductory physics laboratory. The Investigation Design, Explanation, and Argument about Core Ideas Assessment (IDEA) instrument asks students to demonstrate science practices by having them design and conduct an investigation, analyze the collected data, and write an argument. The physics IDEA instrument was validated with (1) upper-division physics undergraduate students, (2) physics graduate students, and (3) physics faculty. By the instrument measuring targeted science practices, this study establishes construct validity. The practical was administered in 12 laboratory sections in the course of one week in order to establish face validity. The results from implementation over a 1 year period will be discussed as well as the implications for our lab curricula.

*This work was supported by NSF DUE-1725655.

PST2B33: 9:30-10:15 a.m. Introductory Physics Students' Insights for Improving Physics Culture

Poster – Acacia Arielle, South Seattle College, 6000 16th Ave. SW, Seattle, WA 98106; aarielle562@southseattle.edu

Kai S. Bretl, Abigail R. Daane, South Seattle College

Amad Ross Columbia University

Women and people of color are underrepresented in classrooms and the field of physics. We can work to address this disparity by empowering students to change the physics culture within their own spheres of influence. Students in introductory, calculus-based physics classes from both two and four year institutions participated in lessons from the Underrepresentation Curriculum, a freely available curriculum designed to bring social justice conversations to the classroom. Post unit, students brainstormed ideas about how to raise awareness of, and ultimately remove, this inequity. We coded students' responses grouping analogous key words and phrases. Our analysis showed that students from both institutions generated similar sets of propositions. Their responses included having intentional conversations about equity issues and actively learning about their own biases. By following students' suggestions, we can create a more inclusive and diverse physics community.

PST2B34: 10:15-11:00 a.m. Investigating How Middle School Students View Different Science Disciplines

Poster – Cynthia Reynolds, The College of New Jersey, 2000 Pennington Road, Ewing, NJ 08628; reynolc5@tcnj.edu

Giovanna Masia, Elizabeth Parisi, AJ Richards, The College of New Jersey

In previous research we found that a large fraction of secondary level students expressed that they disliked physics while also saying they had never been taught about the subject. We also found that students struggled to correctly identify what physics IS, and frequently conflated physics with chemistry or other branches of science. To understand this phenomenon, we have chosen to investigate how students develop their attitudes and beliefs about physics and other sciences. We administered a survey to 5th-8th grade students that revealed how they conceptualize different branches of science. In this presentation we will detail our findings and discuss whether or not students have an accurate understanding of the content encompassed by the different branches of science. We will also discuss how that understanding impacts a student's perception of working in that field.

PST2B35: 9:30-10:15 a.m. Investigating the Effectiveness of Two Different Instructional Interventions

Poster – Rebecca J. Rosenblatt, 218 Willard Ave., Bloomington, IL 61701; rosenblatt.rebecca@gmail.com

Colton Brucks, Josh Love, Amber Sammons, Raymond Zich

In this study, we compare the effectiveness of a 20-minute guided inquiry session that uses the PhET simulation "Fluid Pressure and Flow" to a twice-watched 10-minute video that integrates voice-over explanations and real life examples with recorded demonstrations using the same simulation. Students were assessed pre and post activity on a variety of questions regarding fluid speed and pressure in pipes. An additional posttest was given five weeks after the activity to assess the long term effects of this intervention. To better control this study, students were recruited from a general education physics course that does not cover fluid dynamics in the curriculum. While data collection is still ongoing, we predict -- based on past studies of self-explanation and discovery learning -- that the video curriculum will show larger gains pre to post but the simulation will show improved retention.

PST2B36: 10:15-11:00 a.m. Is it Teaching or is it Physics?*

Poster – Austin C. McCauley, Texas State University, 810 N. LBJ Apt. 17, San Marcos, TX 78666-7397; acm117@txstate.edu

Marshall Adkins, Steven F. Wolf, Eleanor W. Close, Texas State University

The physics department at Texas State University has implemented a Learning Assistant (LA) program with research-based curricula (Tutorials in Introductory Physics) in introductory course sequences. The LA program structure at TXST is informed by the theory of Communities of Practice and the Physics Identity construct (Hazari et al.). We have been reviewing video data of LA prep sessions taken over the past three years in order to characterize LA discussions. In these prep sessions, LAs work through the tutorials together in small groups. As emerging physicists and physics teachers, LAs naturally engage in discussion in these groups that spans many topics directly relevant to the activity being prepared. Initially we attempted to code separately for discussions of physics content ("physics discussion") and discussions of student struggles relevant to teaching the physics content ("teaching discussion"). However, we have concluded that these categories are not meaningfully distinct.

*Supported by NSF DUE-1557405 and NSF PHY-0808790

PST2B37: 9:30-10:15 a.m. iSTAR: An Assessment Instrument on Scientific Thinking and Reasoning

Poster – Lei Bao, The Ohio State University, 191 W Woodruff Ave., Columbus, OH 43210; bao.15@osu.edu

Kathleen Koenig, University of Cincinnati

Yang Xiao, Shaona Zhou, South China Normal University

Jing Han, The Ohio State University

Scientific reasoning has been emphasized as a core ability of 21st century education. To understand how scientific reasoning can be developed among students, researchers and teachers need effective assessment tools on scientific reasoning. For decades, the Lawson's classroom test of scientific reasoning has been the only instrument available for large implementation, but with known validity weaknesses. It is imperative for the STEM education community to be equipped with a valid and updated assessment instrument on scientific reasoning suitable for the 21st century learners. Through a decade of research, a new instrument on scientific thinking and reasoning (iSTAR) has now been developed to its first release version. This presentation will provide the basic designs, assessment features, and application results of the iSTAR instrument. Future work and collaborations on applying iSTAR in research and teaching will also be discussed.

PST2B38: 10:15-11:00 a.m. Learning to Learn by Inquiry: Are Simulations too Challenging for Novices?

Poster – Jonathan Massey-Allard, 2329 West Mall, Vancouver, BC V6T 1Z4 Canada; jmassall@phas.ubc.ca

Ido Roll, Joss Ives, University of British Columbia

Inductive inquiry learning activities, where students are tasked with quantitatively modelling physics phenomena with little guidance from an instructor, have been shown to have substantial conceptual learning benefits. A common implementation is an "invention activity" where students invent a general rule from patterns in instructor-provided data before receiving direct instruction on the target topic. Alternatively, students could be provided with an interactive simulation where students then have the agency to explore and collect data on their own. While this provides a promising opportunity for developing more robust inquiry process skills, it also introduces substantial challenges for novices that may, for instance, only do a shallow exploration and miss crucial features of the domain. We discuss the impact on conceptual learning outcomes and process skill development from a study that tested the impact of these different affordances in a sequence of inductive inquiry activities implemented throughout an introductory E/M course.

PST2B40: 10:15-11:00 a.m. Methodological Development of a New Coding Scheme for an Established Assessment on Measurement Uncertainty in Laboratory Courses

Poster – Benjamin Pollard, University of Colorado Boulder, and JILA Duane Physics, E1B32 Boulder, CO 80309-0390; Benjamin.Pollard@colorado.edu

Robert Hobbs, Bellevue College

Dimitri R. Dounas-Frazer, Western Washington University, University of Colorado Boulder, and JILA

H J. Lewandowski, University of Colorado Boulder, and JILA

There is a need for research-based assessments in laboratory courses, both to improve such courses and to understand the unique learning that occurs in laboratory settings. In particular, a conceptual understanding of measurement uncertainty is a common learning goal in introductory laboratory courses. The Physics Measurement Questionnaire (PMQ) is an open-response assessment for measuring student understanding of measurement uncertainty. The PMQ was developed for use at the University of Cape Town, South Africa, and includes a coding scheme for analyzing responses from that institution. This original coding scheme needed to be modified for our different national and institutional context: the large introductory laboratory course at the University of Colorado Boulder, USA. Here, we document our process to develop a new coding scheme for the PMQ, and describe the resulting codebook. We also present preliminary results using the new scheme, from both before and after the course was transformed.

PST2B41: 9:30-10:15 a.m. Natural Science Transfer Scholars: Building Self-Efficacy, Identity, and Mindset

Poster – Vashti A. Sawtelle, Michigan State University, 567 Wilson Rd., East Lansing, MI 48824-2320; vashtis@msu.edu

Rachel Henderson, Angela Little, Laura A. Wood, Michigan State University

Michigan State University recently received a National Science Foundation S-STEM Grant in partnership with two area two-year colleges (NSF#1742381). The grant provides scholarships and summer research stipends for students alongside programming during their time at the two-year college and when students transfer to Michigan State. The research component of the grant focuses on understanding how two-year college students develop a sense of self-efficacy to complete STEM degrees, a science identity, and a growth mindset. Our team has been interviewing current two-year college transfer students about their experience with the transition, collecting fieldnotes and journal entries from students currently enrolled in the two-year college, and collecting survey data from students at both the two-year and four-year colleges. In this poster, we give an overview of our study as well as preliminary findings from these different data streams.

PST2B42: 10:15-11:00 a.m. Online Learning Communities: How Do they Support Instructors Through Challenges?

Poster – Chandra Anne Turpen, University of Maryland, 6701 Adelphi Rd., University Park, MD 20782; chandra.turpen@colorado.edu

Stephanie Williams, University of Maryland

Adriana Corrales, San Diego State University

Melissa Dancy, University of Colorado

Edward Price, California State University, San Marcos*

Research has shown that physics instructors encounter challenges in adapting research-based curricula and instructional strategies to their own contexts. Change scholars have called for curriculum developers to move from dissemination approaches toward propagation models that more deliberately and explicitly build supportive activities relevant to the uptake of their specific innovations. We investigate faculty online learning communities (FOLCs) as a potential mechanism for supporting faculty through the challenges they face in adapting the Next Generation Physical Sciences and Everyday Thinking curriculum [1]. Based on recordings of online discussions between faculty using this curricula, we document the challenges that instructors share and the ways in which community members react or respond to those challenges in conversations. We find that our FOLCs discussions often normalize challenges and generate possible solutions, and more rarely invite joint problem-solving. We model how variations in these reactions or responses create different outcomes for faculty participants.

*And the rest of the NextGenPET Research Team (Fred Goldberg, Alexandra Lau, and Meghan Clemons) [1] Work supported by NSF#1626496

PST2B43: 9:30-10:15 a.m. Physics is Objective - or is it?

Poster – Abigail R. Daane, South Seattle College, 6000 16th Ave. SW, Seattle, WA 98106; abigail.daane@seattlecolleges.edu

Chris Gosling, McGill University

Moses Rifkin, University Prep

Johan Tabora, University of Illinois-Chicago

Danny Doucette, University of Pittsburgh

Physics is widely perceived as an objective field. Students often echo that perception of physics as bias-free and not subject to human influence. In reality, a host of humans determine the focus of research, the projects that receive funding, and what is published. Using the Underrepresentation Curriculum, a freely available resource designed to bring conversations about equity to the classroom, students explore the question "is physics subjective or objective?" In this presentation, we share students' ideas about the nature of physics and how those ideas may influence their orientation to the scientific community. We posit that the illumination of subjectivity in hard sciences can be a powerful tool for motivating classroom conversations of social justice.

PST2B44: 10:15-11:00 a.m. Physics Self Belief Among Secondary School Students

Poster – Giovanna Masia, The College of New Jersey, 2000 Pennington Rd., Ewing Township, NJ 08618-1104; masiag1@tcnj.edu

Elizabeth Parisi, Cynthia Reynolds, AJ Richards, The College of New Jersey

There is a dramatic underrepresentation of ethnic minorities and women within physics. The reasons for this underrepresentation are not fully understood. To explore this, we have surveyed high school physics students in order to investigate the relationship between a student's physics self-belief, their likeliness to pursue a career in physics, and their sense of belonging within physics. In our analysis we paid special attention to how a student's demographic data affected these variables. In this presentation, we will detail the trends we found between the students' self-belief, their sense of belonging, their likelihood to pursue a career in physics, and their demographics.

PST2B45: 9:30-10:15 a.m. Psychometric Analysis of Instrument Measuring Student Reasoning Skills*

Poster – Brianna Santangelo, North Dakota State University, 1340 Administration Ave., Fargo, ND 58105; brianna.santangelo@ndus.edu

Mila Kryjevskaia, Alexey Leontyev, North Dakota State University

We have been developing and refining a two-tiered instrument aimed at measuring student reasoning in physics. Tier I focuses on assessing student conceptual understanding of physics, while Tier II requires students to apply that conceptual understanding in situations that elicit intuitive rather than formal reasoning approaches. The instrument was developed and administered in algebra-based and calculus-based physics courses. Psychometric evidence was collected to establish reliability and item functioning. This instrument is intended to be used to assess instruction aimed at developing students' reasoning skills in the context of physics.

*This material is based upon work supported by the National Science Foundation under Grant Nos. DUE-1431940, DUE-1431541, DUE-1431857, DUE-1432052, DUE-1432765, DUE-1821390, DUE-1821123, DUE-1821400, DUE-1821511, DUE-1821561.

PST2B46: 10:15-11:00 a.m. Renewed Attention for Interactive Lecture Demonstrations: Scripts and Orchestration Graphs

Poster – Shiladitya Raj Chaudhury University of South Alabama 310 Alumni Circle Mobile, AL 36688 schaudhury@southalabama.edu

This poster takes a fresh look at Interactive Lecture Demonstrations (ILDs) through a framework adopted from the field of computer supported collaborative learning (CSCL). ILDs are well known in the PER literature for their impact on improving student conceptual understanding through instructor-led activities using data from a demonstration (Thornton and Sokoloff, 1997). In other words, the technique is a time-honored whole-class method of student engagement through active learning. From research in the CSCL field we adapt the idea that all active learning designs incorporate two concepts - - enactment scripts and orchestration. The script for doing ILDs is well known, but expert orchestration only comes about with practice. In this poster we present the script and orchestration considerations for a typical kinematics ILD using the PhET Moving Man simulation. We also present visualizations of both Peer Instruction and ILD through creation of 'orchestration graphs' following the model of Pierre Dillenbourg.

PST2B48: 10:15-11:00 a.m. Revisiting an Identity Framework Through Coding Practice-based Identity Statements

Poster – Kelsey M. Funkhouser, Michigan State University, 567 Wilson Rd., East Lansing, MI 48824; kfunkh@msu.edu

Marcos Caballero, Vashti Sawtelle, Michigan State University

We will present on progress of producing a survey to measure physics identity in laboratory settings. We started with a framework from Close et al., that combined two perspectives on measuring and developing identity -- communities of practice (COP) and Hazari et al.'s physics identity. Through analysis of open-ended student responses to a pilot of the practice-based identity survey, we have not found evidence to support the combination of these two perspectives in our context. Our results suggest better alignment with COP on its own within our physics lab classes. In this poster we will outline the process that lead to the distinction in our theoretical framework and our focus on two specific COP dimensions of identity.

PST2B49: 9:30-10:15 a.m. Scientific Practices in Minimally Completed Programs

Poster – Daniel Oleynik, Michigan State University, 2100 Daintree Ave., West Bloomfield, MI 48323; oleynikd@msu.edu

Paul Irving, Michigan State University

Computational problem solving practices are beginning to be the center of many introductory physics courses. Specifically, within P-cubed, students regularly work on computational problems situated in physics that involve minimally working programs. Currently, very little research has been done on minimally working programs in relation to curriculum design, especially with how frequently they facilitate students in engaging with computational practices. After an initial coding of student work in class, we have identified extended periods of time where students were working on aspects of the problem that were not intended by instructors, which we coded as "distractors." Throughout the course of this presentation, we examine these distractors for computational practices and pedagogical benefits.

PST2B50: 10:15-11:00 a.m. Standards for Web Accessibility and Tips to Make Your Website More Accessible

Poster – Erin Scanlon, University of Central Florida, 4111 Libra Drive, Orlando, FL 32816; erin.scanlon@ucf.edu

Zachary W. Taylor, University of Texas - Austin

Jacquelyn J. Chini, University of Central Florida

There have been numerous recent calls to increase the representation of people with disabilities in STEM. One common entry point to physics programs is through departmental web pages where prospective students can find information about the program, including the undergraduate curriculum requirements and graduate research opportunities. If these web pages are inaccessible, they create a barrier to participation for people with disabilities. In order to assess the digital accessibility of undergraduate physics curriculum and graduate physics research web pages, we analyzed a representative sample of 74 institutions using Tenon (web accessibility audit software) and Voiceover (screen reading assistive technology). Overall, we found that all but one institution's web pages were inaccessible. In this poster we will describe the Web Content Accessibility Guidelines 2.0 standards for digital accessibility (which emphasize creating perceivable, operable, understandable and robust web content), common accessibility errors, and possible solutions to these errors.

PST2B51: 9:30-10:15 a.m. Can Tutorial Writers Help Foster Equitable Team Dynamics?*

Poster – Hannah C. Sabo, University of Maryland, 3942 Campus Dr., College Park, MD 20742; hsabo13@gmail.com

Andrew Elby, University of Maryland

This poster argues for a rethinking of one aspect of the instructional division of labor between curriculum developers and classroom instructors. Tools from socio-linguistics helped us investigate how students working through a tutorial position one another—create roles and expectations for each other—which filters their

interactions with each other and the tutorial. An illustrative example comes from a tutorial we designed to be used with the My Solar System PhET simulation. When a planet unexpectedly crashes into its star, a problematic dynamic arises between the students. The tutorial could have prevented this dynamic. We advocate for curriculum developers to attend to the kinds of conversations their activity sheets afford—not just at the coarse grain size of encouraging group discussion, but also at the finer grain size of affording equitable team dynamics.

*Work supported by NSF Grant 1245400.

PST2B52: 10:15-11:00 a.m. The Need for Guidelines/Standards for Research-based Conceptual Learning Assessment Instruments

Poster – Rebecca Lindell, Dr. 5 N 10th St Suite A-1, Lafayette, IN 47901; rlindell@tiliadal.com

In 2014, the American Educational Research Association (AERA), the American Psychological Association (APA) and the National Council on Measurement in Education (NCME) released an updated version of their book Standards for Educational and Psychological Testing (SEPT). These standards provide guidance for both test developers and users based on the latest advances in psychometrics. While many of the standards proposed in SEPT are applicable to the development and use of Research-based Conceptual Learning Assessment Instruments (RbCLAIs), they do not go far enough to cover the unique issues related to the distractor-driven nature of RbCLAIs. In this poster, I will discuss the SEPT standards for RbCLAI development and use, as well as how the SEPT needs to evolve to cover the distractor-driven nature of R-bCLAIs.

PST2B53: 9:30-10:15 a.m. Developing an Interactive Tutorial on a Quantum Eraser*

Poster – Chandralekha Singh, University of Pittsburgh, 3941 Ohara St., Pittsburgh, PA 15260; clsingh@pitt.edu

Emily Marshman, University of Pittsburgh

We developed a quantum interactive learning tutorial (QuILT) on a quantum eraser for students in upper-level quantum mechanics. The QuILT exposes students to contemporary topics in quantum mechanics and uses a guided approach to learning. It adapts existing visualization tools to help students build physical intuition about quantum phenomena and strives to help them develop the ability to apply quantum principles in physical situations. The quantum eraser apparatus in the gedanken (thought) experiments and simulations that students learn from in the QuILT uses a Mach-Zehnder Interferometer with single photons. We also discuss findings from a preliminary in-class evaluation.

*We thank the National Science Foundation for support.

PST2B54: 10:15-11:00 a.m. Developing and Evaluating a Quantum Mechanics Formalism and Postulates Survey*

Poster – Chandralekha Singh, University of Pittsburgh, 3941 Ohara St., Pittsburgh, PA 15260; clsingh@pitt.edu

Emily Marshman, University of Pittsburgh

Development of multiple-choice tests related to a particular physics topic is important for designing research-based learning tools to reduce the difficulties related to the topic. We explore the difficulties that the advanced undergraduate and graduate students have with quantum mechanics formalism and postulates. We developed a research-based multiple-choice survey that targets these issues to obtain information about the common difficulties and administered it to undergraduate and graduate students. We find that the advanced undergraduate and graduate students have many common difficulties with these topics. The survey can be administered to assess the effectiveness of various instructional strategies.

*We thank the National Science Foundation for award PHY-1806691.

PST2B55: 9:30–10:15 a.m. Student Difficulties with the Probability Distribution for Measuring Different Observables in Quantum Mechanics*

Poster – Chandralekha Singh, University of Pittsburgh, 3941 Ohara Street, Pittsburgh, PA 15260; clsingh@pitt.edu

Emily Marshman University of Pittsburgh

Quantum mechanics is challenging, even for advanced undergraduate and graduate students. We have been investigating the difficulties that students have in determining the probability distribution for measuring different observables as a function of time when the initial wavefunction for a given system is explicitly given. We find that many advanced students struggle with these challenging concepts. We discuss some common difficulties found.

*This work is supported by the National Science Foundation.

PST2B56: 10:15-11:00 a.m. Student Difficulties with Operators Corresponding to Observables in Dirac Notation*

Poster – Chandralekha Singh, University of Pittsburgh, 3941 Ohara St., Pittsburgh, PA 15260; clsingh@pitt.edu

Emily Marshman, University of Pittsburgh

Even though Dirac notation is used extensively in upper-level quantum mechanics, many advanced undergraduate and graduate students in physics have difficulty in expressing the identity operator and other Hermitian operators corresponding to physical observables in quantum mechanics using the Dirac notation in terms of the outer product of a complete set of orthonormal eigenstates of an operator. To investigate these difficulties, we administered free-response and multiple-choice questions and conducted individual interviews with students after traditional instruction in relevant concepts in advanced quantum mechanics courses. We discuss the common difficulties found.

*We thank the National Science Foundation for support.

Pre-college/Informal and Outreach

PST2C01: 9:30-10:15 a.m. Comparing Two Implementations of a Citizen-Science Program

Poster – John C. Stewart, West Virginia University, 235 White Hall, Morgantown, WV 26506; jcstewart1@mail.wvu.edu

Kathryn Williamson West Virginia University

Cabot Zabriskie West Virginia University

The Pulsar Search Collaboratory (PSC) is a citizen-science program designed to engage middle and high school students in radio astronomy. The project reserves a set of radio astronomy data for the students that has not been examined by scientists. In its initial implementation, the program was restricted to a few counties in West Virginia and training was delivered in a face-to-face summer camp. With the success of the initial implementation, a national model was constructed that involved a series of online training session and support from hub universities distributed across the country. These changes generated changes in how students participated and persisted in the program which will be explored.

PST2C02: 10:15-11:00 a.m. Intercultural Science Programs: A New, Collaborative Model for Informal STEM Education

Poster – Claudia Fracchiolla, University College, Dublin Belfield, Dublin Co Dublin 4 Ireland; claudia.fracchiolla@ucd.ie

Michael Bennett, University of Colorado Boulder

Zachariah Mmbasu, African Maths Initiative

As society becomes increasingly globalized, educational physics opportunities that promote both global thinking and increased representation are critically needed for ongoing the health of the STEM enterprise. To meet this need, informal physics educators from across the world have joined to develop a series of one-week camps designed to expose students in our local communities to collaborative and intercultural scientific experiences. These camps, will be implemented simultaneously at multiple global sites, will employ curricula featuring both real-time and asynchronous collaboration between student participants. Additionally, the cross-cultural nature of these camps is designed to facilitate their implementation in a number of locales, especially those with limited access to resources. We will discuss design philosophy, curriculum development, and aspects of volunteer training and testing for the camps, as well as future plans for implementation.

PST2C03: 9:30-10:15 a.m. A Final Summary of PSI^3*

Poster – Richard L. Pearson, Colorado School of Mines, 1523 Illinois St., Golden, CO 80401; rlpearson@mines.edu

Lacy M. Cleveland, CEC Early College

Wendy K. Adams, Colorado School of Mines

The PSI3 (Partnerships for STEM Identity: Three Populations of Active Learners) project has developed, taught, and distributed nearly 20 hands-on, minds-on science activity kits to public school districts across Colorado's front range. The collaborative effort of current elementary school teachers and secondary teacher candidates reached nearly 50 classrooms and thousands of students. Key outcomes of the PSI3 project—to develop science identities in both the elementary teachers and their students, as well as to encourage and empower those teachers to teach more science activities—have been achieved, and are manifest through continued kit requests, active teacher participation, and enthusiastic student participation. These lessons, and their associated kits, have inadvertently provided a nearly complete array of standards-based activities. A compilation of the lessons, kit materials, subsequent instructional videos, and other information can be found on the Colorado School of Mines' Teach@Mines website.

*This project is supported by 100Kin10.

PST2C04: 10:15-11:00 a.m. A Two-tiered Approach to Radio Astronomy Instruction with RadioJOVE*

Poster – Nicole Gugliucci, Saint Anselm College, 100 Saint Anselm Drive, Manchester, NH 03102-1310; ngugliucci@anselm.edu

Derek Chisholm, Nathan Letteri, Ana Morrison, Lindsay Yurek, Saint Anselm College

The RadioJOVE Project allows middle, high school, and college students to build, maintain, and use a dipole to observe Jupiter's emissions at 20 MHz. In Spring 2019, a RadioJOVE instrument was assembled at Saint Anselm College as part of Access Academy, an afterschool program for immigrant, refugee, and underrepresented high school students in Manchester, New Hampshire, through the Meelia Center for Community Engagement. Under the mentoring of one professor, four undergraduates with STEM backgrounds learned about the basics of radio astronomy instrumentation and observing, then led a group of 17 high school students in constructing and observing with RadioJOVE. This process required careful lesson planning on two levels: first, a self-directed learning program for the undergraduates, then a series of weekly structured lesson plans for the high school students. This poster will report on the lessons developed and on the outcomes of the project.

*This work is supported by the National Science Foundation DUE-1758227.

PST2C05: 9:30-10:15 a.m. Can a Spoonful of Sugar Help the Science Go Down?

Poster – Shiladitya Raj Chaudhury, University of South Alabama, 310 Alumni Circle, Mobile, AL 36688; schaudhury@southalabama.edu

Anne Wise, The Phi Beta Kappa Society

As the nation's most prestigious academic honor society, the Phi Beta Kappa Society is a leading voice championing liberal arts and sciences education, fostering freedom of thought, and recognizing academic excellence. Physics plays a prominent role in the society's cross-disciplinary efforts to tap its nationwide network of 500,000+ members, 286 chapters, and 50 alumni associations to share the public value of higher education. In order to broaden support for the liberal arts and sciences, PBK launched the National Arts & Sciences Initiative in 2013. In this poster we present some of PBK's strategies for embedding science advocacy into public-facing events and identifying unlikely community champions to voice their support for the study of disciplines such as physics. The poster will include tactics, tips and resources that PBK has used to broaden its impact, creating more dynamic opportunities to cultivate supporters from new or unlikely sources.

PST2C06: 10:15-11:00 a.m. Challenges and Learning Strategies in Studying AP STEM Courses

Poster – Albert Y. Bao, Dublin Jerome High School, 8300 Hyland-Croy Rd., Dublin, OH 43016; 20bao_albert@dublinstudents.net*

Students' experiences in studying AP STEM courses can be an important factor influencing their interests in pursuing career development in STEM fields. Through surveying a group of high school students who have completed multiple AP STEM courses, this research investigates students' experiences regarding typical challenges and learning strategies that students have in studying these AP courses. In addition, the possible influences from students' learning experiences on their interests in developing future careers in the STEM fields were also investigated. This poster will present the outcomes of this study with detailed cases to show common difficulties encountered by the students and useful learning strategies implemented in their learning. Results on possible impacts from students' learning experiences on their career preferences will also be discussed.

*Sponsored by Lei Bao

PST2C07: 9:30-10:15 a.m. Ice Skating and Physics: Supporting Multiple Identities in Informal Spaces

Poster – Brean Elizabeth Prefontaine, Michigan State University, 300 N Hayford Ave., East Lansing, MI 48823-2398; prefont4@msu.edu

Kathleen Hinko, Michigan State University

Lack of both gender and racial diversity is an ongoing and persisting problem within physics, despite funding and programming aimed at attracting students to the field. However, students who feel as though they need to give up their identities, culture, femininity, etc. will not continue to stay within physics. Research in other disciplines shows that both informal and interdisciplinary spaces are important for science identity development, especially for minority populations. We look to examine informal spaces that allow participants to cultivate and develop their physics identity with some of their other identities by blending physics with other fields/interests such as music, sports, hobbies, and art. Here we focus on a trial event created at an ice rink where children and families explored the physics behind an activity they already enjoy, ice skating! We aim to create future events that create an inclusive and welcoming physics environment.

PST2C08: 10:15-11:00 a.m. Where Are the Stars? A Citizen Science Mass Experiment on Light Pollution

Poster – Urban Eriksson, National Resource Center for Physics Education, Lund University Sölvegatan 14 Lund, Skåne 221 00 Sweden; urban.eriksson@fysik.lu.se

Scientific studies have shown that scattered artificial light—light pollution—have unexpected and worrying negative effects on the biology of many organisms, ecosystems, and on human health. However, we use street lamps, illuminated signs, car-light to improve safety and make cities more attractive at night. In the Star-Spotting Experiment, hundreds of thousands of pupils, scouts, and members of the public in Sweden and other countries are being invited to contribute to scientific research about light pollution. The experiment builds on the fact that the more light there is, the fewer stars you see. Hence, we encourage people to count stars where they live, using a simple method, and report via an App. We present results on 1) peoples' awareness of the night sky, 2) how this method compares to other measures of light pollution, 3) possible consequences for ecology, sustainability and urban planning.

Technologies

PST2D01: 9:30-10:15 a.m. Analyzing Student Learning Behavior Through Robotics Programming and Virtual Software

Poster – Michael R. Zurba, University of Manitoba, 687 Jessie Ave., Winnipeg, MB R3M 0Z4 Canada; mzurba@rrvsd.ca

Richard Hechter, University of Manitoba

Many schools have taught programming logic with LEGO EV3 robots to implement or enhance STEM education. There are different approaches to robotics that educators can take considering available equipment or financial resources. We will assess student learning through observations of behavior while learning with actual robots or virtual robotics software (or both simultaneously). Learning behaviors will be selected that are congruent with the direction of Next Generation Science Standards (NGSS) under the assumption that they will be more relevant to modern students, educators, and the corporations in relevant fields (Krajcik, Codere, Dahsah, Bayer, & Mun, 2014). The Interactive, Constructive, Active, and Passive (ICAP) framework (Chi & Wylie, 2014) predicts that students will become more engaged with materials and learning will increase as they progress from passive to interactive learning. This study will analyze these learning behaviors of the students as a reflection of individual student learning during different treatments.

PST2D02: 10:15-11:00 a.m. BuckeyeVR 3D Plot Viewer – A Free Resource for Smartphone-based VR*

Poster – Chris Orban, The Ohio State University, 191 W Woodruff Ave., Columbus, OH 43210; orban@physics.osu.edu

Joseph R.H. Smith, The Ohio State University

Chris D. Porter, The Ohio State University

Although there are a number of smartphone apps that can produce interesting stereoscopic visualizations using a cheap VR viewer (often called Google Cardboard), until recently there did not exist a resource to allow STEM educators to use this VR technology to display user-defined functions, curves and vector fields. The BuckeyeVR 3D plot viewer is a free resource that allows educators to both render a user-defined function in a web interface and to quickly view this function in stereoscopic 3D using smartphone-based VR. This is made possible by a freely available smartphone app for Android and iPhones that can take information from the web interface and reproduce the visualization on the smartphone. This resource is available at buckeyevr.osu.edu and we encourage STEM educators to adopt it and to collaborate with Ohio State in examining the pedagogical benefits of this technology

*Funding from OSU internal sources including the STEAM factory

PST2D03: 9:30-10:15 a.m. Costs and Benefits of a Functional Programming Language in Physics Teaching

Poster – Scott N. Walck, Lebanon Valley College, 101 N College Ave., Annville, PA 17003; walck@lvc.edu

Functional programming languages, such as Haskell, have a reputation for being difficult to learn and use. There is some truth to this, but functional languages are difficult to learn in the same way that physics is difficult to learn; both invite and sometimes require a structured thinking. The thinking required to use Haskell matches surprisingly well with that required for physics. The benefit is that, once learned, functional language allows one to focus less on the computer's needs and more on the structure of physics. We show an example of a PICUP exercise implemented in Haskell to see the benefits. The presenter will also speak from his experience about the costs.

PST2D04: 10:15-11:00 a.m. Design and Evaluation of a Teacher Dashboard for Interactive Simulations

Poster – Diana B. López Tavares, Instituto Politécnico Nacional Calz Legaria, 694 Mexico city, MEX 11500 Mexico; dianab_lopez@hotmail.com

Katherine Perkins, Michael Kauzmann, University of Colorado at Boulder

Carlos Aguirre Velez, Instituto Politécnico Nacional

Do you assign PhET simulations for homework? Do you wonder how your students are engaging with the simulations? In this poster, we present a dashboard prototype that aims to provide useful information to teachers about student-sim interaction that they can use to inform their sim-based instruction, using accessible and interpretable visualizations. The dashboard uses several approaches to visualize student mouse activity data, showing individual student interaction patterns with the simulation as well as the aggregated information of an entire group. Through interviews with teachers, and data collection from college physics courses, the graphs, design, and the ability of the dashboard to provide useful information was evaluated. We find that the dashboard helps to describe student performance, identify students that may be having difficulties, plan future lessons, and improve activity design. We invite you to review and provide feedback on these dashboard designs with your ideas for improvements.

PST2D05: 9:30-10:15 a.m. Mechatronics: Integrating a Makerspace in Introductory Physics Courses

Poster – Stefan A. Jeglinski, UNC Chapel Hill, 130 E Cameron Ave., Chapel Hill, NC 27599; jeglin@physics.unc.edu

A Makerspace component has been integrated into three different courses taught by the Physics and Astronomy Department. The courses are a First Year Seminar in Mechatronics for students of any intended major (first year only); a course in How Things Work, for any student fulfilling a General Science requirement; and a Physical Computing course, primarily for but not restricted to STEM majors. I will present my experiences determining the scope and type of Makerspace projects, share outcomes when students are given either free reign or tightly controlled specifications, how to evaluate projects involving the Makerspace, and lessons learned.

PST2D06: 10:15-11:00 a.m. Statistical Data Basics with Smartphone Sensors

Poster – Martín Monteiro, Universidad ORT Uruguay, Aconcagua 5152, Montevideo, 7 11400 Uruguay; fisica.martin@gmail.com

Uncertainty is inherent to any measurement. In electrical instruments, part of the uncertainty is due to the noise (thermal, electrical, mechanical) present in every device, as well as in any type of signal, causing the measurements to fluctuate in a random way. This is a fundamental physical principle that imposes limits on the accuracy of any measurement. This applies, in particular, to the smartphones built-in sensors: acceleration, angular velocity, magnetic field, luminance, pressure, etc. The unavoidable noise of the sensors, so annoying in any way, can be used, however, in a favorable way, to illustrate basic concepts of statistical treatment of measurements. In the introductory courses of laboratory and experimental physics, it is usual to perform some practice that involves repeated measures of the same physical magnitude, to analyze them statistically. As we will explain here, the same can be done from a series of measurements recorded with the accelerometer of a smartphone.

PST2D07: 9:30-10:15 a.m. Teaching Kinematics with Drones and Video Analytics

Poster – Lars Möhring, University of Cologne, Albertus Magnus Platz, Cologne, NRW 50923 Germany; moehrlars@gmail.com

Andre Bresges, Florian Genz, University of Cologne

We present best-practice lessons as well as empirical data of learning outcomes at intro physics classes, measured with the Force Concept Inventory (FCI). Our drones are hexacopters programmable in SCRATCH via any mobile device. This enables a predict-observe-explain cycle promoting skills of content knowledge, measuring and observing as well as programming and (physical) modeling. Autonomous drones or UAVs become more and more part of our everyday life but the teaching of "real-life" context kinematics still utilizes the behavior of cars, ships, or trains. Knowing the future positions of an object by having access to it's starting point, velocity and acceleration is one of the main problems in kinematics. The reduction in scale and price leads to new possibilities for studying their behavior in 3-dimensional space. The author is interested in discussion about drones in classrooms and further challenges.

PST2D08: 10:15-11:00 a.m. Technology in the Physics Classroom: The Brazilian Landscape

Poster – Katemari D. Rosa, Federal University of Bahia, Instituto de Física, Rua Barao de Jeremoabo s/n Salvador, Bahia 40301-110 Brasil; katemari@gmail.com

Rebeca Dourado, Felipe Bacelar, Federal University of Bahia

Claims for the use of technology in the classroom have been long documented in PER. The effective use of technology, however, can vary across countries. In this presentation, we review the use of technology in Brazil through physics education literature. Looking at high impact publications in Brazilian physics education journals from the last decade, we describe some of our experiences with technology in the classroom. Our findings show a slow growth in articles published discussing technology over the years with a peak in 2012 and a focus on articles about simulations. Even though some growth in the number of articles over the years was found, it's still lower than expected when noted how much technology developed in the last 10 years and even how much we know technology is used in many classrooms. We also found that authors differ greatly in an understanding of the use and potential of learning managing systems, as well as of the concept of virtual experiments.

PST2D09: 9:30-10:15 a.m. Using JupyterHub/Lab for Coursework and Student Research

Poster – Daryl Macomb, Boise State University, 1910 University Drive, Boise, ID 83725-0399; dmacomb@boisestate.edu

Computational skills and experience are increasingly important in upper-division physics and astronomy courses. Unfortunately students often have widely disparate levels of expertise, use many different programming languages, and have facility with different operating systems. One potential way to overcome these difficulties is through JupyterHub, a server-side facility for providing students access to Jupyter notebooks in several languages. This presentation describes using JupyterHub for computer labs, homework, and research projects for astrophysics students. We describe positives, negatives, and moving towards JupyterLab.

PST2D10: 10:15-11:00 a.m. Visual Simulation of Objects Moving Due to Gravitational and Electromagnetic Forces

Poster – Mevlut Bulut, 615 Idle Wild Circle, Birmingham, AL 35205-586;1 mevlutbulut@yahoo.com

Ferhat D. Zengul, Aysegul Bulut, The University of Alabama at Birmingham

Visual simulations without technical nomenclature can be used to lure people (of all ages) towards the beauty and intricacy of matter interactions through gravitational and electromagnetic forces. We will demonstrate a simulation by which, an arbitrary number of objects can be assigned mass, charge, initial velocity, and initial position and then their motions under gravitational and electromagnetic forces can be observed with a real-time animation interface using a state of the art, highly accurate and stable algorithm. Users can keep the full trace history or clear the accumulated traces at any time they want. Object properties can be manipulated during the simulation and setups can be saved and shared with other people.

GA01: 12:00-12:10 p.m. Transforming Traditional Lecturing in Physics to Interactive Teaching

Contributed – Elmar Junker, Technical University of Applied Sciences Rosenheim, Hochschulstrasse, 1 Rosenheim, Bayern D-83024, Germany; elmar.junker@th-rosenheim.de

Claudia Schäfle, TSilke Stanzel, Michaela Weber, Franziska Graupner, Technical University of Applied Sciences Rosenheim

Three physics lecturers at a German University of Applied Sciences changed their teaching style from commonly spread traditional lecturing to fostering student activating methods like peer instruction and just-in-time-teaching. By evaluating student questionnaires, results with force concept inventory (FCI) and exam statistics we report the following aspects for a successful transformation: 1. Online quiz results of student preparation give input about their deficits and misconcepts to adapt individual lessons. 2. E-mail feedback to students to their preparation questions and bonus for quiz participation have motivating impact. 3. The central theme is 'lectured', but interwoven with student questions and well planned peer instruction sessions. 4. The methods are adapted to the teacher's personality and study program needs. 5. Changing a few lessons suffice to start the transformation process, sharing new materials is helpful. After transformation we see higher student activity in lessons, doubled gain in FCI and quicker passed exams.

GA02: 12:10-12:20 p.m. Learning and Retaining Physics Through Social Interaction (LPSI)

Contributed – Pratheesh Jakkala, Illinois College, 1028 W Walnut St., Jacksonville, IL 62650; pratheesh.jakkala@ic.edu

Learning and retaining Physics through Social Interaction (LPSI) is a new pedagogy I developed that produced tremendous results in learning and retaining physics concepts in both introductory and advanced undergraduate physics classes at a small liberal arts college. Each student participates in three different LPSI sessions through out the semester. LPSI involve students discuss physics with their friends, classmates, faculty/staff from the college or family members who are enthusiastic and curious about physics in a casual and informal setting. The topic of interaction is a real-world application of the concepts learned in the class, assigned by instructor two-three weeks in advance. All interactions are either video recorded or audio recorded. The duration of each LPSI session varies from 25 minutes to 45 minutes. A total of 54 students during two semesters participated in LPSI sessions, every student participating in at least three sessions. A whopping 95.4% of the participated students preferred LPSI over regular homework or exams.

GA03: 12:20-12:30 p.m. Examining Study Habits Related to Student Success in Introductory Physics

Contributed – Seth T. DeVore, West Virginia University, 135 Willey St., Morgantown, WV 26506; stdevore@mail.wvu.edu

John Stewart, West Virginia University

Student interaction with class materials is a major element of success in any course, especially in physics courses in which expertise is earned largely through exposure to the problem-solving process. Despite this, student time use has shown incredibly limited correlation with student success even when controlling for factors related to ability. In this study, we will discuss the results of several surveys intended to measure the number of times students make use of resources both provided as part of the class (E.G. reviewing lecture notes, working additional textbook problems, reviewing practice tests) and available through other means (E.G. looking up problems online, watching videos, using the solution manual), both during test preparation weeks and during non-test weeks. The correlations between interaction with these resources and student success will be discussed.

GA04: 12:30-12:40 p.m. Studying Small Group Interactions in a Collaborative Learning Environment Through the Lens of Social Interdependence Theory

Contributed – Miguel Rodriguez, Florida International University, 11200 SW 8th St., Miami, FL 33199; mrodr1106@fiu.edu

Geoff Potvin, Florida International University

Social interdependence theory provides a framework for understanding how groups of individuals may (or may not) cooperate productively towards common goals. Using this lens, we observed student groups that exhibited both high and low social interdependence. These observations took place in a modeling instruction introductory physics course, which is a highly collaborative learning environment in which students spend much of their time working in small groups. We present results of a thematic analysis on in-class video data to highlight variations between the different socially interdependent groups, and also consider student interviews and survey responses on their dispositions towards socially interdependent interactions. The findings of this work will help to highlight group practices that support productive student engagement and learning.

GA05: 12:40-12:50 p.m. Exploring Group Processes and Decision-making for Generating Kinematic Problems

Contributed – Javier Pulgar, University of California Santa Barbara, Santa Barbara, CA 93106-9490; jpulgar@ucsb.edu

Alexis Spina, Danielle Harlow, University of California Santa Barbara

We explore student groups solving ill-structured problems in a mechanics course at a Chilean University. The learning activity consisted of designing a set of circular motion problems for high school students. Subjects identified real-world situations involving circular motion, and implemented kinematic concepts and principles to design questions and activities for hypothetical high school students. Transcriptions of audio files of five student teams during problem-solving sessions allowed us to understand the process of the groups when solving this activity. Evidence suggests that groups engaged in different sequences of processes for deciding and creating problems for younger students. However, they tended to rely on previous activities implemented in the class for generating problems. Further, physics ideas were more frequently addressed in context compared to their theoretical and isolated version. Finally, we discuss the possible implications of designing and implementing ill-structured problems in physics courses at a University.

GA06: 12:50-1:00 p.m. Introductory Laboratory Behaviors: Just Doing, or Doing with Good Reason?

Contributed – Katherine Ansell, University of Illinois at Urbana-Champaign, 1110 W Green St., Urbana, IL 61801; crimmin1@illinois.edu

Mats Selen, University of Illinois at Urbana-Champaign

Introductory physics laboratories aim to enculturate students into the practices of scientists, whether by explicit or implicit methods. However, practices that appear expert-like on the surface may be used by students for less sophisticated purposes. In recent semesters, we have studied the experimental behaviors of students doing a simple physics experiment in groups, looking specifically for what strategies they use in their experiments and evidence indicating the reasons (or lack thereof) for their actions. Using video and written data, we compare groups from two laboratory classroom settings – one explicitly training skills by focusing on the experimental process, and the other implicitly addressing skills and focusing on experimental results. This talk will focus on an experimental practice shared by both groups and explore students' different reasons for engaging in this practice.

GA07: 1:00-1:10 p.m. Student-equipment Interactions in Undergraduate Laboratory Courses

Contributed – Austin N. Hahner, Kansas State University, 1620 Rivendell St., Juntion City, KS 66441; anicholas.williamh@yahoo.com

Eleanor C. Sayre, Kansas State University

Laboratory instruction is a core element of undergraduate programs, but there is little research on how diverse students actually interact in lab groups and with equipment. In this project, we use video-based observations of lab groups enrolled in a prematriculation program for underrepresented minority students. We build a framework for student-equipment and student-student interactions in lab based on linking students' behavior to their epistemological frames. Our framework characterizes the interactions and can be applied in real-time or faster to video data. In this talk, we present the framework. We show how prevalence and sequences of frames is affected by both laboratory activity and participant identities.

Session GB PER: Curriculum and Instruction II

Location: CC - Cascade D **Sponsor:** AAPT/PER **Time:** 12–1:30 p.m. **Date:** Wednesday, July 24 **Presider:** TBA

GB01: 12:00-12:10 p.m. Quantum Mechanics in the Paradigms and Tutorials

Contributed – Paul J. Emigh, Oregon State University, 3167 SE Midvale Dr., Corvallis, OR 97333; paul.emigh@gmail.com

Elizabeth Gire, Corinne A. Manogue, Oregon State University

Gina Passante, California State University, Fullerton

The increasing body of literature on student understanding of quantum mechanics has led to the development of several different curricula for teaching quantum mechanics. However, few studies have detailed how such material is developed and evaluated. We discuss the design of two of these efforts: the Paradigms in Physics program and the Tutorials in Physics. We describe and contrast the design principles that shaped each curriculum, including the instructional strategies chosen, the theories underlying the chosen strategies, and the institutional constraints. The Paradigms is a reformed sequence of upper-division courses that makes heavy use of active engagement and takes a non-traditional approach to the sequencing of physics content. The Tutorials are supplementary worksheets intended to support conceptual understanding in a small-group problem solving setting.

GB02: 12:10-12:20 p.m. Small Group Activities with Surfaces for Thermodynamics

Contributed – Jonathan W. Alfson, 301 Weniger Hall, Corvallis, OR 97331-6507; alfsonj@oregonstate.edu

Paul J Emigh, Elizabeth Gire, Oregon State University

Aaron Wangberg, Winona State University

Robyn Wangberg, Saint Mary's University of Minnesota

Thermodynamics is notoriously tricky, in part because thermal systems have multiple dependent variables, the independent variables are non-spatial, and there is freedom to choose which variables are independent. The Raising Physics to the Surface team has created a suite of small-group activities that use 3D plastic graphs for water vapor to explore thermal states and state variables. In particular, students work in groups to consider: degrees of freedom, partial derivatives as ratios of small changes, and how partial derivatives depend on direction. We will discuss the design and implementation of these activities at Oregon State University.

GB03: 12:20-12:30 p.m. Student Perception and Use of Online Resources in Introductory Physics

Contributed – Charles M. Ruggieri, 136 Frelinghuysen Road, Piscataway, NJ 08854; chazr@physics.rutgers.edu

In the context of our large enrollment introductory physics service courses, we investigated student perception and spontaneous use of online resources as learning supplements to course-provided materials and activities. In this mixed methods study, we first surveyed students on their usage frequency of online resources such as YouTube, Khan Academy, and Chegg, and compared to textbook usage frequency. We then interviewed a subset of surveyed students to investigate the contexts and situations in which they use online resources. We found that students used online resources more frequently than the textbook, and the reported role of the online resources was either to actively support their learning or to provide a means of passive homework completion. Students' decision-making process for actively engaging with online resources as learning tools depended on the time they leave themselves for homework, and the relevance and alignment of course-provided learning materials to the homework and exams.

GB04: 12:30-12:40 p.m. Students' Perceptions of the Math-Physics Interactions Throughout Spins-first Quantum Mechanics

Contributed – Homeyra R. Sadaghiani, California State Polytechnic University Pomona, 3801 W Temple Ave., Pomona, CA 91768-2557; hrsadaghiani@cpp.edu*

Benjamin Schermerhorn, Armondo Villasenor, Darwin Del Agunos, California State Polytechnic University Pomona

Gina Passante, California State University Fullerton

Steven Pollock, University of Colorado, Boulder

One of the purported benefits of teaching a spins-first approach to quantum mechanics is that it allows students to build up quantum mechanical ideas and learn postulates before moving to the more complicated mathematics used in the context of wave functions. In order to begin to explore this claim in a spins-first course, a survey was developed and administered as an extra credit activity at 3 different universities. All universities teach spins-first quantum mechanics but to different student populations. This work compares students' responses to identical questions about the relationship between and difficulty of math and physics from two administrations of the survey given at the ends of the spins and wavefunctions portions of the course. Results offer insight into students' perspectives about the nature and difficulty of mathematics in these two paradigms of quantum mechanics.

GB05: 12:40-12:50 p.m. Teaching Electric Circuits with Air Pressure in Middle Schools

Contributed – Jan-Philipp Burde, Goethe-University, Frankfurt, Max-von-Laue-Str.1 Frankfurt Am Main, HE 60438 Germany; burde@physik.uni-frankfurt.de

Thomas Wilhelm, Goethe-University Frankfurt

Understanding the basic concepts of electricity represents a major challenge to most students. In particular, they often fail to develop a robust understanding of voltage and instead tend to reason exclusively with current and resistance. In order to address these difficulties, a new teaching concept based on the electron gas model was developed. The key idea of the new teaching concept is to introduce voltage even before the electric current by comparing it with air pressure differences. Voltage as an "electric pressure" difference can then be understood as the causal agent of current propulsion just as air pressure differences are the cause of air flow (e.g. bicycle tires). The new approach to teaching electric circuits has proven to be effective in an empirical study with 790 students. The talk will focus on the key ideas of the concept and highlight key findings of the multiple-choice diagnostic assessment.

GB06: 12:50-1:00 p.m. Teaching Nonphysics Majors Vector Superposition Through a Limiting Case Approach

Contributed – Sheh Lit Chang, University of Washington, 3910 15th Ave. NE, Seattle, WA 98195-0001; shehlit@gmail.com

Peter Shaffer, University of Washington

Adding vectors is one of the essential skills that students need to learn in order to gain competence in physics. We have been administering multiple questions, posed to students in various physical contexts, to track their performance in applying vector superposition as they progress through introductory algebra-based mechanics and electromagnetism courses. An exploratory analysis indicates that student responses often vary, depending on context. To address the difficulties that arise, we are designing isomorphic tasks that ask students to reason about vector superposition from a limiting case approach. We report results from a series of repeated interventions and discuss how they might guide us in helping students develop a functional understanding of vector addition.

GB07: 1:00-1:10 p.m. Tracking Students' Learning Behavior Through an Online Learning Module Sequence

Contributed – Geoffrey Garrido, University of Central Florida, 4111 Libra Drive, Orlando, FL 32816; geoff.garrido@knights.ucf.edu

Zhongzhou Chen, Matt Guthrie, University of Central Florida

This study investigates changes in students' learning behavior as they proceed through a sequence of 10 mastery-based online learning modules in order. In an earlier study, we divided students' interaction patterns into multiple categories via a clustering algorithm on the time-on-task information. In this study, we use the same categories to sort students' interaction patterns into one of 28 states. Those states are arranged in an order that reflects the amount of learning effort for each module. Students' interactions can be visualized in a sequence of parallel coordinate graphs, and the most common pathways can be identified through a hierarchical clustering algorithm. Dividing the student population into three cohorts based on their total course credit, we found that after encountering a challenge on module 7, most of the bottom cohort significantly lowered their learning effort, while the top cohort kept the same high level of learning effort.

GB08: 1:10-1:20 p.m. Using Daily "Bell Ringers" To Broach Nature of Science, Pedagogy, and Science Identity

Contributed – Steven J. Maier, Northwestern Oklahoma State University, 709 Oklahoma Blvd., Alva, OK 73717-2799; sjmaier@nwosu.edu

While implementing the Next Generation Physics and Everyday Thinking (NG PET) for elementary education majors, I have used "bell ringers" at the beginning of each class meeting. These bell ringers consist of puzzles, riddles, and logic problems that usually take just a few minutes for students to complete. The intention for using these bell ringers is help students develop a more accurate understanding of the nature of science, model effective pedagogy, and positively impact science identity. In this talk, I'll present examples of activities used as bell ringers* and share preliminary results of a pilot study of students' perceptions.

*To access the original "view only" document, browse to https://tinyurl.com/yyy5xvp2 *To contribute to an editable document, browse to https://tinyurl.com/yylemppl

GB09: 1:20-1:30 p.m. Zoom Scale Explanations of Radiation Sickness: Learning Diagnostic? Learning Difficulty?*

Contributed – Andy P. Johnson, Black Hills State University, 610 Nellie Ln., Spearfish, SD 57783; andy.johnson@bhsu.edu

The Inquiry into Radioactivity (IiR) project develops radiation literacy among non-science undergraduates. IiR's research-based tools and strategies enable most students to understand fundamental ideas about ionizing radiation. To explain radiation – induced cancer and acute radiation sickness, students must trace a chain of causality from interactions with electrons (at the subatomic scale) through ionization, molecular damage, cell damage, and finally to the organism scale. This is called zoom scale thinking. Characteristic student difficulties with this reasoning task point to - something. Do some students just not understand what's going on at one or more size scales? Or is there an intrinsic difficulty in conceptualizing effects across multiple size scales? This talk will analyze student data to illuminate the challenges students have with zoom scale reasoning on the health effects of radiation.

*This work supported by National Science Foundation grant DUE 0942699

Session GC PER: Understanding the Experiences of Underrepresented populations in Physics Courses

Location: CC - Cascade C **Sponsor:** AAPT/PER **Time:** 12–1 p.m. **Date:** Wednesday, July 24 **Presider:** TBA

GC01: 12:00-12:10 p.m. Do I Belong Here?: Understanding Participation and Non-participation in Whole-Class "Board" Meetings

Contributed – Brant E. Hinrichs, Drury University, 900 N Benton Ave., Springfield, MO 65802; bhinrichs@drury.edu

Jared Durden, Ozarks Technical Community College

In University Modeling Instruction, students work in small groups on a problem and then hold a student-led whole-class discussion to develop consensus. While this kind of interactive-engagement has been shown to help students learn, evidence suggests not all students have the same experience or feel equally included. We have developed a preliminary coding scheme based on Wegner's framework from "Communities of Practice", which identifies student modes of belonging through participation and non-participation. In this talk, we present initial results from coding and analyzing reflective student writing assignments on a particularly contentious mid-semester whole-class discussion. Using this lens, we identify students' varying perceptions of the whole-class discussion and how it influenced their participation. By developing a descriptive model of student engagement, we seek to create a predictive model to inform professional development for instructors who teach in student centered classrooms.

GC02: 12:10-12:20 p.m. Locating Agency in Women's Conceptualizations of Success and Physics

Contributed – Brian Zamarripa Roman, University of Central Florida, 4000 Central Florida Blvd., Orlando, FL 32816; b.zamarripa@knights.ucf.edu

Claudia Ragosta, Jacquelyn J. Chini, University of Central Florida

The physics community has invested in addressing gender underrepresentation in physics by supporting women in achieving "success." However, we need to examine our (assumed) shared definitions of success and the extent to which they represent women's personal views of success. In this qualitative phenomenological study, we examine tacit conceptualizations of success and physics, employing a metaphor analysis of the language expressed by 11 women at different career stages in the same physics department during an hour-long interview. A central tenant of metaphor analysis is that metaphors used in everyday life structure our thoughts, which shape our behavior. Thus, locating agency in the expressed metaphors can inform our understandings of an individual's identity formation (thoughts) and persistence (behavior) as a successful physicist. We present conceptualizations of physics and success in terms of structural, ontological and orientational spontaneous metaphors and describe the location of agency expressed in the participants' metaphors.

GC03: 12:20-12:30 p.m. Determining Motivators of Undergraduate Women Pursuing a Physics Degree*

Contributed – Virginia Price, 32 S 32nd St., Disque Hall #816, Philadelphia, PA 19119-2934; virginia.e.price@gmail.com

Valerie Klein, Eric Brewe, Drexel University

Zahra Hazari, Florida International University

Theodore Hodapp, Renee-Michelle Goertzen, American Physical Society

There are several explanations that have been proposed for the low numbers of women completing physics degrees. Determining what influences women to pursue degrees in physics can inform how we recruit and engage women as physics majors. We collected text responses from a sample of undergraduate women physics majors attending the 2015 APS Conferences for Undergraduate Women in Physics. Qualitative analysis of 828 responses was used to extract positive and negative motivational factors, including people, fields of physics, exposure to science, and various aspects of the fields of physics. Strong motivators included people such as high school teachers, parents, and professors. Topics in astronomy inspired much early interest in physics, and respondents also reported a strong affinity to scientific inquiry. By knowing what women find appealing about a physics degree, we can use these results to inform educators and undergraduate physics programs about ways to better engage young women.

*Portions of this work are supported by NSF Grant PHY1622510.

GC04: 12:30-12:40 p.m. Identity Performances of Women of Color and LGBQ+ Physicists at MSIs

Contributed – Xandria R. Quichocho, Texas State Univ-San Marcos, 900 Peques St., San Marcos, TX 78666; x_q1@txstate.edu

Jessica Conn, Erin Schipull, Eleanor W. Close, Texas State University

Existing research on underrepresented/minority students focuses mainly on gender or race/ethnicity and largely ignores the intersection of identities embodied by women of color and on the experiences of lesbian, gay, bisexual, or queer (LGBQ+) students. In addition, the research typically is conducted at Predominately White Institutions. Our current project examines the personal narratives of women of color and LGBQ+ students at a Hispanic Serving Institution through semi-structured interviews and written narratives. The project is proposing a new physics identity framework to better understand the unique experiences of women of color and LGBQ+ physicists. The framework builds on the work of Ong et. al by assuming a critical race and queer lens in our analysis. We propose that these physicists perform their intersectional identities in different ways to achieve success in their environments.

GC05: 12:40-12:50 p.m. The Effect of Culture on Muslim Women Physicists' Career Choice

Contributed – Saeed Moshfeghyeganeh, Florida International University, 11200 SW 8th St., Miami, FL 33199; smoshfeg@fiu.edu

Zahra Hazari, Florida International University

The underrepresentation of women in physics and engineering has been a matter of concern in the United States for decades. At the same time, many Muslim majority countries have the highest rates of women's participation in physics and engineering. To examine how cultural practices and norms influence women's participation in physics, we conducted several interviews with female physicists who were educated in Muslim majority countries and are now faculty at universities in the US. We will present the results of a thematic analysis of the interviews. These results help us to understand differing cultural factors in Muslim majority countries and the U.S. that may affect women's participation in physics as well as lend insight to improving participation and persistence of women in physics career.

GC06: 12:50-1:00 p.m. Dos Neplanteras in Physics/Education/Research

Contributed – Idaykis Rodriguez, Florida International University, 11200 SW 8th Street, STEM TI VH 160, Miami, FL 33199; irodr020@fiu.edu

Brian Zamarripa Roman, University of Central Florida

Students of Hispanic descent are highly underrepresented in physics and few studies exist focusing on their experiences and reasons for their underrepresentation. Although the Hispanic experience is traditionally reduced to a monolithic ethnicity, it is a complex and rich identity deserving closer attention for the physics community to develop its critical sociocultural knowledge of these students. Combining the process of duoethnography, self-analysis and auto history, we engage in dialogic and collaborative discussions as two Hispanic researchers contrasting and analyzing our trajectories into physics and physics education research. We use Anzaldua's Critical Feminist Chicano theory of nepantla, identity development as seen from the in-between state in changing from one identity to another, to reflect and reconstruct our narrative. We compare and contrast our cultural histories and intersecting ethnic, gender, and professional identities to unpack the cultural underpinnings influencing our career trajectories and views of being (in) physics education research(ers).

Session GD Introductory Courses: Analyzing Outcomes

Location: MH - Bryce **Sponsor:** AAPT **Time:** 12–1 p.m. **Date:** Wednesday, July 24 **Presider:** TBA

GD01: 12:00-12:10 p.m. Evaluating Students' Performance on the FCI (force concept inventory) at a Minority Serving PUI (primary undergraduate institution)

Contributed – Qing Xu Ryan, Cal Poly Pomona, 3801 W Temple Ave., Pomona, CA 91768; xuqing12357@gmail.com

Darwin Del Agunos, Armando Villasenor, Alexander Small, Homeyra Sadaghiani, Cal Poly Pomona

As part of an effort to provide evidence for the reproducibility of educational studies for a variety of student body, as well as gaining insights of possible gender or racial gaps in students' performance, we collected a year-long data in introductory physics courses at Cal Poly Pomona (both a PUI and Hispanic serving institution) to understand aspects that affect students' performance on the FCI. In this talk, we discuss background variables that predict students' FCI scores at the end of the term. Such a baseline measure can be used for any future studies conducted at our institution to evaluate the effectiveness of any pedagogical reforms. We will also explore possible gender or racial gaps for our students.

GD02: 12:10-12:20 p.m. Comparison of FCI Results: K12 and Undergrad, Same Instructor

Contributed – John Barr, Lindenwood University, 209 South Kingshighway, St, Charles, MO 63301; jbarr@lindenwood.edu

The Force Concept Inventory (FCI) was given as a pre/post test to high school and undergraduate students in introductory physics classes over a number of years. While the students were almost all unique, the instructor was the same. This talk will explore the FCI normalized gain for students in several types of introductory physics courses at both the high school and undergraduate levels. A comparison of outcomes for the two student education levels will be made. Possible modifiers may include evolving instructional methodology, functional differences in student populations, differences arising from the education levels themselves, or cultural disparity of the two educational institutions.

GD03: 12:20-12:30 p.m. Investigation of Success Outcomes for FTIC and Transfer Students in LA-Supported Introductory Courses

Contributed – Deepa N. Chari, Florida International University, 11200 SW 8 St., Miami, FL 33177; deepu.chari@gmail.com

Geoff Potvin, Hagit Kornreich-Leshem, Laird Kramer, Florida International University

Historically, course grades have been used to characterize student success in undergraduate education. More recently, grade anomalies (the difference between student grades in a particular course compared to their other performances) are being used to characterize student outcomes. In an ongoing study, we report on an analysis of both of these outcomes in Learning Assistant (LA)-supported introductory physics and biology courses. These two courses combine a number of instructional practices and LA-supported student discourse. We are particularly interested in comparing outcomes for FTIC (first time in college) and transfer students, and look at the potential mitigation effect of LA-related pedagogies on grade anomalies for these courses.

GD04: 12:30-12:40 p.m. Assessing Student Performance Outcomes in Introductory Physics Using Multilevel Modeling.

Contributed – Srividya Suresh, The Ohio State University, 191 W Woodruff Ave., Columbus, OH 43210-1117; suresh.62@osu.edu

Amber B. Simmons, Andrew Heckler, The Ohio State University

We are studying the effects instructors have on student performances in introductory physics. Most introductory physics courses come in a two-semester sequence and our analysis is from the first course in the sequence. Our project's goal is to determine whether student performance outcomes vary by instructor. We analyze three binomial outcomes, getting a DFW, A- and above, and repeating the course, using multilevel logistic regression. We conduct our study at the Ohio State University where we analyze registrar data from students enrolled from the fall term in 2012 to the spring term in 2018. The data includes student course grades in physics, standardized test scores, as well as student demographics such as gender, ethnicity, and age. While for most instructors students perform within the average, we do find significant variation in student performance outcomes among some of the instructors while controlling for ACT score and student's age.

GD05: 12:40-12:50 p.m. Temporal Patterns of Students Using Online Essential Skills Application

Contributed – Megan N. Nieberding, The Ohio State University, 4803 Brodribb Ct. Apt. A, Columbus, OH 43220-3256; nieberding.17@buckeyemail.osu.edu

Andrew Heckler, The Ohio State University

There are a variety of basic skills that are critical for success in a physics course. To help students master these skills, we have developed and implemented an online learning application called Essential Skills, which involves 15-30 minutes of practice with instant feedback every week. These assignments have been implemented in both algebra-based and calculus-based introductory physics for the last five years. While Essential Skills has been successful in improving performance on several skills, many questions remain regarding student learning and fluency with specific skills and student engagement with the application. Here we present preliminary findings on timing aspects of student use of the application. We will examine elapsed time to completion, earliness of completion, and time of day that the students work on the assignment. Further, we will describe how this timing data evolves over the course of the semester, including comparisons to student scores in the course.

GD06: 12:50-1:00 p.m. Development of Math Diagnostic Test for Algebra-based Physics Course

Contributed – Beatriz E. Burrola Gabilondo, The Ohio State University, 191 W Woodruff Ave - 1040, Physics Research Building, Columbus, OH 43210; burrolagabilondo.1@osu.edu

Andrew Heckler, The Ohio State University

Our overall goal is to develop "diagnose-and-practice" resources to help students in our algebra-based college physics course improve their performance on math skills necessary for success in the course. In this initial phase of the project, we are developing a diagnostic tool that will be useful for both teachers and students, informing them which skills to practice. The process is iterative, aimed at producing statistically reliable subscales for each skill. Iteration included analysis of individual items and identification and classification of the math skills needed for completing course assignments, including exams. Based on this analysis, we modified the test to better reflect the skills that are relevant to the course. Results show improved reliability. A new version of the test will be implemented in the Autumn 2019 semester. This will lead to a tool that is reliable and easy to implement online.

Session GE K-12 PER II

Location: MH - Birch **Sponsor:** AAPT **Time:** 12–1:10 p.m. **Date:** Wednesday, July 24 **Presider:** TBA

GE01: 12:00-12:10 p.m. High School Student Perspectives on Computation in Different Classroom Contexts

Contributed – Paul C. Hamerski, Michigan State University, 567 Wilson Rd., East Lansing, MI 48824; tallpaul@msu.edu

Daryl McPadden, Marcos D. Caballero, Paul W. Irving, Michigan State University

For many of today's educators and researchers, computation goes hand-in-hand with science education. Integrating computational practices with STEM classrooms gives learners a more realistic view of what science is, and better prepares students for pursuing careers in a world where computation is ubiquitous. This study examines one instance of such integration in the physics classroom of a suburban, racially diverse high school. The students whose perspectives we investigate have multiple formal computation experiences – both in their physics class and their computer science class. Using interviews, in-class recordings, and field notes, we produce a case study on the dual experience that some high school students have with computation, and from this case study we provide an in-depth, organic perspective on the difference between learning computation inside and outside of the physics classroom.

GE02: 12:10-12:20 p.m. Identifying Teacher Learning Goals Involving Computation in High School Physics

Contributed – Daniel P. Weller, Michigan State University, 1224 E Saginaw St., East Lansing, MI 48823; wellerd2@msu.edu

Theo Bott, Marcos D. Caballero, Paul W. Irving, Michigan State University

As a state-wide effort to integrate computational practices into high school physics curricula around Michigan, we developed and administered a week-long summer workshop for high school physics teachers to learn how to program and teach basic programming to their students. Over the course of the year, we followed three teachers as they integrated computation into their physics curriculum. Through structured interviews, we explored their learning goals related to computation. The learning goals spanned conceptual physics, computational thinking practices, and attitudinal outcomes. By characterizing these goals, we were able to evaluate the effectiveness of the professional development series at helping teachers develop computational physics activities designed to address their specific learning goals.

GE03: 12:20-12:30 p.m. Learning Physics Concepts Through Computational Modeling

Contributed – Luke D. Conlin, Salem State University, 352 Lafayette St., Salem, MA 01970-5348; lconlin@salemstate.edu

High school physics classrooms are beginning to provide students opportunities to learn physics through building computational models. A focus on computational modeling has the potential to support students' learning of physics concepts, but there is a risk that the cognitive load of learning a new programming language could distract from the physics. We designed a block-based computational modeling environment and embedding curriculum called C2STEM to support learning of concepts and computation in ways that are mutually reinforcing. In this talk I report on the results of a classroom study (n=174) in which an experimental group of 84 students used C2STEM instead of laboratory investigations. Pre-post performance on assessments of both physics concepts and computational thinking suggests that students were able to learn physics concepts and computational thinking skills in complementary ways. An examination of screen capture video reveals the processes by which the modeling environment supported students learning of physics concepts.

GE04: 12:30-12:40 p.m. Nature of Science in Chinese High School Physics Textbooks

Contributed – Haoli Zhuang, School of Physics and Telecommunication Engineering, South China Normal University 378 Waihuanxi Road Guangzhou, Guangdong 510006 China; 2018021837@m.scnu.edu.cn*

Jianwen Xiong, School of Physics and Telecommunication Engineering, South China Normal University

Lei Bao, Department of Physics, The Ohio State University

This study analyzed the representation of nature of science (NOS) in high school physical textbooks of five editions authorized by the Ministry of Education of China. Specifically, the chapters and sections direct relevant to NOS (e.g., chapter on the "scientific method") and frequently appear with some historical treatment of the development of a topic (e.g. chapters related to Newton's laws of motion) were sampled. It was found that all five editions of physics textbooks were poor in representations of NOS, and on average, only a few pages of the selected textbook samples were dedicated to addressing NOS constructs. The results suggest that the representation of NOS in Chinese high school physics textbooks is desired to be improved to meet the emphasis on helping students to be scientific literacy citizens proposed by the recent reform of the school science curriculum in China.

*Sponsored by Lei Bao

GE05: 12:40-12:50 p.m. STEM Stories in Dayton, Ohio

Contributed – Todd B. Smith, The University of Dayton, 300 College Park, Dayton, OH 45469-2314; tbsmith@udayton.edu

Margaret Pinnell, Mary Kate Sableski, Shannon Driskell, The University of Dayton

The goal of the Dayton STEM Stories project is to increase interest in and ability to pursue science, engineering, and other technical fields. Literacy is key to a student's success as it's a critical skill required for the learning of all other subjects, including science and engineering. Because Ohio's Third Grade Reading Guarantee encourages PK-3 teachers to focus primarily on mathematics and reading, students in these early grades are rarely exposed to science and engineering. This is very unfortunate since research shows that early exposure to science and engineering increases a student's likelihood of pursuing these career fields. STEM Stories provides an innovative, engaging, fun, and highly integrated STEM and Literacy curriculum to second and third grade students. This presentation will provide an overview of the STEM Stories project along with our assessment results.

GE06: 12:50-1:00 p.m. Assessing Students' Explanation and Argumentation in Scientific and Socio-scientific Contexts

Contributed – Yunzhi Mei, South China Normal University, Guangzhou, China 510006; 806809116@qq.com*

Jianwen Xiong

Constructing scientific explanations and participating in argumentative discourse are seen as essential practices of scientifc inquiry. In this paper, we attempt to clarify the distinction and relation between these two practices in science education. Based on two researchers' achievements (Osborne, 2016; McNeill, 2013), we developed two versions of the test to assess students' writing explanation and argumentation. They contained 4 questions divided among scientific contexts and socio-scientific issues. These tests were administered to almost 900 students of 10th,11st,13rd grade in China. The results of students' performance are presented by comparing students of different grades and genders through qualitative and quantitative analysis. The paper concludes by suggesting extensions of these two scientific practices for further research in science education.

*Sponsored by Lei Bao

GE07: 1:00-1:10 p.m. Teachers' CKT-Energy and the Depth of Content During Energy Instruction

Contributed – Robert C. Zisk, Rutgers University, 10 Seminary Pl., New Brunswick, NJ 08901; robert.zisk@gse.rutgers.edu

Eugenia Etkina, Rutgers University

Content Knowledge for Teaching (CKT; Ball, Thames, & Phelps, 2008) describes the knowledge that teachers have for teaching a particular subject. As such, there should be a relationship between teachers' CKT and their classroom practice. In this study, we focus on the relationship between high school teachers' CKT for teaching energy (CKT-E) and the content of their instructional unit on energy in mechanics as measured by their instructional goals and the content of their assessments. We investigate the depth and breadth of the content of teachers' goals and their unit assessment as well as the alignment between teachers' goals and assessments. We then assess the relationship between the content of instruction and teachers' CKT-E as measured by an assessment of teacher's knowledge of teaching energy. While all teachers in the study addressed the same breadth of content, teachers with high CKT-E scores addressed content at a deeper level.

Session GF Pedagogical Reform for Introductory Labs

Location: MH - Amphitheater **Sponsor:** AAPT **Time:** 12–1:20 p.m. **Date:** Wednesday, July 24 **Presider:** TBA

GF01: 12:00-12:10 p.m. 150 Years Later, Introductory Labs Are Poised for Change

Contributed – Ashley R. Carter, Amherst College, A122 Science Center, Amherst, MA 01002-5000; acarter@amherst.edu

Introductory laboratory courses have been a staple of the undergraduate curriculum for 150 years. Yet, since their inception, the courses have drawn the ire of both student and professor alike. Now with calls to update the introductory laboratory that are louder than ever, a look back at the history of the course seems necessary. In this talk, I will describe three historical periods: the lecture-theater style course of the 1700-1800's, the research-grade experiment course in the late 1800's, and the concept-exercise experiment course of the 1900's. I will find that throughout these time periods instructors have faced the same questions we do today. What is the role of the lab course and how much preparation, instruction, authenticity, and complexity are required? With the advent of Physics Education Research, we may start to answer some of these long-debated questions, poising the introductory laboratory for change.

GF02: 12:10-12:20 p.m. Reforming the Introductory Laboratory Using the Investigative Science Learning Environment

Contributed – James Christopher Moore, University of Nebraska Omaha, 1001 Sterling Dr., Papillion, NE 68046-6121; jcmoore@unomaha.edu

We have used the Investigative Science Learning Environment (ISLE) as a framework for reforming the introductory physics laboratory sequence at a university in the Midwest U.S. Lab experiences have been reformed to focus on science abilities and experiment design, in contrast to "cook-book" content-verification labs. Students were tasked with designing and executing observation, testing, and application experiments to answer specified research questions, with these experiences scaffolded to build abilities. Measurements where made using the IOLab system developed at UIUC. We report on a multiple-group quasi-experiment comparing groups completing traditional labs and the reformed labs. Student views and scores on the Physics Lab Inventory of Critical thinking (PLIC) will be compared.

GF03: 12:20-12:30 p.m. Implementing a Design-style Lab Reform in Introductory Algebra-based Electrodynamics

Contributed – William R. Evans, University of Illinois at Urbana-Champaign, 1110 W. Green St., Urbana, IL 61801; wevans2@illinois.edu

Mats A. Selen, Michelle L. McCord, Spencer B. Hulsey, University of Illinois at Urbana-Champaign

At the University of Illinois, we have undertaken a major reform of the lab component of our two-semester algebra-based introductory physics sequence. This reform focuses on sense-making and scientific skills acquisition, inspired by the ISLE framework, and was fully implemented in the first semester of the sequence (mechanics) in the spring of 2018 and in the second semester of the sequence (electricity and magnetism) in the fall of 2018. We present preliminary results on student attitude and performance from the electricity and magnetism course, looking at student surveys and lab work. We compare results from students who took the labs in the reformed, design-style approach with students who took the labs in the older, step-by-step guided approach.

GF04: 12:30-12:40 p.m. Effects of Accurate Feedback in Introductory Lab Courses

Contributed – Joshua Rutberg, Rutgers University, 10 Seminary Place, New Brunswick, NJ 08901; joshua.rutberg@rutgers.edu

Marina Malysheva, Eugenia Etkina, Rutgers University

Building on previous efforts to reform an introductory physics lab for engineering students, we investigated the role of accurate teacher feedback on the development of students' scientific abilities. ISLE labs were used in a second-semester physics lab focusing on electricity and magnetism. The associated lecture course and recitations were not modified in any way. The instructors responsible for the implementation of the labs were undergraduate students who had received minimal training in ISLE beforehand. Student lab reports were scored using the Scientific Abilities rubrics to give feedback to the students. The labs were then scored by experts in ISLE to determine the accuracy of the feedback given by instructors. We then looked at the performance of students taught by different instructors to ascertain the effects that the accuracy of this feedback had on their development throughout the course.

GF05: 12:40-12:50 p.m. Expanding a Model for Design-based Labs Supported by Whiteboards

Contributed – Benjamin T. Spike, University of Wisconsin - Madison, Department of Physics, 1150 University Ave., Madison, WI 53706-1390; btspike@wisc.edu

One year ago, we reported on our development of a suite of introductory mechanics labs at the University of Wisconsin-Madison, with a particular focus on experimental design and scientific thinking. These labs feature open-ended design challenges, a mini-"symposium," and collaborative whiteboarding in place of a formal lab report. Over the past year, we have expanded this model to the second semester physics environment by developing an additional 10 lab experiments covering electricity, magnetism, and optics. In this presentation, we will describe our experience developing the expanded set of design-based labs, present student survey data, and discuss what we have learned about the scalability and sustainability of the overall model.

GF06: 12:50-1:00 p.m. "Choose Your Own Adventure" Project-based Labs for Introductory Physics

Contributed – Dan Roth, Olympic College, 3600 Chester Ave., Bremerton, WA 98337; droth@olympic.edu

I have been dissatisfied with my traditional laboratory exercises using a cookbook-style approach and following a "flavor of the week" schedule which often does not align with content in the lecture. I did not feel that my students were learning the course material (an opinion that has been backed up by some research) or gaining an understanding of the experimental process, including measurement uncertainty. Simply paring down on instructions in an effort to encourage more critical thought did not seem to improve outcomes, and a single lab period is not enough time for students to fully develop an experiment, take preliminary data, consider uncertainty, and revise their experiments. So, I have developed what I call "choose your own adventure" lab projects in which the students work on over the course of several lab sessions to develop and revise their own experiments.

GF07: 1:00-1:10 p.m. All Aboard! Challenges and Successes in Training Lab TAs

Contributed – Danny Doucette, University of Pittsburgh, Allen Hall, 3941 O'Hara St., Pittsburgh, PA 15260; danny.doucette@gmail.com

Russell Clark, Chandralekha Singh, University of Pittsburgh

At large universities, introductory physics labs are often run by student teaching assistants (TAs). Thus, efforts to reform introductory labs should address the need for effective and relevant TA training. We developed and implemented a research-backed training program that focuses on preparing TAs to support inquiry-based learning, to discuss issues of epistemology, and to establish supportive and equitable learning spaces. Primary impacts of this training were identified using observational and ethnographic protocols, and secondary impacts were assessed through an attitudinal survey of students. We will discuss details of the training program and share results that suggest effective training can positively impact both TA practice and student experiences in the physics lab.

GF08: 1:10-1:20 p.m. Implementing Undergraduate Learning Assistants in Introductory physics labs

Contributed – Samuel W. Engblom, University of Illinois - Urbana Champaign, Champaign, IL; Loomis Laboratory of Physics, Urbana, IL 61801; engblom2@illinois.edu

Morten Lundsgaard, Mats A. Selen, University of Illinois - Urbana Champaign, Champaign, IL

Many programs have made extensive use of Undergraduate Learning Assistants (LAs) in discussion and tutorial sections. Our LA program has been designed with the intention of supporting reformed introductory physics labs at the University of Illinois. Preliminary results of implementing undergraduate LAs in a lab environment will be presented, along with plans for scaling up the program to encompass all introductory course labs.

Session GG Ethics in the Practice and Application of Science

Location: MH - Cedar **Sponsor:** Committee on History and Philosophy in Physics **Time:** 12–1:30 p.m. **Date:** Wednesday, July 24
Presider: Bradley McCoy

GG01: 12:00-12:30 p.m. Integrating Ethics into High School and University Physics Courses

Invited – Beverly Karplus Hartline, Montana Technological University, 1300 West Park St., Butte, MT 59701; beverly.hartline@gmail.com

Science curricula rarely mention scientific ethics—especially in introductory courses. Yet students in high school and college have sufficiently developed moral senses to benefit from exposure to the ethical dimensions of science. The government has long mandated training in responsible research for students working on federal grants. This training is provided outside of the curriculum and is many students' first exposure to the ethical issues and choices faced in science. Moreover, anyone can benefit from an ability to think clearly about the ethical issues at the interface of science, engineering, and society. From 2004-2006, the American Physical Society convened the Task Force on Ethics Education, which has published case studies and other resources for teachers and students that are particularly applicable to physics. I will encourage physics teachers to integrate ethics into instruction and will provide links to free resources, including case studies designed for high school and college classrooms.

GG02: 12:30-1:00 p.m. The Ethics of Communicating Complexity

Invited – Carlos Santana, University of Utah, 1495 W 400 S, Salt Lake City, UT 84104; c.santana@utah.edu*

Effective communication is simple and direct, but much of modern science is anything but simple. The systems we study, such as the global climate system, are unimaginably complex. And the methods we use to study these systems, such as computational models designed in pieces by hundreds of different scientists and running on supercomputers, also resist being straightforwardly explained. This gap between the simplicity required for effective communication and the complexity of the topics to be communicated raises ethical issues for the scientist or science educator. Simplifying complex science requires some fudging, but at what point does fudging become dishonest or paternalistic. I reflect on these ethical issues with regards to two case studies from climate science—communicating the results of Extreme Weather Event Attribution to the public, and communicating climate ensemble models to policymakers.

*Invited by Bradley McCoy

GG03: 1:00-1:30 p.m. Ethical Considerations for 21st Century Science and Science Education

Invited – Tom Foster, SIUe Box1654, Edwardsville, IL 62026-1654; tfoster@siue.edu

2018 was a remarkable year for science. Scientists confirmed water on Mars, our understanding of how climate change will impact human life grows daily, genetic manipulation of mosquitos might drive the population to extinction, and we used genetic editing on babies to prevent a known disease. All of these results not only excite the mind but bring up very real ethical questions. Furthermore, how science is conducted has received greater scrutiny. The ethical foundation of conducting science education research are not immune to these changes. Listen in on this presentation as we bring this provocative topic to Provo.

Session GH Machine Learning in Physics and the Physics Curriculum

Location: MH - Arches **Sponsor:** Committee on Physics in Undergraduate Education **Co-Sponsor:** Committee on Educational Technologies **Time:** 12–1:20 p.m. **Date:** Wednesday, July 24 **Presider:** Joshua Samani

GH01: 12:00-12:30 p.m. The Learning Machines Lab: A Research Group Using Machine Learning In STEM Education

Invited – Marcos Caballero, 567 Wilson Rd., Rm. 1310-A, East Lansing, MI 48824-2320; caballero@pa.msu.edu

John Aiken, University of Oslo

Rachel Henderson, Nick Young, Michigan State University

Physics Education Research has helped support and enhance physics education through a wide variety of research studies. In fact, some of the most compelling evidence for making use of evidence-based teaching methods stem from quantitative research studies in PER. Until recently, this work has employed traditional statistical and modeling techniques such as the analysis of the variance and linear regression. As educational data have become more plentiful and complex, quantitative physics education researchers have begun to revisit how we develop and conduct research studies. Some have started to borrow approaches from other fields including data science. In this talk, we will explore the use of machine learning techniques in education research through a series of studies being actively conducted by the Learning Machines Lab, a research collaboration between Michigan State University and the University of Oslo. How the group supports undergraduate researchers to engage with this work will be highlighted.

GH02: 12:30-1:00 p.m. Lessons Learned in Teaching Machine Learning to Physics Students

Invited – Tuan Do, UCLA, 430 Portola Plaza, Box 951547, Los Angeles, CA 90095; tdo@astro.ucla.edu*

Bernadette Boscoe, UCLA

Machine Learning techniques offer the potential to help scientific fields such as physics and astronomy process and analyze the ever-increasing amounts of data that scientists accrue. In addition, as demand for course offerings grows, fields such as physics struggle to create curricula tailored to suit the needs of students. I will discuss lessons learned in my experiences researching and teaching with machine learning approaches. Since Machine Learning encompasses multiple disciplines spanning computer science, math, and statistics, this presents difficulties in identifying what students need to learn and how this relates to domain-specific knowledge, in this case, physics and astronomy. Another challenge is that popular tools used to analyze data were created by the tech industry, and might not be well-suited for scientific aims. I will discuss some examples of machine learning projects in astronomy which may be helpful for graduate students or advanced undergrad courses and seminars. I will also cover successes and challenges in facilitating these projects.

*Sponsored by Joshua Samani

GH03: 1:00-1:10 p.m. Statistical Modeling and Machine Learning Techniques for Predicting Student Outcomes

Contributed – Devyn Elizabeth Shafer, University of Illinois at Urbana-Champaign, 711 S Urbana Ave., Urbana, IL 61801-4215; deshafe2@illinois.edu

New machine learning techniques may offer insight into complex data that violates assumptions of standard regression methods. I will describe and compare several methods used to analyze course-level and institution-level data from the University of Illinois at Urbana-Champaign with the goal of predicting outcomes such as student performance in courses and retention in the engineering program.

GH04: 1:10-1:20 p.m. Using Machine Learning to Predict Student Success in Physics Classes

Contributed – John C. Stewart, West Virginia University, 235 White Hall, Morgantown, WV 26506; jcstewart1@mail.wvu.edu

Seth DeVore, Cabot Zabriskie, West Virginia University

Physics classes form one of the key matriculation barriers for STEM students. If one could identify students at risk of failure very early in the semester, interventions could be directed at these students before they were so far behind that they cannot be salvaged. This work uses a combination of institutional data and data collected within the physics class to predict whether a student will receive an A or B in the class. Both logistic regression and random forests were used to predict student outcomes. Both methods produced similar accuracy but provided complementary insights. Using only institutional variables, an accuracy of 70% was achieved before the semester began. The combination of institutional and in-class variables achieved an accuracy of 78% in the second week of the class which was not matched by in-class variables alone until the fifth week when the first test was given.

Session GJ PER: Student Understanding and Problem-Solving

Location: MH - Aspen **Sponsor:** AAPT/PER **Time:** 12–1:10 p.m. **Date:** Wednesday, July 24 **Presider:** TBA

GJ01: 12:00-12:10 p.m. Teaching Problem-Solving for Transfer to STEM Careers: Understanding Disciplinary Variation

Contributed – Benjamin Zwickl, Rochester Institute of Technology, 84 Lomb Memorial Dr., Rochester, NY 14623-5604; ben.zwickl@rit.edu

Vina Macias, Jacob Poirier, Susan L. Rothwell, RIT

Developing general problem-solving abilities that transfer into students' careers is a common goal of introductory physics. Studies suggest that the similarity between training and application affects the effectiveness of transfer, as does the amount of variation present during training. This study examines problem-solving in four STEM disciplines, all of which routinely take introductory physics. We collected approximately 200 interviews with students, faculty, and employers, and provide three cases that highlight variation in problem-solving task and context. Healthcare emphasized diagnosis and treatment with empathy and compassion. High-risk workplaces in energy emphasized problem prevention and large collaborative teams. Advanced manufacturing identified root causes of process failures to improve yield on high precision parts. Understanding problem-solving across STEM classrooms and careers should inspire problem-solving approaches within introductory physics courses that relate more broadly to STEM careers. (Supported by NSF-1561493)

GJ02: 12:10-12:20 p.m. Exploring Students' Understanding of the Conceptual Knowledge Behind Problem Solving

Contributed – Shih-Yin Lin, National Changhua University of Education, 1 JinDe Rd., Changhua, Changhua 500, Taiwan; hellosilpn@gmail.com

Ting-Chi Yang, National Changhua University of Education

Understanding the conditions under which a physics principle is applicable is essential in problem solving. However, our experience suggests that students may not necessarily understand the conceptual underpinnings behind the equations they use in their solutions. Even for students who are competent in recognizing which principle(s) or concept(s) should be used to solve a given problem, they may have difficulty providing a good justification for why the particular physics principle(s) or concept(s) can be applicable based on the underlying physics involved. We conducted a study to explore students' understanding of the conditions of applicability required for five basic concepts in introductory mechanics, including the kinematics equations, Newton's second law, conservation of momentum, conservation of mechanical energy, and conservation of angular momentum. Findings will be reported.

GJ03: 12:20-12:30 p.m. How Do Students Explain their Reasoning?*

Contributed – Anne T. Alesandrini, University of Washington, Department of Physics, Box 351560 Seattle, WA 98195-1560; aadrini@uw.edu

Paula RL Heron, University of Washington

In addition to getting correct answers, we as instructors want our students to be able to use—and communicate—correct and complete reasoning. Here, we examine written explanations from students in introductory university physics courses to illustrate the breadth of the responses given when students are prompted to explain their reasoning. We analyze these explanations in terms of types, forms, and features, paying attention to what is present beyond what might score points on an instructor's rubric. Rather than focusing on context-specific reasoning difficulties, we examine the commonalities across multiple physics content contexts in what, to students, may constitute satisfying explanations. This broad view of student explanations has the potential to guide instruction aimed at the development of student explanation skills in ways that leverage and are responsive to how students currently explain their reasoning.

*Supported in part by NSF grant DUE - 1821123

GJ04: 12:30-12:40 p.m. Students' Sensemaking Skills and Habits: Two Years Later

Contributed – MacKenzie Lenz, Department of Physics, Oregon State University, 301 Weniger Hall, Corvallis, OR 97330; lenzm@oregonstate.edu

Paul J. Emigh, Kelby T. Hahn, Elizabeth Gire, Department of Physics, Oregon State University

Physics sensemaking is an expert-like skill that can be difficult to teach. A sophomore-level theoretical mechanics course developed at Oregon State University emphasizes sensemaking on par with physics and math concepts. This emphasis includes both explicit instruction and assessment of student sensemaking. We have found that student sensemaking improves during this new course but were curious to see what lasting impacts the course has on students. Seven students were interviewed approximately two years after taking this course. We asked the students about their current understanding and use of sensemaking and to what extent the new course contributed to their sensemaking skills and habits. We found that students have a variety of ideas about what sense making is -- from answer-checking to how you understand anything -- but that this sensemaking-focused course was instrumental in developing their sensemaking.

GJ05: 12:40-12:50 p.m. Students' Conceptual Resources for Understanding the Principle of Superposition*

Contributed – Lauren C. Bauman, Quest University Canada, 3200 University Blvd., Squamish, BC V8B 0N8 Canada; lauren.bauman@questu.ca

Lisa M. Goodhew, University of Washington

Amy D. Robertson, Seattle Pacific University

Superposition is central to understanding numerous physical phenomena, from pulses on a string to electric fields. In this poster, we report the preliminary results of our investigation into introductory undergraduate students' conceptual resources for understanding the principle of superposition. We analyzed 368 written responses to a conceptual question that explored applications and attributes of superposition. We identified four recurring resources related to superposition: (1) additiveness; (2) separability; (3) quantifiability; and (4) localization. Our objective is to support educators by drawing attention to these resources and by suggesting how they can be taken up alongside students to enhance instruction.

*This work is supported in part by grant NSF 0608510.

GJ06: 12:50-1:00 p.m. Perceived Effect on Buoyancy of Weight vs. Gravitational Force

Contributed – DJ Wagner, Grove City College, 100 Campus Dr., Grove City, PA 16127; djwagner@gcc.edu

As part of a larger investigation into students' conceptions about buoyancy, we investigated the prevalence of the belief that the gravitational force on an object changes when the object is placed in a fluid. We also investigated the effect of describing the force as "weight" instead of "gravitational force." During the first phase of the study (spring 2016 to spring 2017), students at two different institutions were asked to identify the correct free-body diagram (FBD) for a ball floating in water, and then for the same ball held down while fully submerged under water. Half of the students were shown FBDs involving "weight," and the other half were shown FBDs involving the "gravitational force." During the second phase of the study (fall 2017 to fall 2018), students at one of the institutions were asked to explicitly compare the strength of either the weight or the gravitational force on the ball when it was falling, floating, and held submerged. This talk will report on the fraction of students who indicated that the weight or gravitational force differed between the scenarios, and will discuss the effects both of the type of question asked and of the wording used to describe the force.

GJ07: 1:00-1:10 p.m. The Research on Students' Perconceptions About Rigid Body Rotation

Contributed – Yijing Bian, No.1, Lane 801,South of Linyan Road, Shanghai, China; 200062 anna_kray@163.com

This paper is about the study of students' preconceptions in the process of learning the concepts of rigid body rotation. The sample of the study consists of 30 students who had not learned the concepts of rigid body rotation at the east of China Normal University. we deeply understand the students' thinking about the problem of rigid body rotation through the think-aloud interviews, and discover the students' potential difficulties in the process of learning the concepts of rigid body rotation. We find that student always think mass will affect the rolling motion.They often cannot know whether objects can be regarded as the point or not.

Session GK PER: Diverse Investigations II

Location: MH - Zion **Sponsor:** AAPT/PER **Time:** 12–1:20 p.m. **Date:** Wednesday, July 24 **Presider:** TBA

GK01: 12:00-12:10 p.m. Accessibility Analyses Demonstrate Physics Websites Create Barriers to Participation

Contributed – Erin Scanlon, University of Central Florida, 4111 Libra Drive, Orlando, FL 32816; erin.scanlon@ucf.edu

Zachary W. Taylor, University of Texas - Austin

Jacquelyn J. Chini, University of Central Florida

There have been numerous recent calls to increase the representation of people with disabilities in STEM. One common entry point to physics programs is through departmental web pages where prospective students can find information about the program, including the undergraduate curriculum requirements and graduate research opportunities. If these web pages are inaccessible, they create a barrier to participation for people with disabilities. In order to assess the digital accessibility of undergraduate physics curriculum and graduate physics research web pages, we analyzed a representative sample of 74 institutions using Tenon (web accessibility audit software) and Voiceover (screen reading assistive technology). Overall, we found that all but one institution's web pages were inaccessible. In this talk, we will present five common accessibility errors as well as possible solutions to these errors. If we don't build accessible websites, then we indicate we do not anticipate people with disabilities to participate in our community.

GK02: 12:10-12:20 p.m. Assessing Instructors Using Student Motivational Factors and Student Performance Outcomes

Contributed – Amber B. Simmons, The Ohio State University, 191 W. Woodruff Ave., Columbus, OH 43210-1168; simmons.697@osu.edu

Srividya Suresh, Andrew F. Heckler, The Ohio State University

We describe a project in its initial stages to examine the effects of an individual instructor on student motivational factors and performance outcomes. This project analyzes students' outcomes using data of students enrolled in introductory physics courses anytime from the fall term of 2016 through the spring term of 2018 at the Ohio State University, representing over 5000 students and 15 instructors. The data includes grades in physics and math courses, cumulative GPA, standardized test math scores, cognitive and motivational factor survey data, and demographics such as major, race, and sex. The project is ultimately aimed at answering: do students' outcomes (e.g. receiving an A or DFW) and motivational factors (e.g. belonging and cost) vary by instructor in the introductory physics series? We will present some preliminary results of the analysis.

GK03: 12:20-12:30 p.m. Interactive Video-Enhanced Tutorials on Problem-Solving in Physics: Preliminary Results*

Contributed – Kathleen M. Koenig, University of Cincinnati, 2600 Clifton Ave., Cincinnati, OH 45221; kathy.koenig@uc.edu

Alexandru Maries, University of Cincinnati

Robert Teese, Michelle Chabot, Rochester Institute of Technology

Interactive video-enhanced tutorials (IVETs) are designed for online learning environments and based, in part, on the problem-solving tutorials created by the PER group at the University of Pittsburgh. The tutorials are adaptive and provide various levels of guidance and scaffolding depending on students' needs. Previous research found the tutorials to be effective when students used them as intended under the supervision of a researcher, i.e., properly engaged with the guidance, but less effective when assigned as homework, suggesting that students do not always mentally engage at the level necessary for learning on their own. This presentation will discuss how the tutorials were redesigned for web-based delivery, such that they can be assigned by instructors along with the regular end-of-chapter homework problems. Preliminary results regarding the behaviors of students as they engage with IVETs at home, as well as impact of these behaviors on their subsequent learning, will be presented.

*Work supported by the NSF IUSE Program (DUE #1821396)

GK04: 12:30-12:40 p.m. Results from the Force Concept Inventory Supplemental Assessment Test (FCISAT)

Contributed – Alex Chediak, California Baptist University, 8432 Magnolia Ave., Riverside, CA 92504; achediak@calbaptist.edu

Kyle Stewart California Baptist University

Jennifer L. Esswein Education Northwest

The FCI is invaluable for gauging student understanding of Newtonian concepts. But semester-long physics courses cover topics that go beyond its scope. To broaden coverage, 15 test items addressing energy, momentum and rotational dynamics have been created to fit seamlessly with the FCI. Data from the FCISAT have now been collected on over 200 students from three different institutions. One has an acceptance rate of 16%. While some consider the FCI to be "too easy" for top-flight students, the similarly-formatted supplemental test items proved more challenging. An Item Response Theory (IRT) analysis reveals that our supplemental test items are of similar difficulty, so the greater challenge comes from the added concepts. Moreover, the supplemental test items appear to have a smaller gender gap (1%) compared to what we observed on the FCI (9%). Therefore the FCISAT has advantages over the FCI, particularly for students with a strong physics background.

GK05: 12:40-12:50 p.m. The PIPELINE Survey: Investigating Perceptions, Experiences, and Pathways in Physics

Contributed – Anne E. Leak, High Point University, One University Parkway, High Point, NC 27268; aleak@highpoint.edu

Daryl L. Moore, High Point University

Benjamin M. Zwickl, Rochester Institute of Technology

To prepare physics majors for a range of careers, we need to understand their perceptions about the value and role of learning physics for the career path they hope to pursue. Additionally, many careers in physics require that students develop skills related to innovation & entrepreneurship that students may not have the opportunity or interest in developing. To better support students in learning career-relevant physics, we designed and implemented the PIPELINE survey. The survey uses a combination of multiple select, Likert, and open-ended response questions to explore physics perceptions, experiences, and pathways. Initial findings from responses of 100 physics majors nationally, have been used to provide summary reports for departments to assist with planning and aligning learning opportunities with career interests. Cross-case and thematic analysis across eight universities have informed research and curriculum-development for instructors and departments to better integrate innovation and entrepreneurship in physics through the NSF-funded PIPELINE project.

GK06: 12:50-1:00 p.m. Understanding Student Perspectives on Their Self-Efficacy and Learning Experiences

Contributed – Jillian Mellen, Rutgers University - New Brunswick, 100 Christopher Columbus Dr., Jersey City, NJ 07302; jillian.mellen@rutgers.edu

Antonio Silva, Geraldine L. Cochran, John Kerrigan, Lydia Prendergast, Rutgers University - New Brunswick

Students' perceptions of their self-efficacy (Bandura, 1977), or confidence in their ability to perform a task, impact their learning experiences (Zimmerman, 2000) and conversely, classroom dynamics impact students' self-efficacy by allowing for different kinds of self-efficacy opportunities (Sawtelle, Brewe, Goertzen, & Kramer, 2012). Previous research indicates that self-efficacy is context specific (Bong & Skaalvik, 2003) and there are specific sources of self-efficacy (Zeldin & Pajares, 2000; Sawtelle, Brewe, & Kramer, 2012). The purpose of this study is to investigate student perceptions of their self-efficacy and sources of self-efficacy in a gateway, flipped, integral calculus course. In this study, we analyzed interviews from 12 students enrolled in a course in integral calculus to understand their perceptions of self-efficacy and how they impact their learning experiences. Findings reveal that students believe that classroom activities and confidence resulting from these experiences impact their learning experiences both inside and outside of the classroom.

GK07: 1:00-1:10 p.m. Investigating Changes in Student Self-Efficacy in a Flipped, Integral Calculus Course

Contributed – Antonio Silva, Rutgers University, 136 Frelinghuysen Rd., Piscataway, NJ 08854-8019; moniegeraldine@gmail.com*

John Kerrigan, Geraldine L. Cochran, Jillian Mellen, Lydia Prendergast, Rutgers University

Self-efficacy (Bandura, 1977), an individual's belief in their ability to succeed at a specific task, is a predictor of student performance and persistence in math (Pajares & Miller, 1994; Cervone & Peake, 1986; Zeldin & Pajares, 2000). Thus, it is important to understand how student self-efficacy changes in different settings. Certain classroom dynamics are more conducive to students' development of self-efficacy as they allow for multiple self-efficacy opportunities (Sawtelle, 2012). Flipped classrooms (Lage, Platt, & Treglia, 2000) reverse traditional classroom lecture and assignments, and may increase self-efficacy. In our study, students used multimedia instruction outside of the classroom, and focused on collaborative problem solving and peer teaching in the classroom, for the purpose of creating a more active learning environment.The purpose of our study was to investigate changes in student self-efficacy in a flipped integral calculus course. Findings included statistically significant increases in student self-efficacy in calculus and some aspects of mathematics.

*Sponsored by Geraldine Cochran

GK08: 1:10-1:20 p.m. The Relation of Personality, Gender, and Achievement in Physics Classes

Contributed – Dona S. Hewagallage, West Virginia University, 135 Willey St., Morgantown, WV 26506; dhh0001@mix.wvu.edu

John Stewart, West Virginia University

This research compares the personality facets of 1911 students in an introductory physics class taken primarily by future engineers and physical scientists using the Big Five Inventory (BFI). The relation of personality to four measures of academic achievement were compared: high school GPA (HSGPA), ACT/SAT mathematics score, physics test average, and physics course grade. Personality explained more variance in college achievement measures than in high school measures. Conscientiousness facet was the strongest predictor of achievement for HSGPA, test average, and grade, but not for ACT/SAT score. A secondary analysis was carried out to investigate whether self-efficacy mediated the relation of personality facets to academic achievement. Self-efficacy was a significant mediator for the conscientiousness facet only. These results were similar for men and women.

Session GL PER: Student Understanding and Cognition

Location: CC - Ballroom B **Sponsor:** AAPT/PER **Time:** 12–1:30 p.m. **Date:** Wednesday, July 24 **Presider:** TBA

GL01: 12:00-12:10 p.m. Exploring Student Reasoning in Physics via Reasoning Chain Construction Tasks*

Contributed – MacKenzie R. Stetzer, University of Maine, 5709 Bennett Hall, Room 120, Orono, ME 04469-5709; mackenzie.stetzer@maine.edu

J. Caleb Speirs, University of Maine

Beth A. Lindsey, Penn State Greater Allegheny

Mila Kryjevskaia, North Dakota State University

An emerging body of research suggests that poor student performance on certain physics tasks – even after research-based instruction – may stem more from the nature of human reasoning than from specific conceptual difficulties. As part of a multi-institutional effort to investigate the nature of student reasoning in physics and to leverage the findings to improve instruction, we have designed research tasks focused on student construction of qualitative inferential reasoning chains. In these "chaining" tasks, students are provided with correct reasoning elements and are asked to assemble them into an argument in order to answer a physics question. This talk will highlight our efforts to leverage dual-process theories of reasoning to impact student performance by manipulating aspects of the chaining task format.

*This material is based upon work supported by the National Science Foundation under Grant Nos. DUE-1431940, DUE-1431541, DUE-1431857, DUE-1432052, DUE-1432765, DUE-1821390, DUE-1821123, DUE-1821400, DUE-1821511, DUE- 1821561, and DRL-0962805.

GL02: 12:10-12:20 p.m. Investigating Student Reasoning Chains via Network Analysis*

Contributed – J. Caleb Speirs, University of New England, 11 Hills Beach Rd., Biddeford, ME 04005; caleb.speirs@gmail.com

MacKenzie R. Stetzer, University of Maine

Beth A. Lindsey, Penn State Greater Allegheny

Students are often asked to construct qualitative reasoning chains during scaffolded, research-based physics instruction. As part of an ongoing, multi-institutional effort to investigate and assess the development of student reasoning skills in physics, we have been designing tasks that probe the extent to which students can create and evaluate reasoning chains. We have recently reported on a novel online "chaining" task in which students are provided with correct reasoning elements (i.e., true statements about the physical situation as well as correct concepts and mathematical relationships) and are asked to assemble them into an argument that they can use to answer a specified physics problem. This talk will illustrate the role that network analysis techniques may play in extracting meaningful information about student reasoning from these chaining tasks.

* This material is based upon work supported by the National Science Foundation under Grant Nos. DUE-1431857, DUE-1431541, DUE-1431940, DUE-1432765, DUE-1432052, and DRL-0962805.

GL03: 12:20-12:30 p.m. Classroom Interventions to Promote Coherence in Student Reasoning*

Contributed – Mila Kryjevskaia, North Dakota State University, Physics Dept., 2755, South Engineering 218, Fargo, ND 58108-6050; mila.kryjevskaia@ndsu.edu

Beth Lindsey, Penn State Greater Allegheny

MacKenzie R. Stetzer, University of Maine

Andrew Boudreaux, Western Washington University

Paula R. L. Heron, University of Washington

Research has shown that, even after research-based instruction, students who demonstrate correct conceptual understanding on one task often fail to use that knowledge on related tasks. Observed inconsistencies can be accounted for by dual-process theories of reasoning (DPToR), which assert that human cognition involves two thinking processes: a fast and automatic "heuristic" process, and a slower, more deliberate "analytic" process. Inconsistent responses can arise when the heuristic process generates an incorrect response that the analytic process fails to reject. While DPToR have been used to explain observed response patterns, few validated classroom interventions have thus far been produced. In this collaborative investigation, we have been developing and testing practical, classroom interventions designed to promote coherence in student reasoning. These interventions, designed for situations in which the requisite conceptual understanding is likely to be present, seek to "slow down" student thinking, creating space for productive engagement of the analytic thinking process.

*This material is based upon work supported by the National Science Foundation under Grant Nos. DUE-1431940, DUE-1431541, DUE-1431857, DUE-1432052, DUE-1432765, DUE-1821390, DUE-1821123, DUE-1821400, DUE-1821511, DUE-1821561

GL04: 12:30-12:40 p.m. Studying Student Physics Thinking with a Cognitive Network Model

Contributed –Timothy Malcolm Sault, East Carolina University, 2706 Stantonsburg Rd., Apt 1B, Greenville, NC 27834-7269; Timsault@gmail.com

Steven F. Wolf, Aaron M. Bain, East Carolina Uninversity

Students express their ideas, both correct and incorrect, based on the responses they give to exam questions. We utilize the analytical framework of network analysis to analyze common student ideas. Cognitive networks are made of multiple-choice exam responses (nodes) that are connected by the joint selection frequency (edges). These networks are useful in identifying student logical connections between physics ideas. By developing a model to describe these cognitive networks, we study their structure as well as structural differences between novice and intermediate physics students. When specifically examining the network structure of incorrect responses, we can identify whether students are making "smarter" mistakes based on logic, or simply guessing. We believe these response methods will be associated with more defined network structure, and more random network structure, respectively.

GL05: 12:40-12:50 p.m. Comparing Instructional Implications of Misconceptions, Resources and Dual Process Theory

Contributed – Andrew F. Heckler, Ohio State University, 111 W Woodruff Ave., Columbus, OH 43210; heckler.6@osu.edu

Over the past few decades, there has been much discussion about implicit and explicit instructional implications of adopting the perspectives of misconceptions or resources when considering student responses to questions and student thinking. Meanwhile, in the field of cognitive psychology, there has advanced a perspective of dual process theory when considering human responses to questions, decision making, and problem solving. However, there has been relatively little discussion about the instructional implications about such a perspective, especially in PER. Here I will discuss such instructional implications for dual process theory and compare and contrast with other perspectives.

GL06: 12:50-1:00 p.m. Context-Sensitivity of Resources for Understanding Mechanical Waves: Procedural versus Mechanistic Resources

Contributed – Lisa M. Goodhew, University of Washington - Seattle, 3910 15th Ave. NE, Seattle, WA 98195; goodhewl@uw.edu

Amy D. Robertson, Seattle Pacific University

Paula R. L. Heron, University of Washington - Seattle

Rachel E. Scherr, University of Washington - Bothell

The resources theoretical framework models thinking as the context-sensitive activation of pieces of knowledge. In this talk, we highlight one aspect of the context-sensitivity of resource use: that different kinds of questions reproducibly elicit different kinds of resources. We identified the conceptual resources used by students from multiple universities, in response to written questions about superposition and reflection of mechanical pulses. Some of these resources are parts of mathematical models, problem-solving steps, or algebraic procedures ("procedural" resources), while other resources are pieces of causal, mechanistic, or explanatory reasoning about wave phenomena ("mechanistic" resources). Our preliminary results suggest that questions that ask students to predict an outcome of some physical process more commonly elicit "procedural" resources, while questions that tell student the outcome of some physical process and ask them to explain the outcome more commonly elicit "mechanistic" resources. The context-sensitivity demonstrated by our analysis may have implications for how instructors design their teaching.

GL07: 1:00-1:10 p.m. Cognitive Impact of Explicit and Implicit Retrieval Practice on Learning

Contributed – Tianlong Zu, Purdue University, 525 Northwestern Ave., West Lafayette, IN 47907; tzu@purdue.edu

Jeremy Munsell, N. Sanjay Rebello, Purdue University

Retrieval based learning has been demonstrated to be effective in promoting deeper learning and better retention than restudying in psychology. Consistent with this idea, different pedagogical methods have been demonstrated efficiency in promoting physics learning. Two examples are the popular clicker/peer interaction method developed by Eric Mazur, and frequent quizzes implemented in online courses such as MOOC. Despite these successes, to a lesser degree is our knowledge about the cognitive impact of retrieval based strategies on learning. Thus, in this study, we compared two forms of retrieval practice: explicit and implicit. After a pretest and learning, half of the students practiced explicit retrieval with guided questions, the other half practiced implicit retrieval by engaging with cued problem solving. Together with students' immediate and delayed problem solving performance, we report how the two groups of students reacted to two cognitive tasks differently: judgment of learning and cognitive load measurement.

GL08: 1:10-1:20 p.m. Effect of Visual Cues and Outcome Feedback in Online Assessment

Contributed – Jeremy Matthew Munsell, Purdue University, 2819 Horizon Dr. Apt 2, West Lafayette, IN 47906; jmunsell@purdue.edu

Tianlong Zu, Sanjay Rebello, Purdue University

A study measuring the effect of visual cues and outcome feedback on transfer and delayed transfer problem solving conducted both in an algebra-based physics course as well as on Amazon Turk Prime. The study consisted of four problem sets related to motion and energy and the participants were randomly organized into four conditions where they saw some combination of visual cues and answer feedback or a control condition where they received neither. We found statistically significant improvements on near transfer in the feedback conditions (cue + feedback and feedback only) on one problem set and marginal improvements on the other problem sets. Interestingly, the cued condition was lowest performing when initial problem or pre-survey performance, were used as a covariate. These results contrast with previous research on the use of visual cues and feedback completed in a face-to-face interview setting

GL09: 1:20-1:30 p.m. Affect in Physics Problem Solving

Contributed – Muxin Zhang, University of Illinois, Urbana Champaign, 2057 S. Orchard St, Apt. B, Urbana, IL 61801; mzhang17@illinois.edu

In the past decades, physics education researchers have developed many cognitive models to explain students' problem solving difficulties, with recent evidence supporting epistemological framing and automatic, bottom-up mechanisms. However, these cognitive models usually exclude students' emotions and affect, when in fact, research in psychology has shown that affect can influence information processing and memory forming. In this talk, I will discuss my exploration of the interaction between affect and cognition in physics problem solving with a review of literature and a study design.

Session GM Evidence-based Approaches to Community Partnerships

Location: CC - Cascade A/B **Sponsor:** Committee on Science Education for the Public **Time:** 12–1:30 p.m.
Date: Wednesday, July 24 **Presider:** Michael Bennett

GM01: 12:00-12:30 p.m. Designing the Performing Physics Program for Different Community Contexts

Invited – Simone Hyater-Adams, Ms. 440 S 45th St., Boulder, CO 80305; simone.hyateradams@colorado.edu

Claudia Fracchiolla, University College Dublin

Noah Finkelstein, University of Colorado Boulder

Kathleen Hinko, Michigan State University

The Performing Physics program is a research-based informal program that integrates physics and performance art, and is going through an iterative design-based process to develop an effective model. There have been two iterations of the program so far: one with high schoolers in an Arts high school after school program, and one with middle school aged youth in a week-long summer camp. The research and development of this program is still in process, but the first two iterations have provided useful information about the nuanced needs of different community partners. This talk will discuss the tensions in community partnerships, as well ass the features that proved successful in navigating the stakeholders for each iteration.

GM02: 12:30-1:00 p.m. Community Partnerships in an Informal STEM Program

Invited – Michele McColgan, Siena College, 515 Loudon Road, Loudonville, NY 12211; mmccolgan@siena.edu

Robert Colesante, Siena College

The Siena College Informal STEM program serves 5th – 8th grade students in a nearby urban school district. This talk will describe the relationship that we've developed with the district's science coordinator, 5th and 6th grade teachers, data services personnel, and grants staff. The talk will describe the strategy we used to select the nearby district and our motivation to provide a long-term, informal STEM experience for 5th - 8th grade students. Finally, results of school outcome data and program survey data will be presented.

GM03: 1:00-1:30 p.m. Physics, Fieldtrips, and Facilitation: Using Research-Practice Partnerships to Transform Learning

Invited – Danielle B. Harlow, UC-Santa Barbara, Department of Education, Santa Barbara, CA 93106-9490; danielle.harlow@ucsb.edu

MOXI, The Wolf Museum of Exploration + Innovation is a new interactive science center focused on physical science ideas. MOXI's exhibits were informed by research on science learning and designed to align with the Next Generation Science Standards (NGSS) so that MOXI would complement children's learning in school. It now is an outstanding resource for physical science learning. UCSB, MOXI, local schools, and afterschool programs have developed programs and research through a productive researcher-practitioner partnership. Our current research and programs focus on experiences that engage visitors and school children in the practices of science and engineering. Much of our work focuses on the adults who educate children and visitors – in schools and in museums - in order to impact the largest number of children possible. Leveraging the unique resources of each institution and expertise of partners has the potential to transform both formal and informal education settings.

Session GN Upper Division/Graduate Courses

Location: CC - Soldier Creek **Sponsor: AAPT** **Time:** 12–1:30 p.m. **Date:** Wednesday, July 24 **Presider:** TBA

GN01: 12:00-12:10 p.m. Quantum Matrix Diagonalization Visualized

Contributed – Daniel V. Schroeder, Weber State University, 2508 University Circle, Ogden, UT 84408-2508; dschroeder@weber.edu

Kevin Randles, Weber State University

Bruce R. Thomas, Carleton College

Numerical matrix methods are becoming more common in quantum mechanics courses, thanks to the availability of software with easy-to-use diagonalization routines. Usually we treat these routines as black boxes, but we then miss an opportunity to visualize the diagonalization process and build intuition for the high-dimensional vector space in which the quantum states live. With these goals in mind, we have developed interactive codes in Mathematica and JavaScript for visualizing quantum matrix diagonalization. Students can use these codes to find the bound states of a one-dimensional quantum well of any shape.

GN02: 12:10-12:20 p.m. Investigating Student Understanding of Electromagnetic Fields in Matter

Contributed – Bert C. Xue, University of Washington, 3910 15th Ave. NE, Seattle, WA 98195-1560; bertxue@gmail.com

The Physics Education Group at the University of Washington has been conducting research on student understanding of concepts and skills covered junior-level electrodynamics courses and using the results to design tutorials to supplement instruction. One of the findings is that in learning about electromagnetic fields in materials, many students have difficulty in relating displacement and auxiliary fields to polarized and magnetized materials, respectively. This talk will illustrate how students reason about these fields and how the findings are motivating an instructional approach that focuses on helping students construct a physical interpretation of divergence and curl as 'sources' of vector fields.

GN03: 12:20-12:30 p.m. Developing a Robust Clicker Question Sequence for Larmor Precession in Quantum Mechanics

Contributed – Paul D. Justice, University of Pittsburgh, 3941 O'Hara St., Pittsburgh, PA 15260; paj42@pitt.edu

Emily Marshman, Chandralekha Singh, University of Pittsburgh

Effective use of clicker questions in physics courses at all levels can be an excellent formative assessment tool and can help students learn physics concepts and develop their reasoning and metacognitive skills. Here we discuss our research on the development and both out-of-class and in-class validation of an effective clicker question sequence for helping students learn about the time-dependence of expectation values in quantum mechanics using the Larmor precession of spin. We also discuss the in-class evaluation which involved analyzing data from the implementation of the clicker question sequence which was earlier validated out-of-class in two upper-level undergraduate quantum mechanics courses taught by two different instructors at the same institution who used two different textbooks. We thank the National Science Foundation for award PHY-1806691.

GN04: 12:30-12:40 p.m. Conceptual Investigations Using PhET Simulations in Upper Division Solid State Physics

Contributed – Sara J. Callori, Department of Physics, California State University, San Bernardino, 5500 University Pky., San Bernardino, CA 02407; sara.callori@csusb.edu

Justin Perron, Department of Physics, California State University San Marcos

PhET Simulations are free, interactive simulations designed to help students conceptually investigate a wide range of topics within physics and other STEM fields. Here, we report on the development of worksheets to aid students in approaching new topics in an upper division Solid State Physics course. We used three PhETs to help students engage with topics dealing with energy bands and their connection to material properties: Band Structure, Conductivity, and Semiconductors. For each activity we designed structured worksheets to lead students through a qualitative investigation of the relevant physics. Overall, student feedback shows that incorporating PhET activities into class helped students understand and engage with new topics.

GN05: 12:40-12:50 p.m. Survey on Upper-Division Thermal Physics Content Coverage

Contributed – Katherine D. Rainey, University of Colorado Boulder, 1550 South Evanston St., Aurora, CO 80012; katherine.rainey@colorado.edu

Bethany R. Wilcox, University of Colorado Boulder

Thermal physics is a core course requirement for most physics degrees and encompasses thermodynamics and statistical mechanics content. However, the primary foci of thermal physics courses vary across universities. This variation can make creation of targeted materials or assessment tools for thermal physics difficult. To determine the scope and content variability of thermal physics courses across institutions, we distributed a survey to over 90 institutions to solicit content priorities from faculty and instructors who have taught upper-division thermodynamics and/or statistical mechanics. We present results from the survey, which articulate key similarities and differences in thermal physics content coverage across institutions. We will discuss implications of these findings for the development of instructional tools and assessments that are useful to the widest range of institutions and physics instructors.

GN06: 12:50-1:00 p.m. Resonance: Using Peer Mentoring Circles to Build Community for Physics Majors

Contributed – Laura J. Tucker, University of California, Irvine, 4129 Frederick Reines Hall, Irvine, CA 92697-4575; tucker@uci.edu

Rebecca Riley, Franklin Dollar, University of California, Irvine

Resonance is a new peer mentoring program in the Department of Physics & Astronomy at UC Irvine. Our goals are to build community among physics students, inspire excitement about physics, and help students navigate challenges of the first year. Small groups of four to six incoming students meet at least once a month together with two continuing physics majors who serve as mentors. We discuss the mentee and mentor response to group mentoring, outcomes from our pilot year, and future plans.

GN07: 1:00-1:10 p.m. Relationship Between Physics Majors' Identity Development, Career Expectations, and Retention

Contributed – Zeynep Topdemir, Georgia State University, 431 One Park Place, Atlanta, GA 30303; ztopdemir1@gsu.edu

Brian D. Thoms, Joshua S. Von Korff, Amin Bayat Barooni, Georgia State University

It has been reported that only 43% of the physical science majors stay in their original field, while the rest either change their major or drop out of college (1). This study investigates the influence of physics identity development and career expectations on the retention of undergraduate physics majors. We have interviewed twenty students and surveyed forty students who are at different stages of their undergraduate program to determine the experiences, beliefs, and attitudes that influence undergraduate physics majors to stay in physics. We examine how these experiences are related to physics identity development, career expectations, and career-related actions. Chen, X. (2013). STEM Attrition: College Students' Paths into and Out of STEM Fields (NCES 2014-001). National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education. Washington, DC

APS PLENARY

Jack Burns
NASA/SSERVI Network for Exploration & Space Science (NESS)

1:30–3:00 p.m.
Wednesday, July 24

CC - Ballroom C

Hydrogen Cosmology: Observing the Dark Ages of the Universe from the Farside of the Moon, *by Jack Burns*

After the Cosmic Microwave Background photons decoupled from baryons, the Dark Ages epoch began: density fluctuations imprinted from earlier times grew under the influence of gravity, eventually collapsing into the first stars and galaxies during the subsequent Cosmic Dawn. In the Dark Ages, most of the baryonic matter was in the form of neutral hydrogen (HI), detectable via its ground state's "spin-flip" transition. This line's rest frame frequency (wavelength) of 1420 MHz (21-cm) arrives today highly redshifted to low radio frequencies (?100 MHz) due to cosmic expansion. A measurement of the redshifted 21-cm spectrum maps the history of the HI gas through the Dark Ages and Cosmic Dawn and up to the Epoch of Reionization, when the near absence of HI extinguished the signal. Recent reported observations by the Experiment to Detect the Global Epoch of Reionization (EoR) Signature (EDGES) claimed the detection of an absorption trough at 78 MHz (redshift z~17), similar in frequency to expectations for Cosmic Dawn, but ~3 times deeper than was thought possible from standard cosmology and adiabatic cooling of HI. Interactions between baryons and slightly-charged dark matter particles with an electron-like mass provide a potential explanation of this difference but other cooling mechanisms are also being investigated to explain these results. The Cosmic Dawn trough is affected by the complex astrophysical history of the first luminous objects. Another trough is expected during the Dark Ages (at frequencies below 30 MHz), prior to the formation of the first stars and thus determined entirely by cosmological phenomena. I will describe the results of a NASA-funded concept study for the Dark Ages Polarimeter PathfindER (DAPPER), operating in a low lunar orbit above the radio-quiet farside. DAPPER will use the Dark Ages trough to investigate divergences from the standard model and new physics such as heating or cooling produced by dark matter. DAPPER's science instrument consists of dual orthogonal dipole antennas and a tone-injection spectrometer/polarimeter based on high heritage components from the Parker Solar Probe/FIELDS, THEMIS, and the Van Allen Probes. DAPPER will be deployed from the vicinity of NASA's Lunar Gateway and transfer to a frozen 50×125 km lunar orbit using a deep space spacecraft bus which has both high impulse and high delta-V. This orbit will facilitate the collection of radio-quiet data over a 26 month lifetime for the mission. This research was supported by NASA cooperative agreement 80NSSC19K0141 and the NASA Solar System Exploration Research Virtual Institute cooperative agreement 80ARC017M0006

Pearl Sandick
University of Utah

WIMPs in the Sky, *by Pearl Sandick*

The question of the identity of dark matter is one of the most important outstanding puzzles in modern physics. Of the many potential explanations proposed, perhaps the most-studied is a new species of elementary particles called Weakly Interacting Massive Particles (WIMPs). The properties of dark matter are being probed in a variety of ways, for example by terrestrial experiments buried deep underground as well as satellite experiments looking for signals from space. I'll discuss the prospects for "discovering" dark matter, focusing on the indirect detection technique, and how WIMPs may reveal themselves via signatures of their annihilation or decay in and around our Galaxy.

Session PERC PERC Bridging

Location: CC - Ballroom C **Sponsor:** AAPT/PER **Time:** 3–4:30 p.m. **Date:** Wednesday, July 24 **Presider:** TBA

A Collective Exploration of Physics Beyond the Classroom

Shane Bergin, University College Dublin (UCD), Ireland

This talk will explore learning physics beyond the classroom, laboratory, and lecture hall. Grounded in our collective experience of running, or participating in, informal physics programmes, and scholarship from this emerging sub-discipline, I hope to construct, with your help, goals and questions that we might engage with over the PERC meeting. To that end, the session will be an active one. In advance of this session, you may like to reflect on informal physics programmes you have participated in, or led. In doing so, consider your motivations, the practices and community of people involved. Think, too, about how they may have affected you. During the session, you'll be invited to discuss, in small groups, your experiences of those programmes. I hope we can build on these to co-construct community-level ideas, concerns, goals, etc. around

Making Through a Lens of Culture, Power, & Equity: Visions for Learning and Teaching in Informal Settings

Paula Hooper, Northwestern University

Physics education in informal settings often happens in places that are described as makerspaces or tinkering settings. Claims are made by the branded maker community that the creation of objects with physical and digital tools will provide equitable access for children of all ages, cultural and socioeconomic backgrounds to STEM learning that will open career paths in which they are underrepresented. But these broad claims need a lot of conceptual and pedagogical work to help educators design spaces and activities that shift the nature of learning and teaching within informal settings to be responsive to the needs of all children. This presentation will consider the questions -What allows the physics of sound to be a material for exploration/investigation within a makerspace that is designed to be equitable and inclusive? How can educators come to think about learning and teaching where equity and science ideas are intertwined? We will discuss four principles from equity-oriented and making/tinkering research: critical analyses of educational injustice, historicized approaches to making as cross-cultural activity, ongoing inquiry into the sociopolitical values and purposes of making, and explicit attention to pedagogical philosophies and practices (Vossoughi, Hooper, Escude 2016). We will examine two cases that embody some of these principles that can help this community to recognize and design for equitable informal STEM learning environments. One case is a teaching interaction within an after school program where students are engaged in exploring sound with physical and digital tools. The other is an example of a professional development design that engages both formal and informal educators in grappling with how inquiry-oriented pedagogical structures can become tools for valuing multiple paths of sense making about science ideas.

Session HA Post-deadline Abstracts I

Location: CC - Cascade E **Sponsor: AAPT** **Time:** 3:30–5 p.m. **Date:** Wednesday, July 24 **Presider:** TBA

HA01: 3:30-3:40 p.m. ISLE Framework and the Development of the Preservice Physics Teachers

Contributed – Marianne Vanier, Rutgers University, 10 Seminary Place, New Brunswick, NJ 08901; mmdvanier@gmail.com

Eugenia Etkina, Rutgers University

We report on the study that examines how pre-service physic teachers (PSTs) develop habits* and skills necessary to center their teaching on science practices through the use of the Investigative Science Learning Environment (ISLE) ** framework. PSTs at Rutgers University teach laboratories in an ISLE-reformed introductory physics course as part of their teacher preparation program. This additional teaching experience is coupled with weekly reflections on a Google group page and the traditional mandatory student teaching in schools. The analysis of the PSTs' reflections on teaching in this course and traditional student teaching internship beholds how they learn and develop the skills and habits corresponding to the NGSS role of the physics teacher.

* Etkina, E., Gregorcic, B., and Vokos, S. (2017). Physical Review, Physics Education Research, 13, 010107 * *Etkina, E. (2015). American Journal of Physics, 83 (8), 669-679.

HA02: 3:40-3:50 p.m. Redesigning the Upper-level Research Experience for BS Physics Major at Rowan University

Contributed – David R. Klassen, Rowan University Department of Physics & Astronomy, 201 Mullica Hill Road, Glassboro, NJ 08028; klassen@rowan.edu

As originally designed our BS Physics degree had an upper-level experimental capstone experience that we labeled Advanced Lab. The concept was that since we had a thriving research environment we could get students into the experimental physics labs where they would learn lab techniques and gain experience with modern equipment (e.g. SEM, XRD, sputtering deposition, etc.). Students would work for half the semester on one project with one mentor then change projects and mentors for the second half. This put considerable strain on the experimentalists and also did not really give students enough time with the projects to be meaningful. We recently reconfigured the experience by converting into two Physics Research Methods courses and moved them into the junior year. I will discuss our reasonings and an initial look at our outcomes after having run the sequence for a full year.

HA03: 3:50-4:00 p.m. Development of an Undergraduate Science of Martial Arts Course

Contributed – Joseph Johnson, 501 E 38th St., Erie, PA 16546-0002; jjohnson@mercyhurst.edu

Katie Kilmer, Paul Ashcraft, Mercyhurst University

Mihwa Park, Texas Tech University

It is often the case that universities offer a limited number of options for non-science majors to take interesting science courses to meet their general education elective requirements. This is particularly true for physics-based courses meeting this requirement. With the aim of meeting this need while also increasing interest and enrollment in physics courses in general, a Science of the Martial Arts course was developed, marrying physics content, anatomy and physiology, and the martial arts. The course was also coupled with a study abroad option to Japan. This presentation will describe the development and implementation of this course at our medium sized, liberal arts university to a pool of students that do not have scientific backgrounds. Specifically, we will describe the course development process, the lab and lecture strategies implemented, and the learning outcomes associated with the study abroad component of the course.

HA04: 4:00-4:10 p.m. Faraday Rotation

Contributed – Jin Wang, UM, 4901 Evergreen Road, Dearborn, MI 48128; jinwang@umich.edu

Thomas Sutter, Magnolia Landman, Fedda Saleh, University of Michigan

In this work, observations of Faraday Rotation on linearly polarized laser light is presented as well as an experimental method of measuring the Verdet constant of transparent dielectrics. Historically, Faraday rotation was the first experimental evidence of a connection between electromagnetism and light. It was first observed by Michael Faraday in 1845. This phenomena is of immense practical and historical importance, it has applications such as optical isolators and measuring intense magnetic fields. Faraday rotation is a rotation of the polarization angle of linearly polarized light passing through a medium immersed in a magnetic field parallel to the path of the light. The Verdet constant parameterizes the degree of rotation for a specific material and wavelength of light. In the experiment presented here, an alternating and approximately spatially uniform magnetic field was produced by driving a solenoidal coil of wire with square wave voltage waveform. The Verdet constant of SF–59 Schott glass at 654.3 nm was found to be 21.26 ± 0.57 rad/(T m). The linear dependence of Faraday rotation on the strength of the magnetic field is demonstrated.

HA05: 4:10-4:20 p.m. Investigating Common Middle School Physical Science Misconceptions with Network Clustering

Contributed – Jacqueline Doyle, Center for Astrophysics | Harvard & Smithsonian, 60 Garden St, MS-72 Cambridge, MA 02138; jacqueline.doyle@cfa.harvard.edu

Philip M. Sadler, Gerhard Sonnert, Center for Astrophysics | Harvard & Smithsonian

We surveyed N = 24630 middle school students across the country with 30 questions covering the NRC physical science standards, drawn from the expert-validated MOSART item bank. Items were designed to include incorrect responses are commonly chosen by students (i.e., misconceptions). We cluster the responses to these questions to find patterns in student understanding and misconception of these topics. We discuss the most common patterns of correct and incorrect responses, how these patterns are similar and dissimilar to each other, and how identifying these patterns in their students may help teachers better assess their students' reasoning in a classroom setting.

HA06: 4:20-4:30 p.m. Implementation of a Variation of Studio Physics at the American University in Cairo

Contributed – Mohammad T. AlFiky, The American University in Cairo, Physics Department, School of Sciences and Engineering, New Cairo, P.O.Box 74, 11835 Egypt; alfiky@gmail.com

Ehab Abdel-Rahman, Karim Addas, Hosny Omar, The American University in Cairo

At the American University in Cairo (AUC), the physics department is reforming the traditional way of teaching the calculus-based introductory sequence of Mechanics and EM courses by implementing a variation of the studio format, a hybrid version. The course sequence format has changed from the traditional two lecture sessions (75-minute each) plus one lab session (of 3 hours) per week to two 75-minute sessions (with variety of active learning techniques) each is followed directly by another 75-minute session (of hands-on experimental activity focusing on the main concept of the preceding session). The hybrid version is hosted in two newly renovated labs (of capacity around 30 students) with modern equipment which was purchased by the ASHA grant a few years ago. In addition, the physics department offers regular problem sessions and physics clinic (where students have more opportunities to discuss physics problems) whose structures have been improved. The lecture and lab session activities are guided by PER. We would like to share our experience during this implementation and to get the feed back from the AAPT community on these changes.

HA07: 4:30-4:40 p.m. Development of Maker education-linked Physics Teaching Material for High School

Contributed – SE HWAN YOON, Korea National University of Education 250, taeseongtabyeonro, gangnaemyeon, heungdeokgu Cheongju-si, Chungcheongbuk 28173 republic of korea eduhwan1@knue.ac.kr

Kwang soo Ryu

The term of 4th Industrial Revolution emerged from the World Economic Forum (WEF) in 2016 and, it became a paradigm of modern society based on ICT. To prepare for this, the Korean government has been gradually introducing the maker education to the elementary and middle schools as of 2019. However, the high schools has been still lacking the curriculum and space conditions to experience the maker education. In this study, we has developed the physics teaching material for the high school students to experience the maker education easily. Specifically, the students can explore the features of the retro-reflection phenomenon under the theme of 'reflection of light' in the physics I curriculum. and we have designed the teaching material with the aim of using retro-reflection to make objects that can be useful in everyday life in their own form. Finally, we hope that the results of this study can induce the positive awareness of the maker education by providing the opportunities to experience the purpose of maker education in everyday topics, and it contributes to the spread of the maker education-linked science education culture in school.

HA08: 4:40-4:50 p.m. Action Research for Implementing Active-Learning High School Physics Lessons in Japan

Contributed – Sachiko Tosa, Niigata University, Ikarashi-2-cho, 8050-banchi, Nishi-ku Niigata, Niigata 950-2181 Japan; stosa@ed.niigata-u.ac.jp

In spite of a strong emphasis on the use of active-learning type instructional strategies, high school lessons in Japan are known to be one-way knowledge transmission (Ministry of Education, 2018). This study examines the effects of implementing active-learning type instructional strategies in a particular high school physics class in Japan As the first step, characteristics of the physics class were identified through an analysis of the observation data of the class for three months. The results indicate that the lessons were conducted mostly by the transmission of knowledge despite the fact that the teacher included elements that would help students relate physics knowledge to their daily lives. A plan for implementing active-learning type instructional strategies was developed by the teacher and researchers. Impacts of action research on student academic performance, teacher teaching, and teacher's beliefs will be discussed in the presentation.

HA09: 4:50-5:00 p.m. Robeson Planetarium: After the Floods

Contributed – Ken Brandt, Robeson Planetarium and Science Center, 4320 Kahn Dr., Lumberton, NC 28358; kenneth.brandt@robeson.k12.nc.us

The Robeson Planetarium and Science Center succumbed to the floodwaters associated with Hurricanes Matthew in 2016, and Florence in 2018. That could have been the end of the story, but it is not. Come find out about partnerships, perseverance, and resilience as we plot a course towards rebuilding.

Session HC Post-deadline Abstracts II

Location: CC - Cascade C **Sponsor: AAPT** **Time:** 3:30–5 p.m. **Date:** Wednesday, July 24 **Presider:** TBA

HC01: 3:30-3:40 p.m. Concept Question Use Across Multiple Sections of Introductory Electromagnetism

Contributed – Aidan MacDonagh, Massachusetts Institute of Technology, 100 Memorial Dr. 2-23A, Cambridge, MA 02142; aamacdon@mit.edu

Alexander J. Shvonski, Michelle Tomasik, Peter Dourmashkin, Massachusetts Institute of Technology

We examine student responses to in-class concept questions given in a large-scale, introductory electromagnetism course at MIT. The course has 8 sections with approximately 90 students per section, and each section's instructor uses the same set of in-class concept questions, to which students submit responses using our LMS. By analyzing the comprehensive dataset of student responses, we sought to understand how concept questions were used in class, thereby determining the educational experience of the students between sections. We found that most students were asked a majority of the questions at least once (instructors used anywhere from 73% to 92% of available questions), but there was much more variation in the number of follow-up attempts given (ranging from 0% to 77% amongst sections). We consider the effects that these differences in concept question use might have on learning outcomes.

*Sponsored by Alexander J Shvonski.

HC02: 3:40-3:50 p.m. Assessment of Relevance in Algebra-based Physics for Non-Majors

Contributed – Gen Long, Saint John's University, 8000 Utopia Pkwy., Jamaica, NY 11439-0001; longg@stjohns.edu

In this presentation, we report an ongoing exploration of assessing the teaching of College Physics to non-major students including Biology, Toxicology and Biomedical, etc. In our traditional classroom setting, we try to educate the students about the relevance of Physics to their own majors, which wasn't emphasized in previous teaching. We're working on to find out whether or not this helps students learn more actively, through self-assessment, and assessment done on the learning outcomes. Pre and post assessments on physics and math prerequisite were also conducted.

HC03: 3:50-4:00 p.m. Integration of Cost-effective Sensors into Introductory Physics Labs

Contributed – Matthew Fairbanks, California State University, Maritime Academy, 200 Maritime Academy Drive, Vallejo, CA 94590; matthew.fairbanks@gmail.com

The physics faculty of California State University Maritime Academy are in the process of modernizing the University's physics lab curriculum to include more modern sensors and more inquiry-based experiments and activities. To that end, we have begun using wireless PocketLab sensors - which integrate many standard sensors into a single, compact package - into our existing experimental apparatus. We will discuss some of the lessons learned during this process: student response, the strengths and weaknesses of the PocketLab platform, and plans for the future.

HC04: 4:00-4:10 p.m. Let's Get Physical: Exploring Kinematics in the Gym

Contributed – Jyl Stoltenberg, South Seattle Community College, 8509 S. 117th St., Seattle, WA 98178; jcoh83@gmail.com

Azita Seyed Fadaei, South Seattle Community College

In the series of lab experiments, students were to observe patterns of motion of objects, uniform motion and then non-uniform motion in an Algebra-based physics course. We extended the idea to the daily life. In the viewpoint of a personal trainer, human movement derives from the very basic concepts of kinematics. So delving into further exploration of how the role plays into the body mechanics, exercise execution and strength development is of the great import to this study. The purpose of the recorded elements was to be able to simplify the concepts of motion witnessed in the gym and make comparisons of kinematic variables. By comparing the graphs from each sport activity, both in lab and from client training sessions, we sought to show how uniform and non-uniform motion and the subsequent relationships of position vs. time and velocity vs. time make up the very foundation of training.

HC05: 4:10-4:20 p.m. Demo Based Recitations

Contributed – Joseph F. Brinkley, Austin Community College, 11928 Stonehollow Dr., Austin, TX 78758; jbrinkle@austincc.edu

In a demo based recitation section, students are asked to analyze a physical apparatus, and make necessary measurements before solving problems. In their problem solving, they must use their own measurements as part of the problem solving process. In this talk, I will give a couple of examples of demo based recitation questions used in first year physics courses.

HC06: 4:20-4:30 p.m. Current Political New York Times Articles that Help Teach Physics

Contributed – John P. Cise, Austin Community College, 2508 b Flora Cv, Austin, TX 78746-6902; jpcise@aol.com

Recent political events reported in the *New York Times* have been rich with physics applications. Political event articles involving: Newton, Statics, Centripetal force, Projectiles, Energy, Power, Buoyancy will be presented as useful physics learning applications. These one page edited New York Times political articles are used by the author as : introductions to physics concepts, quiz questions, etc. They are listed as at AAPT ComPADRE site and this specific talk is at http;//CisePhysics.homestead.com/files/NYTPoliticalPhysics.pdf and at the vast NYT Physics Application site: http://CisePhysics.homestead.com/files/NYTPhysics2016E.pdf

HC07: 4:30-4:40 p.m. Teachers' Disciplinary-Boundedness in the Implementation of Integrated Computational Modeling in Physics

Contributed – Rebecca E. Vieyra, 225 C St. SE, Washington, DC 20003; rebecca.elizabeth.vieyra@gmail.com

Joshua Himmelsbach, Andrew Elby, University of Maryland

Computational modeling has received significant attention as a way to support and expand an understanding of physics. However, the use of programming as a representative tool to model physics often challenges high school teachers' historic dependencies on algebra-based thinking. In this presentation, we will provide a synthesis of teachers' perceptions about the discipline of physics, and show data that suggest that teachers who display stronger "boundary-stretching" attitudes about physics are significantly more likely to persist in the inclusion of computational modeling across a four-year program funded by 100Kin10 and the NSF. We will present the tool we developed to assess teachers' thinking, correlate these thinking patterns to teachers' long-term persistence project, and describe the potential implications of our findings.

HC08: 4:40-4:50 p.m. The Trouble with Significant Figures

Contributed – Larry K. Smith, Snow College, 150 College Ave., Ephraim, UT 84627; Larry.Smith@snow.edu

John S Denker

Consider: (a) deciding how much to round off, (b) representing uncertainty, and (c) representing actual significance, in the sense of importance or meaningfulness. These are three important things, but they are not the same thing. Unfortunately, some introductory science texts use the method of “significant figures” (also known as “significant digits”) to cover all of these things. Blurring the distinctions leads to conceptual errors, incorrect numerical results, and wasted effort. There are good reasons why students don't like and don't understand significant figures. Various problems with significant figures are explained. https://tinyurl.com/y5xp97x3

HC09: 4:50-5:00 p.m. The Secondary Pre-teachers' Perception of Good Science Teaching in Korea

Contributed – Arum Noh, Korea National University of Education, 250, Taeseongtabyeon-ro, Gangnae-myeon, Heungdeok-gu Cheongju-si; dkfma341421@gmail.com

NamIn Hong, HyukJun Choi, Korea National University of Education

This research surveys how the secondary pre-service teachers (hereinafter referred to as pre-teachers) recognize good science teaching, and lets the pre-teachers evaluate their teaching based on their survey to see whether their science teaching is good. This study intends to compare differences between their perception about good science teaching and their actual teaching. Based on a good science teaching questionnaire (Lee, 2016), the good science teaching perception survey questionnaire were created and implemented for 48 pre-teachers. As a result, in the three areas of educational content, method and environment and atmosphere, pre-teachers gave a lower score in their science teaching than the perception score for good science teaching. In addition, their teaching execution required in the conventional method was achieved while they felt it was more difficult to develop teaching for high-dimensional thinking power. Based on the results, we present some suggestions for overcoming the difficulties that pre-teachers have in carrying out good science teaching.

HC10: 5:00-5:10 p.m. Operate gifted education program to cultivate various competencies

Contributed – Yongsik Lym, Korea national University, 59, Wolgye-ro, Gwangsan-gu, Gwangju, Republic of Korea Gwangju, korea 62263 south korea lys3631@gmail.com

This school is a middle school that operates a local community gifted school and has been operating math and science gifted education for many years. The problem has been that the number of applicants has gradually decreased over the years, and there have often been cases of even underperforming middle school seniors. The reasons for this include the uniform teaching method that has been customary in the past and the curriculum that does not reflect various educational factors such as career, personality and creativity. In order to break away from this formalized education system, the school attempted to converge gifted education with diverse capabilities of students. The four elements of the program were career, scientific aptitude, personality, and creativity. As a result of its operation, it explored science-related high schools and universities and conducted activities with counselors to develop awareness of career. The elements of scientific literacy were allowed to study the facilities related to mathematics and science and to build virtues by operating an exploratory classroom. The character category was designed to foster a sense of cooperation and social skills by visiting a group training center to encounter various group activities and team work tasks. Activities to cultivate creative elements led to an opportunity to visit the invention center and make similar inventions in person, and took a long time to select and solve research tasks for each group in the school. This year's operation indicated that overall satisfaction with the activity was higher than in the past.

Session Poster Session 3

Location: CC - Exhibit Hall C **Time:** 3:30–5 p.m.
Date: Wednesday, July 24

Persons with odd-numbered posters will present their posters from 3:30 to 4:15 p.m.; those with even-numbered posters will present from 4:15 to 5 p.m. Posters will be available until 5 p.m.

PST3A01: 3:30-4:15 p.m. Physics Teaching Habits: How Can We Study them Using Student Reflections?*

Poster – Marianne Vanier, 10 Seminary Place, New Brunswick, NJ 08901-1267; mmdvanier@gmail.com

Eugenia Etkina, Rutgers University

The poster will show the patterns that emerged from our analysis of nearly 300 preservice physics teachers' reflections while they develop teaching habits* and skills in agreement with the NGSS teaching requirements. At Rutgers University, the teaching experiences in an ISLE-reformed introductory physics course are added to the usual mandatory student teaching in schools and the specific coursework in physics education. We were interested in the changes in the preservice physics teachers' reflections (content, emergent themes, theme evolution etc.) over two years in the program as the indicators of professional growth.

* Etkina, E., Gregorcic, B., and Vokos, S. (2017). Physical Review, Physics Education Research, 13, 010107

PST3A02: 4:15-5:00 p.m. Examination of Dilemmas for a Culturally Relevant Approach to Physics Instruction

Poster – Clausell Mathis, Florida State University, 1130 High Meadow Dr., Tallahassee, FL 32311; cm15j@my.fsu.edu

Mark Akubo, Sherry Southerland, Florida State University

The motivation for developing this project started with the question: What is the intersection of students' culture with physics ideas? A variety of researchers have found that students have a higher level of engagement, performance, and identification when the instructor uses cultural resources for instruction (Ramburuth & Tani, 2009; Scherff & Spector, 2011). I proposed a culture-based approach to physics instruction where cultural norms and patterns are used in developing concepts and building on students' interests and norms. For this study, I followed a African American Physics teacher as she developed and implemented a culturally relevant physics curricula in alignment with the Next Generation Science Standards. Using a qualitative case study approach, I examined the dilemmas she experienced during the planning and enactment of lessons, using Windschitl's (2002) framework of dilemmas. Data collection was done through observation, field notes, and semi-structured interviews.

PST3A03: 3:30-4:15 p.m. Students' Strategies to Solve Conceptual Physics Problem

Poster – Mihwa Park, Texas Tech University, 3002 18th, Lubbock, TX 79409; Mihwa.Park@ttu.edu

Since the new science standards in the U.S., NGSS (Lead States, 2013), was released, the direction of developing science assessments has been toward revealing students' reasoning even in college level science courses. This stresses to give students opportunities to reason qualitatively about problems, which, in turn, forces to develop open-ended questions that students can write their answer to reveal their reasoning. The underlying assumption of open-ended questions could be that qualitative explanation questions will elicit students' reasoning and assess their understanding of core scientific concepts and scientific practice better than multiple-choice or simple calculation questions. Previous studies found that experts tend to start with the application of general principles of science that results in a conceptual analysis of problems while novices tend to start by selecting equations for an algebraic problem solution. Thus, giving students opportunities to reason qualitatively about problems would help them think like experts. The current study investigated students' strategies to answer qualitative physics questions. Participant students were first- year college students who were taking an introductory level physics course. The results indicated although conceptual qualitative questions were given, students still used equations to explain scientific process. The study also revealed that their utilities of equations could be in play as a conceptual analysis tool for a physical situation. In the presentation, its implications to physics lessons will be discussed.

PST3A04: 4:15-05:00 PM Measurement of Kinetic Friction with Different Velocity Using Timoshenko Oscillator

Poster – Yangming Li, No.2, Southeast University Road, Jiangning District Nanjing, Jiangsu 211189 China; 898201834@qq.com

Gao Yichen

A Timoshenko oscillator, which consists of a plate with periodic motion with the combined influence between gravity and kinetic friction on its rotating supports, is built to illustrate the relation between the frequency of the vibration and the coefficient of kinetic friction. Our experiment allows us to explore the friction's low in relatively high-velocity regime. Our experimental results show that the Coulomb's law of kinetic friction is only valid under the situation of small relative velocities and the kinetic friction becomes smaller when the velocity is increased. Usually the measurement of coefficient of kinetic friction is done at a low relative velocity, but our experiment allow us to explore the friction's low in higher relative velocities.

PST3A05: 3:30-4:15 p.m. Dynamics of a Looping Pendulum

Poster – Ding Zimin, No.2, Southeast University Road, Nanjing, Jiangsu 211189; 3523971828@qq.com

A looping pendulum consists of a horizontal rod and a string connected to a heavy load and a light load. The string is put over the horizontal rod and the light load is pulled down so that the heavy load is lift up. After the light load is released, it will sweep around the rod, keeping the heavy load from falling to the ground. Our experiment allows us to explore the relationship between the falling distance and the mass of the heavy load. And the trajectory of the light load can also be figured out. Our experimental and theoretical results show that the falling distance of the heavy load increase with the increase of the mass of the heavy load. The trajectory of the light load is the combination of two different Archimedes curves.

PST3A06: 4:15-5:00 p.m. Integrated Space Science Resources for Undergraduate Instruction

Poster – Rebecca E. Vieyra, 225 C ST SE, Apt B, Washington, DC 20003; rebecca.elizabeth.vieyra@gmail.com

Ramon Lopez, University of Texas at Arlington

Brad Ambrose, Grand Valley State University

Janelle Bailey, Temple University

Shannon Willoughby, Montana State University

In this poster we provide an overview of the current status of instructional materials development by a team funded by the NASA subcontract to Temple University and AAPT. The team has been funded to create research-based instructional materials at a variety of levels with a focus on post-secondary education. Some of these materials might also be applicable to a high school context with minimal modification.

PST3A09: 3:30-4:15 p.m. An Analysis of Google Analytics Data

Poster – Kevin M. Lee, University of Nebraska, 244D Jorgensen Hall, Lincoln, NE 68588-0299; klee6@unl.edu

Christopher M. Siedell, Emily Welch, University of Nebraska

An Analysis of Google Analytics Data Kevin M. Lee, Christopher M. Siedell, & Emily Welch The web site at https://astro.unl.edu has been host to a variety of technology-based introductory astronomy teaching materials for many years. These include computer simulations, a library of dynamic peer instruction materials, animated ranking and sorting tasks, and videos of astronomy demonstrations. Google Analytics has been used to track visitors to the web site and inform the developers on the usage of these materials. Recently this database of tracking information has grown to span a complete decade. This poster will be a retrospective on the lessons learned regarding the relative usage of the different packages of teaching materials, how that usage grew over time, the types of institutions making use of the materials, what can be concluded regarding that usage, and interesting related anecdotes. We will also address what can't be learned from Google Analytics due to the protection of visitor's anonymity. We acknowledge the vital support of the National Science Foundation and statistics will be provided on curriculum materials developed under NSF grants #0231270, #0404988, #0737376, #1044658, and #1245679.

PST3A10: 4:15-5:00 p.m. Classifying Instructor Beliefs on Incorporating Computation into Undergraduate Physics Courses

Poster – Sameer Barretto, University of Michigan, 9260 Fellows Creek Dr., Plymouth, MI 48170; sambarr@umich.edu

Thomas Finzell, University of Michigan

Over the course of a year, we interviewed ~20 faculty members in the Physics Department of a large research university in the Midwest. In this poster, we will be presenting the classification scheme that we developed to determine the beliefs and convictions of said faculty, and analyze the impact that has on the way they incorporate (or do not incorporate) computation into their classes.

PST3A11: 3:30-4:15 p.m. Conceptual Dynamics Under Traditional Instruction Observed Using the FMCE

Poster – Michi Ishimoto Kochi, University of Technology, Tosayamda-cho Miyanokuchi Kochi, 782-8502 Japan; ishimoto.michi@kochi-tech.ac.jp

Lecture-centered physics instructions are the traditional and standard instruction of introductory physics in colleges and high schools today. Few studies on students' conceptual changes under the traditional instructions are reported unlike studies on those under more effective instructions. The conceptual dynamics of the traditional instruction could be different from that of effective instructions because ineffective instructions are prone to more cognitive biases. This study reports an analysis of conceptual changes under a lecture-centered traditional instruction observed in a Japanese college using the Force and Motion Conceptual Evaluation. The findings indicated that the instruction had weakened the fragile target concept to a higher degree rather than suppressed the robust novice conceptions, suggesting that the TR instruction was improper for novice students' conceptual learning. Conceptual dynamics under traditional instruction observed using the FMCE.

PST3A13: 3:30-4:15 p.m. Challenges and Opportunities for a Joint REU-RET Program at BYU

Poster – Jean-Francois Van Huele, Brigham Young University, Department of Physics and Astronomy, Provo, UT 84602-4681; vanhuele@byu.edu

John Colton, Heather Peterson, Brigham Young University

In this contribution we discuss challenges and opportunities of running an NSF-funded Research Experience for Undergraduates (REU) and Research Experience for Teachers (RET) joint program in physics and astronomy at Brigham Young University (BYU). We present our current program and address the challenges that come with the recruitment and selection of applicants and faculty mentors, the preparation of the academic and social activities, the realizationation of the program objectives and the evaluation of the program outcomes. How do we combine the expectations of the hosting institution and those of the funding agency to develop a program that provides the greatest opportunities to all participants?

PST3A14: 4:15-5:00 p.m. Concept Question Use Across Multiple Sections of Introductory Electromagnetism

Poster – Aidan MacDonagh, Massachusetts Institute of Technology, 100 Memorial Dr. 2-23A, Cambridge, MA 02142; aamacdon@mit.edu*

Alexander J Shvonski, Michelle Tomasik, Peter Dourmashkin, Massachusetts Institute of Technology

We examine student responses to in-class concept questions given in a large-scale, introductory electromagnetism course at MIT. The course has 8 sections with approximately 90 students per section, and each section's instructor uses the same set of in-class concept questions, to which students submit responses using our LMS. By analyzing the comprehensive dataset of student responses, we sought to understand how concept questions were used in class, thereby determining the educational experience of the students between sections. We found that most students were asked a majority of the questions at least once (instructors used anywhere from 73% to 92% of available questions), but there was much more variation in the number of follow-up attempts given (ranging from 0% to 77% amongst sections). We consider the effects that these differences in concept question use might have on learning outcomes.

*Sponsored by Alexander J Shvonski.

PST3A15: 3:30-4:15 p.m. Enhancing Student Preparation for Lab Activities Through Pre-lab Videos

Poster – Belter E Ordaz-Mendoza, University of Connecticut, Department of Physics, 2152 Hillside Road, unit 3046, Storrs, CT; 06269 belter.ordaz@uconn.edu

Diego Valente, Zac Transport, University of Connecticut

It is well known that students who are well prepared for their laboratory activities are likely to obtain improved learning outcomes. Students in introductory physics courses often come to laboratory sessions unprepared, demonstrating a lack of familiarity with the equipment and spending valuable time in the beginning of the lab session attempting to familiarize themselves with the equipment and procedure. We have sought to address these issues by creating pre-lab videos for our Physics for Engineers II course at the University of Connecticut, adapting the well-accepted principles of a flipped classroom and video-enhanced instruction that have successfully been utilized in the lecture portion of Physics for Engineers introductory courses for the last six years. We present the methodology behind designing pre-lab videos and embedded assessments to engage students. We also present preliminary data we have collected on completion and performance of the pre-lab assessments and student feedback acquired through surveys.

PST3A16: 4:15-5:00 p.m. Implementing Design Experiments in a Blended Learning, Introductory Electromagnetism Class

Poster – Alexander J. Shvonski, Massachusetts Institute of Technology, 22 Dearborn St., Apt 2, Medford, MA 02155-4315; shvonski@mit.edu

Pushpaleela Prabakar, Jacob K. White, Peter Dourmashkin, Michelle Tomasik, Massachusetts Institute of Technology

We describe design-based physics experiments that we developed and implemented in a large-scale, introductory physics course at MIT. The residential course, 8.02 Electricity and Magnetism, has over 700 students, with 8 sections total (about 90 per section), and is built upon an "active learning" structure, where students interact with each other and online materials during class. We introduced 4 new in-class experiments, each having an open-ended, design component, which explored a practical application of electromagnetic concepts. During these experiments, students followed instructions and answered questions on MITx (our online LMS). We also integrated the experiments with pre- and post-experiment assignments to support and reinforce the material covered. We describe how we structured these experiments, some considerations with respect to implementation on a large scale, and also report student feedback.

PST3A17: 3:30-4:15 p.m. Quantum for Kids: You Got This!

Poster – Tyler B. McDonnell, 3429 Tulane Drive, Apt 22, Hyattsville, MD 20783; tylerbmcdonnell@gmail.com

Early exposure to STEM topics helps students identify misconceptions that may take shape at a young age, which can provide them with the foundation to navigate more complex concepts later in their academic careers. Often physics is not covered in K-12 curriculum; moreover, there is not a large focus on quantum physics due to the complexity of the of the subject. To address this issue, outreach activities are frequently designed by higher institutions and are implemented to incite thought and interest on concepts. The University of Maryland SPS received the Marsh W. White Award from SPS National to design a program of activities focusing on several quantum concepts for elementary school students that introduces them to the world of quantum through diverse learning experiences.

PST3A18: 4:15-5:00 p.m. Enhancing High-Level Thinking in an Introductory Electricity and Magnetism Lab

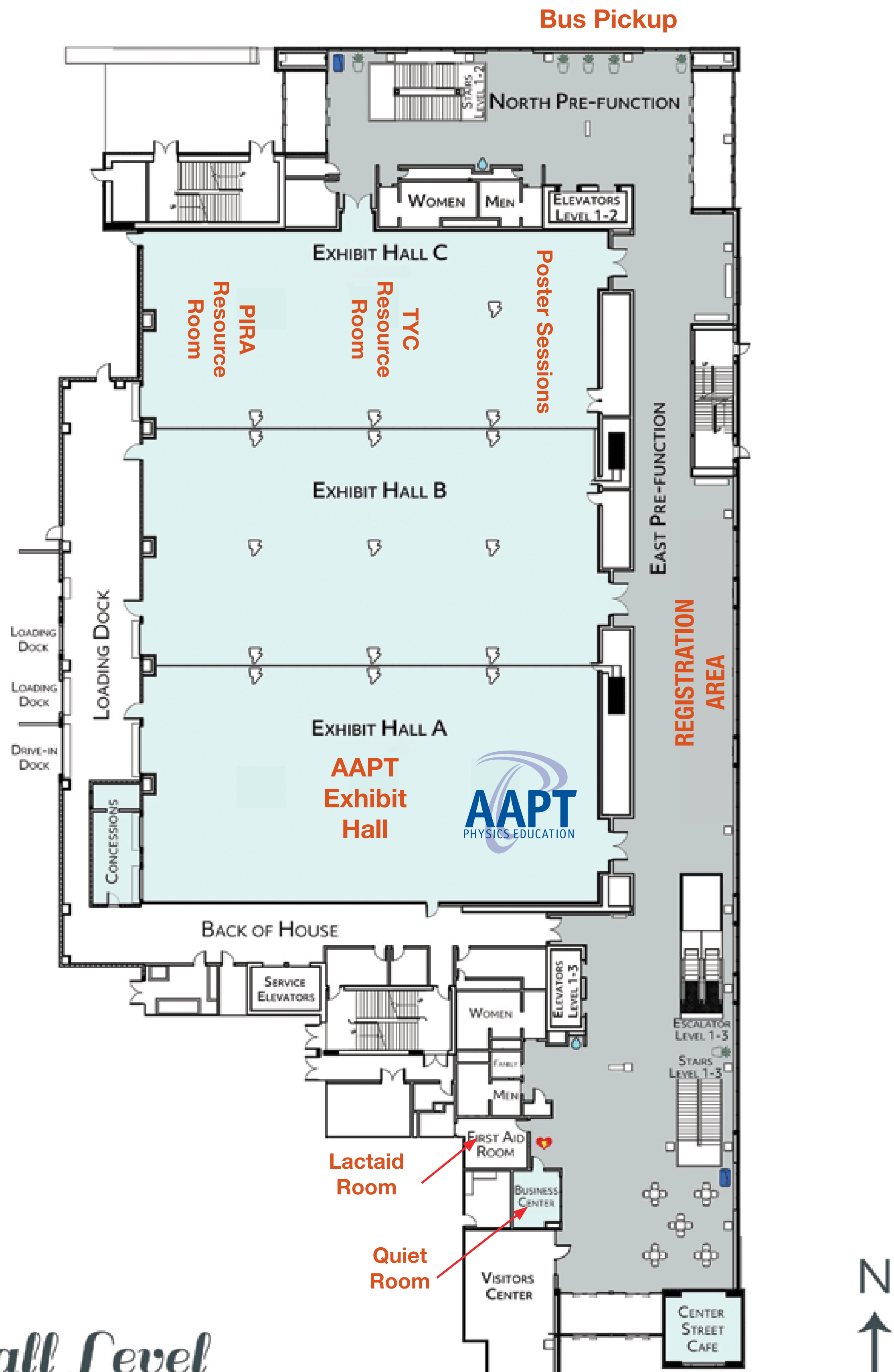
Poster – Hyewon K. Pechkis, California State University, Department of Physics, Chico, CA 95929; 3012093340

Paul Arpin, Joseph A. Pechkis, California State University, Chico

We are redesigning our more traditional introductory physics Electricity and Magnetism labs to enhance students' higher-level thinking and problem-solving skills. Specifically, we introduce physics education research-based instructional technology (e.g. "virtual" experiments) into our labs to reduce DFW rates and are building a faculty learning community. In particular, we have incorporated more design- and inquiry-based activities alongside PhET simulation activities into the labs. Our initial results indicated an increase in scores on the Conceptual Survey for Electricity and Magnetism for students who have taken the redesigned labs compared to those of students who have taken tradition labs. This work was funded through the Laboratory Innovations with Technology through the Chancellor's Office at California State University.

Meeting Participants Index

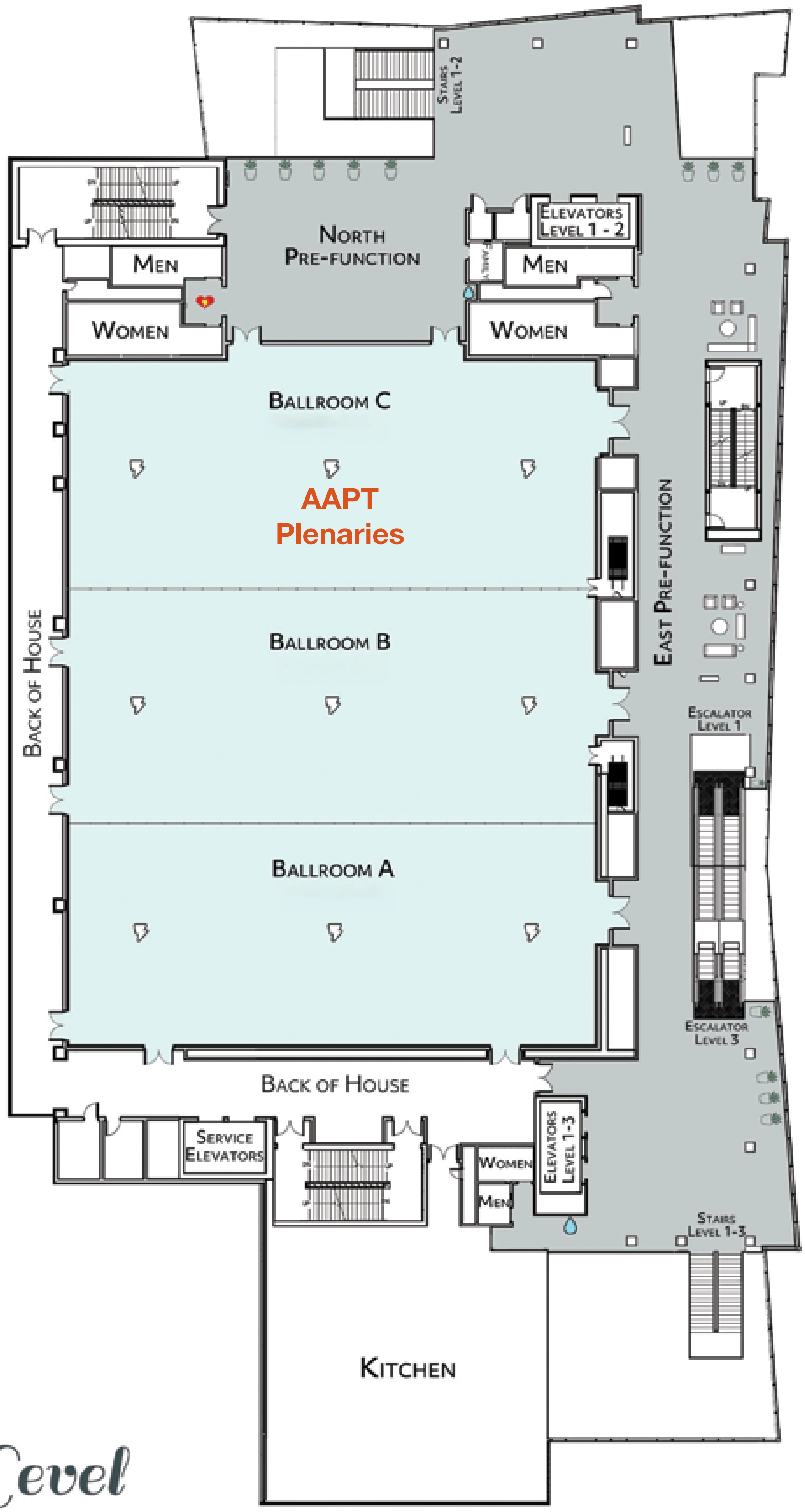
Map of Convention Center 1st Floor



Level 1

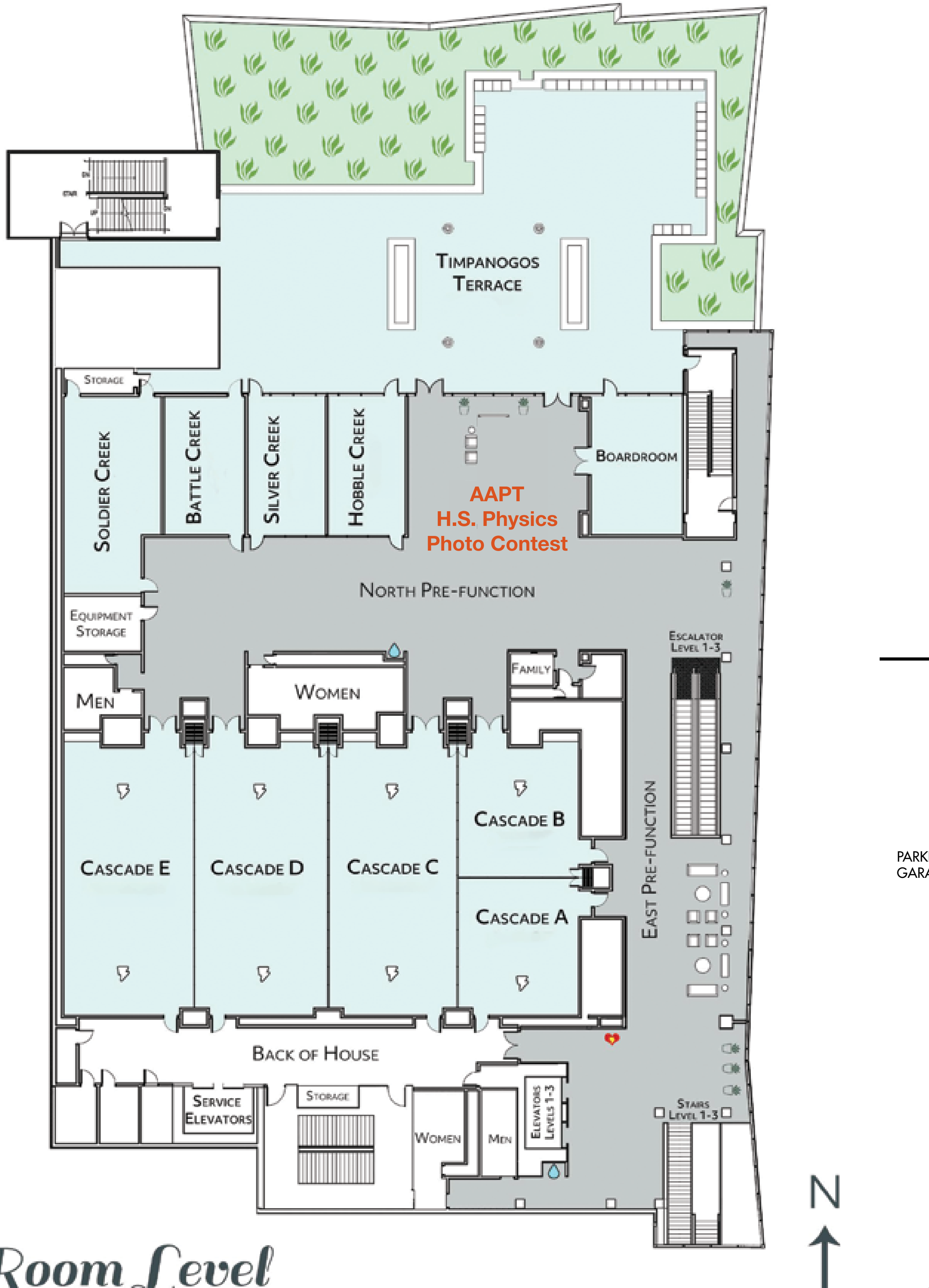
Exhibit Hall Level

Map of Convention Center 2nd Floor



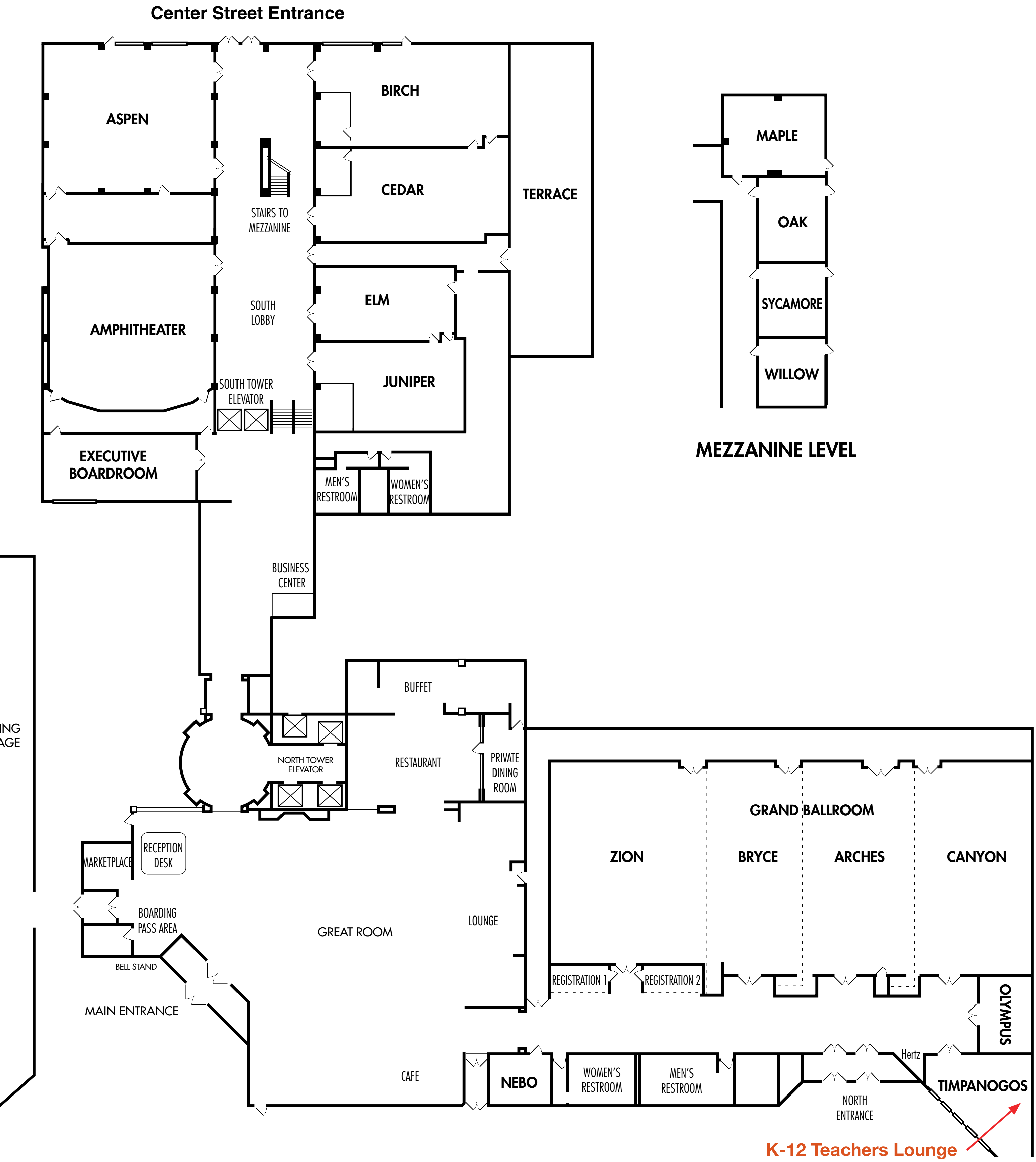
Level 2
Ballroom Level

Map of Convention Center 3rd Floor

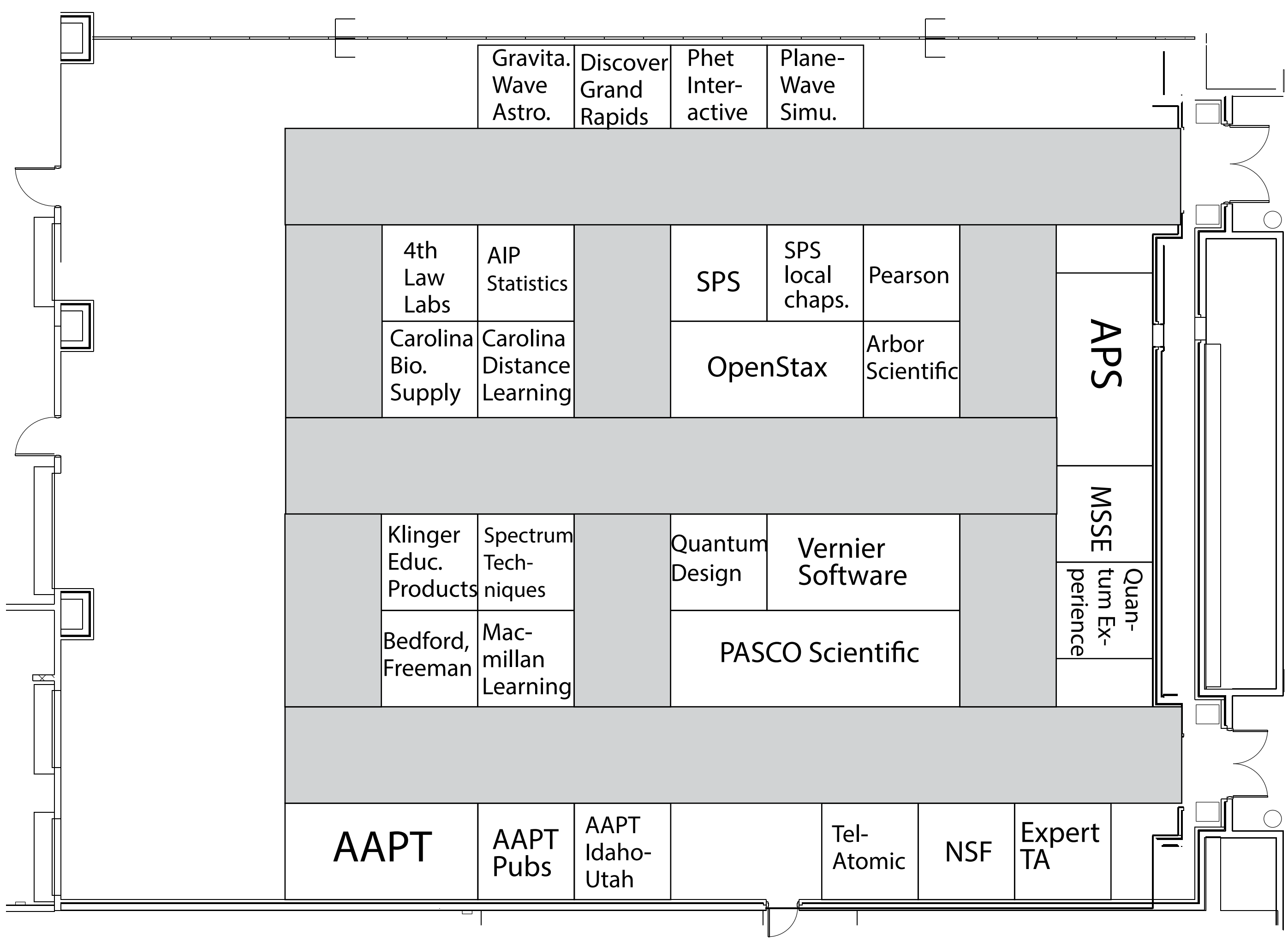


Level 3
Meeting Room Level

Map of Provo Marriott Hotel



Map of AAPT Exhibit Hall



Map of Brighman Young University

Food

- SLABpizza
- Cupbop Provo
- Thai House Cuisine
- J Dawgs
- Brick Oven Provo
- Costa Vida
- Wendy's
- Panda Express
- Ernest L. Wilkinson Student Center
- Commons At The Cannon Center
- BYU Creamery on Ninth

Coffee

- Einstein Bros. Bagels

Bus stop

- BYU South Campus Station

Buildings

- Joseph Smith Building
- Eyring Science Center

Map of Utah Valley University

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There are a few notes we would like you to review and confirm before proceeding.

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- The Utah Valley Convention Center assumes no responsibility for the safety of equipment, configurations, security or data files resulting from connection to the wireless network.
- If you make changes to your laptop's configuration, make sure that you are able to change them back so that you can keep your computer as safe as possible.

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- Does the wireless network you are connected to begin with "UVCC_PUBLIC_WIFI"?
- Open a browser window and accept the terms and conditions before you try to do anything else. You must accept the terms and conditions before web-based programs will run correctly.
- Search for a stronger Wi-Fi signal if possible; it could be that the access point nearest you is congested or has a weak signal to your location.
- Are your wireless card settings correct? Is your wireless card enabled (can you browse and see wireless access point)?
- If applicable, check your firewall settings to see if that may be limiting access.
- Make sure you have your browser homepage set to something; don't have it set to a blank page